WOH-115

CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0349607 2

ORNL 1686
Chemistry

Cy. 7

QUANTITIES AND REACTIONS OF SOLID SURFACES

A Bibliography

Elizabeth P. Carter

CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION

LIBRARY LOAN COPY

DO NOT TRANSFER TO ANOTHER PERSON

If you wish someone else to see this document, send in name with document and the library will arrange a loan.

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
CARBIDE AND CARBON CHEMICALS COMPANY
A DIVISION OF UNION CARBIDE AND CARBON CORPORATION

UCC

POST OFFICE BOX P
OAK RIDGE, TENNESSEE

ORNL 1686

Copy No 7

Contract No W-7405-eng-26

QUANTITIES AND REACTIONS OF SOLID SURFACES

A Bibliography

Elizabeth P Carter
Reference Assistant
Central Research Library

February 10, 1954

Aircraft Nuclear Propulsion Division

R C Briant, Director

DATE ISSUED
APR 7 1954

OAK RIDGE NATIONAL LABORATORY
Operated by
CARBIDE AND CARBON CHEMICALS COMPANY
A Division of Union Carbide and Carbon Corporation
Post Office Box P
Oak Ridge, Tennessee

3 4456 0349607 2

ORNL 1686
Chemistry

INTERNAL DISTRIBUTION

1 C. E Center
2 Biology Library
3. Health Physics Library
4. Metallurgy Library
5-9 Central Research Library
10 Reactor Experimental Engineering Library
11-15 Laboratory Records Department
16. Laboratory Records, ORNL R C
17. C. E Larson
18 L. B Emlet (K-25)
19 J P. Murray (Y-12)
20 A M Weinberg
21 E H Taylor
22. E D Shipley
23 R C Briant
24 F C VonderLage
25 J A Swartout
26 S C Lind
27 F L. Culler
28 A H Snell
29 A Hollaender
30 M T. Kelley
31 G H Clewett
32 K Z Morgan
33 J H Frye, Jr
34. C P. Keim
35 R S Livingston
36 T A Lincoln
37 A S Householder
38 C S Harrill
39 C. E. Winters
40 D W Cardwell
41. E. M. King
42 A J Miller
43. D. D Cowen
44 J A Lane
45. G M Adamson
46 D S Billington
47 F. F Blankenship
48 E P Carter
49 A P Fraas
50 C. B Graham
51 W R Grimes
52 F Kertesz
53 R N Lyon
54 W B McDonald
55 W D Manly
56 L A Mann
57 H H Mason
58 J. C Morris
59. G F Petersen
60 H F Poppendiek
61 H W Savage
62 G P Smith
63 W. K Stair
64 C D Susano
65 W C. Tunnell
66 J M Warde
67. J C White
68 M. J. Skinner
69-71 ANP Reports Office

EXTERNAL DISTRIBUTION

72 R F Bacher, California Institute of Technology
73. Division of Raw Materials, Denver
74. Division of Raw Materials, Ishpeming
75 Sandia Corporation
76-326. Given distribution as shown in TID-4500 under Chemistry Category

DISTRIBUTION PAGE TO BE REMOVED IF REPORT IS GIVEN PUBLIC DISTRIBUTION

TABLE OF CONTENTS

	Page
Preface	6
Measurement of Surface Quantities	7
Area	9
Roughness	13
Tension	18
Physico-Chemical Reactions of Surfaces	23
Adsorption	25
Cleaning	36
Electrolytic Polishing	37
Oxidation	40
States	52
Physico-Mechanical Reactions of Surfaces	55
Friction	57
Lubrication	78
Mechanical Polishing	93
Mechanical Wear	97
Indexes	109
Publication	111
Author	119
Subject	122

PREFACE

Dry friction is the nucleus of this bibliography, however, the large role which surface effect plays in the phenomenon of friction[1] made it necessary to encompass material pertaining to other characteristics of solid surfaces With slight variation, Tolley's classification of surface quantities and reactions[2] has been followed in arranging the references

An attempt has been made to compile a bibliography which is representative of the recent trend in the field, therefore, the survey was limited to Chemical Abstracts, volumes 41 through 47, number 12 (1947 - June 1953)

Appreciation is extended to Mr W K Stair for much helpful guidance in defining the scope, and to Mrs Helen H Mason for assistance in fabricating the bibliography

---

[1] Gregg, S J , The Surface Chemistry of Solids New York Reinhold, 1951, p 1, 173

[2] Tolley, G , "Surface Reactions of Metals," Metal Industry 75, 68-70, (1949)

MEASUREMENT OF SURFACE QUANTITIES

AREA

(1)

J Chem Soc 1952, 1736-44 | THE ADSORPTION METHOD OF MEASURING SURFACE AREAS | Marischal Coll, Aberdeen, Scot R M Barrer N Mackenzie D Macleod

In order to investigate the accuracy of the gas-adsorption method of measuring surface areas, 11 new multilayer equations similar to that of Brunauer, Emmett, and Teller (B E T) (cf C A 32, 4037g) are derived These equations, together with those of B E T and Hüttig (cf C A 42, 7598a), are examd with exptl sigmoid isotherms of N on montmorillonite and of N and of NH_3 on attapulgite In the derivations of the new equations, it is assumed that the volatility of sorbate mols increases, the higher is the layer in which they are located Use of this assumption has the effect of reducing the excessive adsorption predicted by the B E T equation at high relative pressures In the case of 3 of the more successful equations, the device is used of adjusting one const to obtain the best fit of the equations to the exptl data The characteristic plots of a no of the new isotherm equations are linear to large relative pressures The ratio of the extreme values of v_m, the vol of gas adsorbed when the entire adsorbent surface is covered with a complete unimol layer, on montmorillonite for 12 equations is 1 57 1 and that on attapulgite for 11 equations is 1 39 1 The corresponding ratios for the 3 or 4 best-fitting equations are 1 15 1 and 1 12 1, resp It is suggested that when a no of different characteristic plots of a given set of data are linear over most of the relative pressure range and the v_m values derived from each of the successful equations are in satisfactory agreement with one another, then the adsorption method can be a good abs measure of surface area (C A 46, 8459e)

(2A)

Corrosion Pub Co, Pittsburgh, 1948 | STUDIES OF METAL SURFACES BY LOW-TEMPERATURE GAS ADSORPTION pp 82-90 | Paul H Emmett

The paper deals with a new method of measuring areas, based upon gas adsorption, and the possibility of its application to the study of metal surfaces The abs surface area of a solid can be detd if the vol of an adsorbed monolayer of gas is known The theoretical and exptl results described show that by measuring the low-temp adsorption isotherms of suitable inert gas (N for example) near the b p of this gas, it is possible to obtain a reliable estimate of the abs surface area of the solid being measured The results obtained coincide with those obtained by use of the micrographs and electron microscope Total areas ranging from 100 sq cm to 2000 sq cm per sample can be measured either on plane or on spherical smooth and nonporous samples

The low-temp gas-adsorption methods were successfully applied (1) to the study of metal catalysts, where they not only yielded values for the surface area but also revealed the fraction of the catalyst surface covered by promotors, and (2) to est the smoothness of electrodeposited layers, anodic depositions on Al, for example The method makes possible the detn of the av thickness of a corrosion or protective layer (C A 42, 8057f)

(3)

Z Metallkunde 40, 249-55 (1949)	A METHOD FOR DETERMINATION OF THE ABSOLUTE SURFACE OF BASE METALS	Otto Erbacher Gisela Jensen-Hellmann Auguste Mellin

Adsorption values, representing surface condition, for Ag, Cu, Zn, Cd, Al, and Mg, detd by removal of Pb from a soln of $Pb(NO_3)_2$ in MeOH and in pyridine, are tabulated (C A 43, 8325c)

(4)

Trans Inst Chem Engrs (London) and Soc Chem Ind (London), Roads and Bldg Materials Group, Advance copy Feb 4, 1947, 27-33	ADSORPTION AND HEAT-OF-WETTING METHODS OF MEASURING SURFACE AREA	S J Gregg

The exptl methods and the comparative advantages of detg a surface area by the adsorption of gases, adsorption of solutes from soln , and heat of wetting are discussed (C A 41, 5374d)

(5)

J Chem Soc 1949 (Suppl Issue No 2), S259-74	THE EMANATION METHOD	Otto Hahn

By incorporating in a solid a radioactive element that decays to a gaseous product, usually emanation, the nature of the solid can be studied The surface area of the solid, its inner surface, deformations due to chem and phys transformation, and solid-state reactions can be studied by following the rate of release of radioactive gas Many methods of incorporation are described Exptl methods are described for following the escape of emanation either by γ- or β-radiation measurements The behavior of emanating power under various conditions such as aging, humidity, temp of pptn and heating, are described for oxides, salts, glasses, crystals, and colloids, and related to other chem and phys changes such as the Tammann loosening temp , transition temps., hydrate transitions, and solid-state reaction (C A 44, 9206a)

(6)

J Research Natl Bur Standards 46, 51-5 (1951)	SURFACE-AREA DETERMINATION BY ADSORPTION OF NICROGEN FROM NITROGEN-HELIUM MIXTURES	Wm V Loebenstein Victor R Deitz

Research Paper No 2174 See C A 44, 2323f (C A 45, 7845d)

(7)

J Chem Phys 17, 1004-5 (1949)	SIMPLIFIED TECHNIQUE FOR SURFACE-AREA DETERMINATION BY ADSORPTION OF NITROGEN	Natl Bur of Standards, Washington, D C W V Loebenstein, et al

A new simplified procedure for detg surface areas by the Brunauer-Emmett-Teller (C A 32, 4037[9]) method is described It is based on the preferential adsorption of N from N-He mixts The method has the peculiar advantage that no vacuum pumping system is required (C A 44, 2323f)

(8)

J Metals 4, Trans 657-60 (1952)	SURFACE AREAS OF METALS AND METAL COMPOUNDS A RAPID METHOD OF DETERMINATION	Georgia Inst of Tech , Atlanta C Orr, Jr , et al

The results of this investigation give added confirmation of the validity of the gas adsorption methods as a means of measuring surface areas and indicate that fatty acid adsorption is a valuable companion technique Liquid-phase adsorption, because extensive sample evacuation or heating is unnecessary, and because the method is rapid, should be usable with heat-sensitive and high-vapor pressure materials as well as in process-control work with metals and with other more stable materials (C A 46, 6059i)

(9)

J Am Chem Soc 70, 3830-7 (1948)	PHYSICAL ADSORPTION II A COMPARISON OF METHODS OF ESTIMATING SURFACE AREAS OF CRYSTALLINE SOLIDS BY GAS ADSORPTION	Sydney Ross

Adsorption isotherms for ethane at -183° on carefully prepd cubic crystals of NaCl and KCl were interpreted by the method of Gregg (cf C A 37, 1912[1]), of Harkins and Jura (cf C A 38, 5125[5]), and of Brunauer, Emmett, and Teller (cf C A 32, 4037[9]) Gregg plots of $\pi\sigma$ against $\pi\Sigma$ yield lines for a low-pressure "gassy" phase and a higher-pressure condensed phase π is the 2-dimensional surface pressure, σ is the area per adsorbed mol , and Σ is the total area of the sample By considering the special characteristics of the 100 planes of the NaCl and KCl crystals in relation to the size of the ethane

mols probable mol areas are estd for the mols of ethane in the "gassy" and the condensed phases, and the total area of the samples is calcd from these estd mol cross-sections and the Gregg plots For NaCl, the areas thus estd (2250 and 2433 sq m per g) compare favorably with those deduced from the B E T plots (2260 sq m per g) and from the plots of H and J (2350 sq m per g) Similarly for KCl the two Gregg values for the areas are 3190 and 3416 sq m per g compared to a value of 3430 for the B E T method The adsorption data in the monolayer region agree with two equations of the form $\pi(\sigma - \sigma_0) = ikT$ where σ_0 is the incompressible area per mol for each of the two phases and is an inverse function of the lateral mol cohesion in each of the two phases (C A 43, 2066b)

(10)

J Phys and Colloid Chem 51, 644-7 (1947)	A LIMITATION OF THE DETERMINATION OF SURFACE AREA BY THE POINT B" METHOD	Southern Research Inst , Birmingham, Ala Locke White, Jr

The point B' method (cf Emmett and Brunauer, C A 31, 7322^5) for selecting the point on a low-temp adsorption isotherm corresponding to a monolayer of adsorbed gas will agree with the Brunauer-Emmett-Teller (B E T) method (cf C A 32, 4037^9) only when the const C of the B E T equation has a value somewhat larger than 9 (C A 41, 4994d)

(11)

Am Ink Maker 26, No 1, 25-7, 59 (1948) cf C A 42, 2155f	GAS ADSORPTION--A NEW PRINTING-INK RESEARCH TOOL	Nat'l Printing Ink Research Inst , Bethlehem, Pa Albert C Zettlemoyer

Methods for surface-area measurement and pore-size detn by gas adsorption according to Brunauer, Emmett, and Teller (C A 32, 4037^9) are described and illustrated Phys adsorption of gases on solids is considered to take place with a close-packed first layer The area occupied per mol can be calcd from the d of the normal condensed phase Total surface areas calcd from the adsorption of various substances on active magnesias by using these values were nonconcordant This leads to the conclusion that, when adsorption takes place in preferred positions, the ratio of the moles of adsorbate A to the moles of adsorbate B, required to complete a unimol layer on the surface can be expressed in terms of whole simple numbers (C A 42, 2835h)

(12)

Arkiv Kemi, Mineral Geol A21, No 17, 26 pp (1946)(in German)	SURFACE EXCHANGE OF SOLIDS AND THE DETERMINATION OF SURFACE AREA	Chalmers tech Hockschule, Goteborg Karl E Zimens

The limitations of Paneth's method (C A 16, 2244) are discussed The results of previous workers with Pb and Ag salts are tabulated Z sets forth the conditions under which Paneth's equation can be operative there must be no marked exchange with the inner crystal, and all the atoms lying in the phase boundary must undergo exchange (C A 41, 895h)

ROUGHNESS

(13)

Metall 4, 359-65 (1950)	SURFACE TESTS AND THEIR STANDARDS	Wetslar,Ger H Becker

Various means of testing the quality of metallic surfaces are described 4 references (C A 44, 10643e)

(14)

U S Patent 2,420,646 May 20, 1947	DETECTING FLAWS IN METAL ARTICLES	Ralph Bloom, Jr Edwin N Klemgard Bela Ronay Rudolph W Miller

Imperfections in the surface of any metal object of whatever shape may be detected by means of an oil soln of a dye in CCl_4 The surface to be examd is cleaned with CCl_4 and treated with the dye soln , which penetrates any crack or flaw present Excess soln is wiped off and after about 1 min the area is covered with a fine absorbent powder such as diatomaceous earth or white talc The dye seeps up and colors the powder Good results come from using an oil consisting of sol cutting oil 8, oleic acid 5, and Diesel fuel oil 87% This may be satd with alizarin-type gasoline dye The stain in the powder may be photographed if desired (C A 41, 6183g)

(15)

J Electrodepositors' Tech Soc 26, No 4, 8 pp (1950)	A SIMPLE INSTRUMENT FOR MEASURING SURFACE TRUTH OF METAL SURFACES AND THE AMOUNT OF POLISHING REQUIRED	G E Gardam

Inspection of the reflected image from the test surface of a strongly illuminated pattern of light and dark stripes reveals surface roughness and asymmetries not noticeable by simple visual inspection (C A 44, 6366a)

(16)

Kunststoffe 38, 74-6(1948)	OPTICAL METHODS FOR TESTING SURFACE QUALITY	F Gottwald

Methods and app for measuring roughness and reflectivity are described (C A 43, 9171)

(17)

Finish 7, No 6, 27-30 (1950)	MEASUREMENT OF SURFACE ROUGHNESS I	Nat'l Research Council E Green

A general discussion of instruments developed for comparing, measuring, and delineating the surface profiles of metallic materials (C A 44, 7595a)

(18)

Métaux, Corrosion, Usure 19, 12-17 (1944)	ELECTROCHEMICAL STUDY OF SURFACE ROUGHNESS	E Jandon

An elec method for the study of electrolytic corrosion is described with particular reference to its use with untreated and phosphated metal surfaces The test electrode is combined with a Hg_2Cl_2 electrode in the corroding soln to form a cell, a condenser may be alternately charged by the cell and discharged through a resistance and a ballistic galvanometer in series, which allows the e m f to be measured at any moment The function $(E_o-E)/(E-E_F)$, where E_o, E, and E_F are the e m f initially, after a time (t), and finally (after corrosion is well advanced) is plotted against t The interpretation of the curves obtained serves as a quicker alternative to wt -loss measurements (C A 44, 8797f)

(19)

Arch Metallkunde 2, 46-9 (1948)	SURFACE-ROUGHNESS MEASUREMENT BY MEANS OF THE OBLIQUE-SECTION METHOD	H Klemm

As with other surface-measuring methods, the values may be related to the mean line or to the bottom of the depressions The magnification created by taking the section at an acute angle to the surface makes possible the observation of surface irregularities At the same time a general impression of the surface profile is gained The section is prepd in the same manner as for metallographic work Polishing is not necessary If the last sanding pass is made vertical to the section, the roughness stands out more clearly (C A 43, 95e)

(20)

Bull Acad. Sci. U R S S, Classe Sci Chim 1948, 50-6 (in Russian)	NEW METHOD OF DETERMINATION OF THE THICKNESS OF NATURAL PASSIVATING FILMS ON METALS	S Ordzhonikidze Aviation Inst, Moscow I V Krotov T M Khachadurova

The depth δ of a scratch produced on a polished Al surface by a needle loaded with weights w up to 15 g was detd by the decrease of wt of the foil after mech polishing just sufficient to erase the scratch, δ is independent of the length of time elapsed between the 1st polishing and the scratching expt, from 15 min to 18 hrs, and is a regular function of w, with w = 0 52, 1 02, 2 00, 4 02, 9 00, 15 00 g, δ = 8 5, 12, 26, 31, 78, 310 μ The curve of δ against w consists of 2 branches, with a discontinuity at w = 2 00 Evidently, the 2 portions of the curve correspond to 2 different mechanisms of the scratching, at w less than 2 00, the passivating oxide film is merely dented by the needle, and depressed along with the metal, at

w more than 2 00 it is pierced The shape of the 2nd branch of the curve can be represented by the parabolic equation $\delta^2 = kw$, easily derived by geometrical considerations, on the basis of the conical shape of the needle tip If the assumption of the 2 different mechanisms along the 2 portions of the curve is correct, then the 2nd portion represents the variation of the depth l of the metal alone, while the 1st portion corresponds to the variation of $l + d_1$, where d_1 = thickness of the passivating film Extrapolation of the 1st portion to w = 0 gives d_1 = 500 A This, however, is the thickness as measured perpendicularly to the macroscopic surface, if one takes into account the microscopic unevenness of the surface, as a result of the formation of ridges in polishing, then the true thickness $d = d_1 \sin(\alpha/2)$, where α = angle at the top of the ridge Thus, d is less than d_1, and, with $\alpha = 30^\circ$, d = 135 A which corresponds closely to the thickness estd from optical observations Shallow scratches produced with low w less than 10 g repassivate very rapidly in air, as evidenced by the failure to deposit Cu (from 1 N $Cu(NO_3)_2$ 20 cc + 1 N $CuCl_2$ 20 cc) on such scratches, Cu is only deposited on deeper scratches produced with w more than 10 g (C A 42, 4886d)

(21)

Rev Mét 42, 305-7 (1945) — SURFACE-STUDY MEETING — Georges Chaudron

A discussion of surface-irregularity measurements, electron-microscope examn of the surface, superfinish, and the influence of electrolytic polishing on the surface properties and particularly on resistance to corrosion (C A 41, 79g)

(22)

Metal Progress 56, 225-7 (1949) — A NEW METHOD FOR SURFACE REPRODUCTION — K B Mather

Pressing a reasonably flat metal surface into a fine-grained photographic emulsion at 15,000 lb per sq in , developing the plate, and examg microscopically give a 3-dimention pattern which can be standardized to measure surface roughness quantitatively (C A 43, 7393g)

(23)

Metallurgia 38, 71-4 (1948) — A REFINED METALLOGRAPHIC TECHNIQUE FOR THE EXAMINATION OF SURFACE CONTOURS AND SURFACE STRUCTURE OF METALS — A J W Moore

A detailed account is given of taper-sectioning technique as a means of studying the surface features of metals By cutting a metallographic section obliquely to the surface, a section is obtained with the vertical component of the surface contour greatly magnified, relative to the horizontal

one A section cut at an angle of $5^{o}43'$ will give a distortion ratio of 10 (ratio of magnification in the vertical and horizontal directions) Photomicrographs are presented showing taper sections of steel surfaces, and the detailed techniques used in their prepn are described The front surface is usually protected by electrodeposition of a metal of similar hardness to the specimen Ni is quite suitable for protecting steel, while Ag is quite satisfactory for protecting Cu This technique of taper sectioning has been found useful for studying the mechanism of surface damage due to sliding metals (C A 42, 7685f)

(24)

Trans Austalian Inst Metals 3, 37-40 (1950), Australasian Engr Oct 7, 1950, 65-8	THE STRUCTURE OF A METAL SURFACE	A J W Moore

After a description of the Van der Waals forces and the chemisorption that can be predicted from the application of probability functions, this survey shows how metal surfaces encountered in practice compare with this simplified picture Real surfaces show large irregularities in contour, relatively thick films of foreign atoms and considerable deformation at or near the surface The techniques for the measurement of these surface features and the types of results obtained for them are described 19 references (C A 46, 8447c)

(25)

Z Metallkunde 39, 170-2 (1948)	THE MEASUREMENT OF SURFACE ROUGHNESS OF METALS WITH THE ELECTRON MICROSCOPE	Suddentschen Labs , Mosbach, Germany Robert Seeliger

Equipment for measuring smoothness of polished steel surfaces is described (C A 42, 7685h)

(26)

Zavodskaya Lab 13, 635-7 (1947)	SURFACE ANALYZER FOR THE EVALUATION OF ROUGHNESS	M M Tennenbaum

The surface is explored by a needle transmitting its vibrations to 2 Seignette salt piezoelec elements The app indicates irregularities of a level of the order of 0 025 μ and is capable of amplification from 40 to 40,000 times The recording ribbon can move at 5, 25, or 125 mm /sec , corresponding to horizontal magnifications of, resp , 16, 80, and 400 (C A 42, 8538h)

(27)

Metal Finishing 49, No 5, 54-61 (1952) cf C.A 44, 9906i	VISUAL AND OPTICAL EVALUATION OF METAL SURFACES	Welding Research Council, New York, N Y Helmut Thielsch

A discussion of the major optical procedures including visual examn , projection, microscopic examn , the optical comparator, replica techniques, electron-microscope methods, optical and mech sectioning, and interferometer studies The most important characteristics of these methods are summarized in a table (C A 46, 6576i)

(28)

Soc Roy Belge Ing et Ind Bull No 5, 225-30 (1952)	STUDY OF THE ROUGHNESS DURING THE ELECTROLYTIC POLISHING OF MILD STEEL	Univ Brussels Gaétan van Dijck

Mild steel (0 06-0 08% C) with a Brinell hardness of 114 was polished electrolytically in a $HClO_4$-alc electrolyte with continuous flow of the liquid past the sample at 30 v and 300 amp /sq dm The roughness of the surface was measured with a com profilimeter For const polishing times, the roughness of the surface after electrolytic polishing was a linear function of the initial roughness In general an increase in polishing time increased the smoothness of the polished surface (C A 47, 2614b)

(29)

J Electrochem Soc 97, 71-4 (1950)	THE DETERMINATION OF THE ROUGHNESS OF METALLIC SURFACES	Massachusetts Inst of Technol Carl Wagner

It is shown that the polarization capacity of an electrode can be measured readily with the aid of a ballistic galvanometer The polarization capacity/ unit apparent area can be considered to be approx proportional to the roughness of the surface of the electrode Results obtained on Ag electrodes illustrate the influence of pretreatment and aging (C A 44, 2871c)

(30)

J Phys and Colloid Chem 53, 1466-7 (1949)	SURFACE ROUGHNESS AND CONTACT ANGLE	Westinghouse Research Labs Robert N Wenzel

Roughness that modifies wetting cannot be detd from surface profiles, but the roughness factor is the ratio of actual surface to that of a smooth surface having the same geometric shape and dimensions and might be detd by measurements for total area, such as gas adsorption (C A 44, 3334g)

TENSION

(31)

J Phys and Colloid Chem 52, 969-75 (1948)	SURFACE TENSION OF SOLIDS AND METHODS OF MEASURING THE SAME	Fordham Univ , New York, N Y George Antonoff

Mixts of edible oils with certain pigments give pastes of high surface tension, which can be used for detg the surface tension of solids by finding the mixt that just begins to wet the solid The surface tension of the paste can be measured by detg the wt necessary to break one rod away from another when both are moistened with the liquid Expts and arguments are presented to prove that this method gives reliable results and that viscosity effects do not enter Deviations from the theoretical law found by some authors are due to the failure to attain equil (C A 42, 6605g)

(32)

Compt Rend 233, 409-10 (1951)	METHOD OF DETERMINING THE SURFACE TENSION OF SOLIDS	Carl Benedicks

A method based on the effect of neg wetting permits the evaluation of surface tension of solids Values from 87 dynes/cm for sugar for 228 dynes/cm for tempered steel were measured By their order of magnitude these figures are in accord with the provisions of the theory and with the results of an exptl method applicable to amorphous substances The surface tension of solids increases regularly and in an accelerated fashion with hardness (C A 47, 18h)

(33)

Naturwissenschaften 34, 313-14 (1947)	THE SURFACE ENERGY OF SOLID METALS	R Fricke

The surface energy of solid metals calcd from heat of sublimation (F , C A 36, 695[3]) and extrapolated to the m p was compared with directly detd surface tensions of liq metals also extrapolated to the m p For hexagonal dense spherical packing (Zn and Cd) the two values are very close together For all other metals, cu face or space centered (Al, Pt, Cu, Ag, Au, Pb, Fe) the surface tension for the liquid metal is from 30 to 70% of the surface tension calcd for the solid The surface energy of the metal at its m p is only a small part of the heat of vaporization (C A 43, 5652i)

(34)

Z Elektrochem 52, 72-5 (1948) cf C A 37, 5308[8], 43, 5652i	THE SURFACE TENSION OF SOLID METALS	R Fricke

Solid-to-gas surface tensions, σ_{sg}, calcd for solid metals from heats of sublimation compare favorably with σ_{sg} values calcd from experimentally detd σ_{lg} and σ_{sg}/σ_{lg} values for Mg, Zn, Cd, Al, Ni, Pt, Cu, Ag, Au, Pb, Cu, Fe, and W (C A 43, 8255e)

(35)

Zhur Fiz Khim 23, 115-23 (1949)	THEORY OF THE SURFACE TENSION OF METALS	A E Glauberman

Surface tension σ of metals is detd by the excess of potential energy of surface particles, and nonelectrostatic forces produce only a neg correction which agrees with the virial theorem If z, e, d, and R are valency, electron charge, half lattice spacing, and ionic radius, resp , $\sigma = az^2e^2/2\ d^3 [1 - (b\pi R^3/3\ d^3)]^2$, a = 0 0074 and b = 2 for face-centered and a = 0 0087 and b = 1 for body-centered lattice The values calcd from this equation (valid for the abs zero) are similar to exptl σ of molten metals (C A 43, 4991c)

(36)

Proc Phys Soc (London) 62A 639-48 (1949)	SURFACE FORCES IN LIQUIDS AND SOLIDS	C Gurney

A theoretical treatment extending earlier consideration of liquid surfaces to solids The aspects treated include stresses in the uncontaminated surfaces of solids at temps at which migration of atoms takes place, uniform stresses in uncontaminated surfaces of solids at temps. at which migration of atoms does not take place, the Laplace 0 force and equil at angles of contact, and surface energy and surface tension (C A 44, 894d)

(37)

Bull Chem Soc Japan 17, 81-3 (1942)	A METHOD FOR MEASURING THE SURFACE ENERGY OF SOLIDS	Osamu Kimura

A float pycnometer method was used to measure the surface energy of solids The surface energy of $CaSO_4\ 2H_2O$ was found to be 3 9 x 10^2 dynes/cm (C A. 41, 4348b)

(38)

Selected Govt Research Repts (London)(Powder Metallurgy) 9, 1-21 (1951)	THE SURFACE ENERGIES OF METALS AND ALLOYS	C J Leadbeater

The surfaces of metals and alloys function inevitably in all stages of production and subsequent treatments, but frequently, as in the sintering of metallic powders or in the application involving surface catalysis, they play an all-important role Five different methods of detg surface energy

were used The max -bubble-pressure method (Hogness, C A 16, 181) appears to be the most reliable, but no purpose is served in making too fine a comparison between this and other methods, since differences up to 10% for Sb are found in the results of 3 investigators who used the bubble method A table is given of the surface energies of Bi, Zn, Cd, Sb, Sn, Pb, Cu, Ag, Au, Hg, and Al The problem of the theoretical derivation of surface energies was considered on the basis of the binding energy and electronic theory of metals The fundamental relation of surface energy and temp is $\sigma_T = \sigma_0 - T(d\sigma_0/dT)$ (σ_0 free surface energy, σ_T total surface energy) The summary of ratios of σ_0 calcd /observed indicates that the different methods of treatment have not produced consistent values, undoubtedly on account of the entirely different types of models used The problem of cohesive energy of metals has been solved very successfully for a few metals by the application of the electron theory 32 references (C A 46, 7838d)

(39)

J Phys Chem (U S S R) 21, 161-2 (1947)(in Russian), cf C A 40, 5973[5]	SURFACE TENSION OF METALS	Phys -Chem Research Inst , Gor'kiĭ A G Samoĭlovich

The elec field present in the surface layer acts on the ions of the metal and causes their compression This produces the tendency of the exposed metal surface to contract This compression is greater than the extension of the surface layer due to Maxwell's pressure and the pressure of the electron gas (C A 41, 6099e)

(40)

Zhur Fiz Khim 23, 1127 (1949)	THEORY OF THE SURFACE TENSION OF METALS	A G Samoĭlovich

Glauberman's theory (C A 43, 4991c) is criticized (C A 44, 5061)

(41)

J Applied Phys 21, 721 (1950)	AN ABSOLUTE MEASUREMENT OF COPPER-COPPER INTERFACIAL FREE ENERGY	General Elect Research Lab G W Sears

A copper (solid)-copper (solid) interfacial free energy of 860 ergs/cm^2 was detd using Smith's method (Smith, C A 42, 5819e) of balancing interfacial tensions (C A 44, 8727b)

(42)

Proc Phys Soc (London) 63A, 444-57 (1950)	THE SURFACE TENSION OF SOLIDS	Bristol Univ , Engl R Shuttleworth

For a one-component liquid, surface free energy and tension are equal The surface tension of a crystal face is related to, but not equal to, the surface free energy Thermodynamic formulas of surface physics are reviewed The surface free energy appears in the expression for the equil contact angle and in the Kelvin expression for the excess vapor pressure of small drops, but the surface tension appears in the expression for the difference in pressure between the 2 sides of a curved surface The surface tensions of inert-gas and alkali halide crystals, calcd from expressions for their surface energies, are neg The surface tensions of homopolar crystals are zero if it is possible to neglect the interaction between atoms that are not nearest neighbors Surface tensions are calcd for the (100) faces of the crystals of Ne, A, Kr, and Xe and for the (100) faces of NaF, NaCl, NaBr, NaI, KF, KCl, KBr, KI Except for NaF the calcd values are neg (C A 44, 7607e)

(43)

Australian Chem Inst , J and Proc 14, 268-85 (1947)	THE DETERMINATION OF THE SURFACE ENERGIES OF SOLIDS	K L Sutherland

A review of theoretical and exptl methods 65 references (C A 43, 5250f)

PHYSICO-CHEMICAL REACTIONS OF SURFACES

ADSORPTION

(43A)

Oxford Univ Press, London, England 1949	THE PHYSICS AND CHEMISTRY OF SURFACES Third Edition	Univ College, Southampton Neil K Adam

Chapter
I Liquid Surfaces Capillarity
II Surface Films of Insoluble Substances
III Surface Films of Soluble or Volatile Substances Adsorption on Liquid Surfaces
IV Results of the Measurement of Surface Tension
V Solid Surfaces General Properties
VI Spreading and Lubrication
VII Solid Surfaces Fine Structure, Adsorption and Catalysis
VIII Electrical Phenomena at Interfaces
IX The Measurement of Surface Tension
Index
(C A 45, 6038h)

(43B)

Longmans, Green and Co , New York, N Y , 1951	SURFACE CHEMISTRY An Introduction to Its Principles and Applications	A E Alexander

Chapter
I An Outline of the Historical Development of Surface Chemistry
II Insoluble Monolayers at Air/Water and Oil/Water Interfaces
III Adsorbed Films at Air/Water and Oil/Water Interfaces
IV The Gas/Solid Interface
V The Solid/Liquid Interface
VI Electrical Phenomena at Interfaces
Index
(C A 45, 8341c)

(44)

J Am Chem Soc 74, 3556-61 (1952)	HETEROGENEITY OF METAL SURFACES	Princeton Univ Princeton, N J M Boudart

It is proposed that an atom is chemisorbed on a clean and bare metal surface by means of a no of covalent-resonating (metallic) bonds If a fraction θ of this ideal surface is covered with adatoms, a double layer is set up which changes the work function of the adsorbent by an amt $\Delta\phi$ and the adsorption

heat by an amt Δq If the adatoms do not interact, $\Delta \phi$ and Δq vary linearly with θ Moreover, $\Delta q = (n/2)\Delta\phi$, where n is the no of valence electrons of the adatom taking part in the bonding This effect is termed "induction' It provides a quant explanation of the fall in adsorption heat with coverage in all cases where pertinent data are available Horizontal interactions between adatoms, as well as heterogeneity existing prior to adsorption, also contribute to the fall in adsorption heat on a real surface However, induction" is capable of explaining some facts which cannot be ascribed to these effects Some consequences of "induction" are given in connection with problems in chemisorption and catalysis The nature of "active centers" on a metal surface is elucidated (C A 46, 10780h)

(45)

Trans Faraday Soc 47, 900-8 (1951) PHYSICAL AND CHEMICAL ADSORPTION OF LONG-CHAIN COMPOUNDS ON RADIO-ACTIVE METALS Cambridge Univ , Engl F P Bowden A C Moore

A metal foil about 0 001 cm thick and a few sq cm in area was used as the adsorbing surface It was irradiated with neutrons and washed until no further radioactivity was extd The method is sufficiently sensitive under favorable conditions to detect chem reaction of a single monolayer over only one mm of metal surface The adsorption of a long-chain fatty acid, alc , or ester on Pt and Au is phys On Zn, Cd, or Cu the adsorption can be followed by chem reaction This occurs readily with stearic acid and to a lesser extent with Et stearate The metal soap formed is physically attached to the surface and in the presence of solns of the adsorbate a relatively thick film of soap may be formed adjacent to the metal surface The radioactive results, the friction measurements, the electron-diffraction studies and the adsorption expts are in general accord and show a fairly clear distinction between phys adsorption without reaction and adsorption involving chem reaction at the metal surface (C A 46, 2372c)

(46)

J Am Chem Soc 70, 2925-30 (1948) THEORY OF ADSORPTION OF GASES ON SOLIDS Melvin A Cook

A theory modeled after the Brunauer-Emmett-Teller theory is developed for the unrestricted phys adsorption of gases on solids In this theory an attempt is made to describe more accurately the adsorption forces by introducing terms expressing (1) the interaction forces of adsorbed mols with the adsorbent and (2) the adsorbate interaction forces, the latter being largely empirical The equations derived in this manner are found to agree with the sigmoid isotherms over the entire range of relative pressure above 0 05, certain obvious modifications being required to provide agreement for $x < 0\ 05$ Heats of adsorption derived from the theory appear consistent with isosteric and calorimetric heats of adsorption The theory is useful in extrapolating adsorption isotherms in the high-relative-pressure range to provide information on surface pressures of films on solids (C A 43, 1237c)

(47)

J Am Chem Soc 71, 791-7 (1949)	EXTRAPLATION OF ADSORPTION ISOTHERMS TO HIGH RELATIVE PRESSURES AND THE DETERMINATION OF THE SURFACE PRESSURE OF ADSORBED FILMS ON SOLIDS	Melvin A Cook Douglas H Pack

A previously described multilayer adsorption equation that takes into account mol interaction among the adsorbed mols is shown to agree with several Type II isotherms (cf C A 34, 5716[8]) over the entire range of relative pressures from 0 05 to 1 0 Methods are outlined for handling the complex infinite series of the theoretical equation The convergence and divergence properties of the equation are discussed The Bangham equation (cf C A 31, 6077[2]) derived from the Gibbs' adsorption equation for the surface pressure π of an adsorbed film is integrated by means of the crit adsorption isotherm equation and found to yield values that agree well with those obtained by graphical integration of the exptl isotherms The theory offers a method for evaluating the surface pressure from all types of phys adsorption isotherms, including those exhibiting capillary condensation (C A 43, 6033g)

(48)

Proc Roy Soc (London) A212, 505-8 (1952)	AN OPTICAL METHOD OF MEASURING THE THICKNESS OF ADSORBED MONOLAYERS	Univ Cambridge, Engl J S Courtney-Pratt

The interferometric techniques developed by Tolansky were used to study films adsorbed on solid surfaces A unimol layer of fatty acid was spread over mica A highly reflecting layer of Ag was then deposited on both sides of the mica specimen, and the thickness of the acid layer detd by multiple-reflection interferometry The values so obtained were in agreement with x-ray data on the length of the fatty-acid mol The layers were uniform in thickness, multimol layers were absent The method provides direct and independent evidence that mols of a fatty acid, spread by the retraction technique, are adsorbed on a solid surface as a uniform unimol layer Uniform unimol and multimol layers can be formed by deposition from a Langmuir trough The method provides direct and independent evidence of the properties of mol layers adsorbed on solid surfaces There is no evidence that the solid substrate can produce any long-range surface effect leading to the attachment and orientation of multimol layers in polar liquid adjacent to it The accuracy is high and thickness of film can be detd optically to $\pm$ 3 A (C A 46, 8461f)

(49)

Bull acad sci U R S S, Classe sci tech 1945, 813-20, (in Russian) cf C A 40, 4932[2]

ANALYSIS OF THE PROCESS OF ABSORPTION OF GASES BY METALS

I A D'yakonov
A Samarin

Hydrogen absorption isobars of various metals fall into 2 distinct groups one with weaker absorption rising with temp at 400-1600° (Si, Cu, Ag, Cr, Fe, Co, Ni), the other with stronger absorption falling with rising temp (Ti, Zr, Th, V, Cb, Ta, La, Ce, Pr, Pd) Isotherms in the first group, corresponding to simple solid soln, are straight lines in terms of the square root of the gas pressure, p In the second group, the plot against $\sqrt{p}$ is linear only at low pressures, the isotherm then bends upward and attains a horizontal satn level at high pressures In systems of this type, there is a transition e between regions of solid soln and compd formation depending on temp and pressure In the Ag-O system, the min at 400° exhibited by the isobars corresponds to a transition from chem interaction to solid soln above the min, as is evidenced by the linearity with $\sqrt{p}$ above 600° The generalized isotherm of absorption (cc gas per g metal) against $\sqrt{p}$ for each system consists of 3 continuous branches (1) a first linear portion corresponding to soln in the metal of atoms of the gas, followed by (2) a second linear portion of steeper rising slope corresponding to soln in the metal of a gas-metal compd, and (3) a final horizontal 3-phase branch of complete satn This general scheme permits the classification of metal-gas systems The scheme is not obligatory for all systems, e g, γ-Fe-N, which corresponds to branch (2) passing through the origin of the coordinate system with branch (1) wholly absent Higher temp favors region (1), as is seen in particular on Pd-H isotherms, with rising temp, the simple solid-soln region extends increasingly into higher pressures, the isotherm itself being shifted downwards (C A 41, 2367d)

(49A)

Interscience Publishers, Inc, New York, 1949

SURFACE CHEMISTRY

Faraday Society

Papers presented for a discussion at a joint meeting of the Société de Chimie Physique and the Faraday Society held at Bordeaux from 5 to 9 October 1947 in honour of Professor Henri Devaux published as a Special Supplement to Research a journal of science and its applications

Part III Films on Solid Surfaces

Phase Changes in Adsorbed Films at the Gas/Solid Interface
S J Gregg

Surface Attack of Metals by Fatty Acids and the Formation of Lubricating Layers
D Tabor and E D Tingle

Les Films Intercalaires L'Intercalaire Solide/Solide et le Film Lubriciant
M A Marcelin
Étalement des Huiles à la Surface des Métaux Projetés
P Cotton
Index
(C A 43, 5660a)

(50)

Research (London) Suppl , Surface Chemistry 1949, 205-16, cf C A 42, 6602d

PHASE CHANGES IN ADSORBED FILMS AT THE GAS/SOLID INTERFACE

S J Gregg

A study of the film compressibilities calcd from the adsorption isotherms permits elucidation of the transformations between the different states in gas films adsorbed on solids Calcd abs values of the compressibilities are of the same order as those established for films on water Adsorption hysteresis appears to arise in many, but not all, instances from a suspended phase transformation within the film (C A 43, 8789e)

(50A)

Reinhold Publishing Corp , New York, 1951

THE SURFACE CHEMISTRY OF SOLIDS

Univ College of South-West of England, Exeter
S J Gregg

Chapter

I Introduction
II Adsorption of Gases and Vapours by Solids
III Adhesion and the Effect of Adsorption on it
IV Active Solids
V Films on the Surfaces of Liquids
VI Interpretation of the Adsorption Isotherm
VII The External Surface of a Solid
VIII The Electron Microscope and Electron Diffraction Their Application to Surface Problems
IX Friction and Lubrication
X The Spreading of a Liquid Over a Solid
XI Adsorption From Liquids Chromatography
XII Determination of the Specific Surface Area, the Surface Energy and the Density of a Solid
XIII Catalysis and Chemisorption
XIV The Part Played by Surface in Chemical Reactions
XV Conclusion
Index
(C A 45, 10031c)

(50B)

Reinhold Publishing Corp , New York, 1952	THE PHYSICAL CHEMISTRY OF SURFACE FILMS	Univ of Chicago William D Harkins

Chapter
I The Nature and Energetics of Surfaces
II Films on Liquids
III Films on Solids
IV Properties of Soap Solutions
V Mechanism of Emulsion Polymerization
VI The Role of the Electric Double Layer in the Behavior of Lyophobic Colloids
Index
(C A 46, 5952d)

(51)

Discussions Faraday Soc 1950, No 8, 18-27, cf C A 44, 894h	THEORIES OF ADSORPTION AND PROPERTIES OF SURFACE LAYERS BEHAVIOR OF A MOLECULE NEAR A METAL SURFACE	Univ Bristol, Eng K Huang G Wyllie

The energy changes assocd with electron transfer to or from a mol at distances from the metal surface may be such that the quantum-mech tunnel effect can be neglected The distribution of charge on a large adsorbed mol is found by a self-consistent treatment of the image field The representation of electronic conditions at the catalytic metal surface in terms of Pauling's resonating bond theory of the metal structure, with the formation of largely covalent bonds between definite metal atoms and the absorbed reactants, is proposed as giving a reasonable phys approximation to the real situation (C A 45, 9985c)

(52)

J Am Chem Soc 68, 1941-52 (1946), cf C A 40, 4275[6]	SURFACES OF SOLIDS XIV A UNITARY THERMODYNAMIC THEORY OF THE ADSORPTION OF VAPORS ON SOLIDS AND OF INSOLUBLE FILMS ON LIQUID SUBPHASES	Univ Chicago George Jura Wm D Harkins

On compression of an oil film on water the succession of phases is (1) gas, (2) liquid expanded, (3) liquid intermediate, (4) liquid condensed, and (5) higher pressure condensed The same successtion is found in films on solids Except for the gaseous state no valid equations of state for films have been developed Empirical equations of state are derived for the phases (1), (2), (3), and (4) + (5) These equations are valid, each for the sp phase only, for either oil monolayers on water or for adsorbed films on solids The effects of temp are in general the same on a solid subphase as on water in the low-pressure region, but the sign of the entropy term is

reversed at high pressures On water, stable oil films are unimol , but on solids at high vapor pressures the film becomes in general thick and multimol without affecting the general phase relations There is one exception, on solids the higher-pressure-condensed film has a higher compressibility than the lower-pressure-condensed film whereas on water the reverse of this is true The relations of the various phases on the surface of a solid are capable of statistical treatment The general phase relations of adsorbed films on solids are essentially the same as those of monolayers of oil on water 32 references (C A 41, 1908c)

(53)

J Phys Soc Japan 6, 135-8 (1951), cf C A 45, 1836a	STRUCTURE OF THIN METALLIC FILMS FORMED BY EVAPORATION ON MOLYBDENITE	Nagoya Univ Yoshiro Kainuma

Au, Cu, Ni, Pt, and Al were evapd on the cleavage surface of molybdenite to a thickness of 20-100 A at 25-500° and a pressure of 10^{-4} mm Electron-diffraction examns were made at room temp Sym , asym , and random orientations were observed When the (111) plane of the metal is parallel to the cleavage surface and the (110) axis of the metal is parallel to the (100) axis of molybdenite, 2 types of arrangements, which are mirror images, are possible When both orientations occurred in the same amt , the preferred orientation was called sym when one of these orientations predominated, the preferred orientation was called asym Au exhibited sym orientation from 25 to 200° and asym orientation from 200° to 500°, Ni exhibited sym orientation at 100° to 200° and at 450° and assym orientation from 200° to 400°, Cu exhibited random orientation at 25° and sym orientation from 50° to 500°, Pt exhibited sym orientation from 250° to 430°, and Al exhibited random orientation from 75° to 375° Presumably the preferred orientation is induced by the periodic field of the surface force and not by steps and cracks (C A 45, 9331f)

(53A)

Chemical Publishing Co , Brooklyn, 1950	THIN FILMS AND SURFACES	Winifred Lewis

Chapter

I Introductory
II The Structure of Metal Surfaces and of Surface Films (of Oxide, etc)
III The Structure of Thin Films
IV The Production of Thin Metallic Films
V Properties of Metallic Films and Surfaces
VI The Properties of Surface and Thin Films of Aluminum and its Alloys
VII Some Applications of the Properties of Aluminum Films and Surfaces
Appendix
References
Index

(C A 44, 3347b)

(54)

Bull Chem Soc Japan 24, 200-2 (1951) (in English), cf C A 46, 4885c	UNIMOLECULAR FILMS IV STABILIZATION OF MONOPARTICLE FILMS OF NONPOLAR SUBSTANCES BY STEARIC ACID	Kyushu Univ , Fukuoka Ryôhei Matsuura

Pressure-area diagrams were detd for mixed films of paraffin m 53°, paraffin m 47°, anthracene, phenanthrene, chloronaphthalene, m 100-110°, triphenylmethane, polystyrene, and raw rubber with stearic acid The pure hydrocarbons do not form films, above 50% stearic acid the films are very stable It is proposed that the films are micellar films consisting of aggregated nonpolar mols The particle radii in A were calcd to be, in the order named above and excepting polystyrene, 40, 30, 55, 71, 200, 68, and 370, resp

Ibid , p 203-6	V UNIMOLECULAR FILMS OF HARDLY SPREADABLE SUBSTANCES STABILIZED BY STEARIC ACID AND CETYL ALCOHOL	Tsunetaka Sasaki Ryôhei Matsuura Nobumasa Fujimoto

The film area-compn curve for novolac resin-stearic acid mixt is linear above 30% stearic acid, the region of stable films The film area of 1 2 sq m /mg at zero stearic acid concn is twice that of the unstabilized film Film-area measurements were made with the azo dyes 1-(p-tolylazo)-2-naphthol(I), 1-(o-tolylazo)-2-naphthol(II), Sudan III (III) and Sudan IV with hexadecyl alc as stabilizer The addition of cupric ion to the underlying H_2O at a pH of 7 causes the halving of the film area of I and III as a result of formation of chelate compds (C A 46, 10776b)

(55)

Proc Roy Soc (London) A204, 514-24 (1951), cf C A 41, 3949a, 42, 5216d	ORIENTATION OF FATTY ACID AND SOAP FILMS ON METAL SURFACES	Univ Cambridge, Engl J W Menter D Tabor

The orientation and structure of films of lauric, myristic, palmitic, stearic, and octacosanoic acids and certain of their heavy metal soaps on surfaces of Pt, Ag, Cu, Cd, Zn, and mild steel were studied by electron diffraction Films were applied by retraction of molten drops and by rubbing at room temp The effect of surface temp on orientation was studied For all films there was a characteristic temp at which disorientation occurred For acids on nonreactive metals the transition occurred near the m p On reactive metals, Zn and Cd, disorientation occurred near the softening point of the corresponding soap, suggesting soap formation Soap films were found to disorient near their softening point Film transition temps as shown by electron diffusion were correlated with the transition temps as shown by the coeff, of friction (C A 35, 6098^4, 39, 5074^5) and found to be in fair agreement (C A 46, 4875f)

(56)

Proc Roy Soc (London) A204, 525-33 (1951), cf preceding abstr	STRUCTURE OF THIN FILMS OF ALIPHATIC ESTERS AND ALCOHOLS ON METALS	Univ Cambridge Engl J V Sanders D Tabor

The structure and orientation of thin films of octadecyl and melissyl alc , Me and Et stearate, and melissyl melissate in thin cryst layers and as films on Pt, Cu, Cd, Zn, and mild steel were studied by electron diffraction The orthorhombic structures of thin cryst layers observed at room temp in transmission expts changed to hexagonal at a temp just below the m p for both alcs and esters Films prepd by either retraction from the melt or soln or by rubbing were oriented in the 1st layer with the hydrocarbon chain normal to the metal surface Disorientation occurred for both alcs and esters as the surface temp approached the m p The temp of disorientation shown by electron diffraction correlated well with that shown by measurements of coeff of friction (C A 46, 4875h)

(57)

Bull Chem Soc Japan 24, 274-8, (1951), cf C A 47, 22d	UNIMOLECULAR FILMS VII EFFECT OF METALLIC IONS ON THE UNIMOLECULAR FILM OF STEARIC ACID	Kyushu Univ , Fukuoka Tsunetaka Sasaki Ryôhei Matsuura

Metallic ions are classified into 2 groups according to their effects on the pressure-area curve for the unimol film of stearic acid spread on the surface of the soln The first group (Ca, Ba, Mg) causes the film to condense, whereas the second (Th, Al, Cu, Fe, Zn, Hg, Co, Ni) causes the film to expand The difference is explained in terms of the mol structure of the corresponding metallic soaps, characteristic of the nature of the metallic ions of each group Soaps of the 1st group have simple structures, whereas those of the 2nd group have polymeric structures

Ibid , p 278-81	VIII RIGIDITY OF THE MONOLAYER OF STEARIC ACID ON THE SURFACE OF SALT SOLUTIONS	Ryôhei Matsuura

Relative rigidity measurements with the surface viscometer (C A 47, 23a) show that metallic ions in the substrate that cause expansion of the unimol film also render it remarkably rigid as compared with ions causing film contraction A study of expansion patterns of the stearic acid film in the presence of metallic ions confirmed this conclusion

Ibid , p 282-5 IX EFFECT OF DISSOLVED DYES ON THE MONOLAYER OF STEARIC ACID

Phloxine and Congo red cause film expansion in acid soln , chrysodine, crystal violet, and night blue cause expansion in alk soln The mechanism is complex, involving chiefly Van der Waals adsorption in the case of phloxine and Congo red Stearic acid forms ionic complexes with the basic dyes, similar to those formed with Th and Al ions Crystal violet causes less expansion of cetyl alc monolayer films, because the alc is less ionizable than is stearic acid (C A 47, 41681)

(58A)

Symposium on Properties of Metallic Surfaces Inst Metals, London, 1952, 23-58 RADIOISOTOPES IN THE STUDY OF METAL SURFACE REACTIONS IN SOLUTIONS Carnegie Inst Technol , Pittsburgh, Pa Massoud T Simnad

The chief characteristics of radioisotopes, their advantages and limitations in tracer work, and the effect of radiation on matter are discussed The exchange between metals and ions in soln is discussed, previous expts and explanations are criticized, and from the results of recent expts several generalizations are made regarding the mechanism of this phenomenon The passivating action of chromates was studied with the aid of tagged chromate ions in soln and the results are shown to corroborate the film theory of Hoar and Evans (C A 27, 13) Self diffusion and isotopic exchange in surface films and aq solns are discussed in view of their important part in governing the behavior of metals in soln The identification and location of surface inhomogeneities in metals by activation analysis and by intentional addn of radioisotopes are described Radiotracer studies of the deposition of traces of ions on to metal surfaces are summarized (C A 47, 2610d)

(59)

Nature 163, 441 (1949) STRUCTURE OF MOLECULAR FILMS OF STEARIC ACID ON COPPER J A Spink

Electron-diffraction patterns of uni- and multi-mol layers of stearic acid on Cu were obtained that show the existence of crystallites of a metal soap on the Cu surface The patterns indicate that the Cu stearate crystals are oriented with their (001) planes parallel to the metal surface (C A 43, 7769f)

(60)

Offic Dig Federation Paint and Varnish Production Clubs No 333, 650-70 (1952)	METAL SURFACE PHENOMENA	Massachusetts Inst of Technol , Cambridge Herbert H Uhlig

Unsatisfied valence forces at the surface of a metal lead to a state of tension of the surface atoms and compression of metal underneath These forces also account for adsorbed films of substances bonded to the metal surface in varying degrees Films with low energies of bonding are so-called physically adsorbed, and with high energies of bonding are said to be chemisorbed Adsorbed layers account in major part for (1) friction and lubrication phenomena (rate of wear), (2) catalytic activity, and (3) passivity and corrosion resistance, particularly of the transition metals (C A 47, 3774f)

(61A)

Symposium Grenslaagverschijnselen, Verhandel Koninkl Vlaam Acad Wetenschap , Belg 1947, 38-61, discussions 62-3 (English summary)	ADSORPTION OF GASES BY SOLID MATERIALS	A van Itterbeek

Both activated, unimol adsorption, and van der Waals'multimol adsorption are discussed on the basis of Langmuir's, Polanyi's, and Brunauer-Emmett's theories Van der Waals' adsorption involved 2 kinds of energy, one resulting from direct interaction between surface and gas mols , and one due to forces acting between adsorbed mols When the latter prevails, the isotherm curve has an S shape, and the adsorbed layer may tend to form a film (C A 43, 3263f)

(62)

Australian J Sci Research A5, 288-302 (1952)	THE HYSTERESIS OF ADSORPTION ON SOLID SURFACES	Commonwealth Sci and Ind Research Organization, Sydney R G Wylie

The effect of surface discontinuities on 2-dimensional phase transitions is examd theoretically Hysteresis is related semiquantitatively to nucleation, profile, and interfacial free energy of the α-phase (C A 46, 9930g)

CLEANING

(63)

U S Patent 2,421,863 June 10, 1947	DRIVING OUT OCCLUSIONS OF GASES LIKE HYDROGEN FROM THE SURFACE LAYERS OF WORKPIECES	Richard Beck (vested in the Attorney General of the U S

A metal surface is cleaned of occluded gases, oxide films, and embedded nonmetallic impurities, such as carbides, by making it the anode in an aq bath having a pH not lower than 7 Current impulses lasting sufficiently long to remove impurities, but not long enough to cause oxidation, are used The duration of these impulses may be from 1 to 60 sec , and they are repeated until gas evolution over the whole surface becomes uniform A metal coating is then deposited by electroplating Fe sheets cleaned by this method, plated with Ni, and exposed to boiling distd water showed a corrosion resistance superior to that of sheets which had been cleaned by cathodic degreasing and an anodic treatment uninterrupted for 30 sec The process is also applicable to removal of occluded H_2 from an electrodeposited metal, such as from Ni previous to Cr plating (C A 41, 7284h)

(64)

Proc Am Electroplaters' Soc 35, 215-21 (1948)	METAL CLEANING AND A SIMPLE TEST FOR SURFACE CLEANLINESS	George B Hogaboom

Metal-cleaning problems are reviewed Steel, when dipped in a soln contg 40 g /l $CuSO_4$ and 17 g /l H_2SO_4, takes a clear, semibright, uniform, adherent Cu deposit if the surface is clean (C A 43, 8899f)

(65)

Monthly Rev Am Electroplaters' Soc 34, 430-41 (1947)	A SURFACE-ACTIVE AGENT FOR THE CLEANING OF METALS	Allied Chem and Dye Corp , Buffalo, N Y O M Morgan

A detergent of the alkyl aryl Na sulfonate type, Nacconal NR, is shown to improve the cleaning efficiency of both alk and acid metal cleaners Cleanliness of the surfaces of the test specimens was detd quantitatively by measuring the intensity of fluorescence under ultraviolet radiation The intensity of fluorescence is proportional to the amt of oil on the surface (C A 41, 4082g)

(66)

U S Reissue 22,887 June 3, 1947	REMOVING OXIDE FROM METALS	Harry R Spence Horace W Hooker

A reissue of U S patent 2,395,694 (C A 40, 2778[7]) (C A 41, 4434d)

ELECTROLYTIC POLISHING

(67A)

Pittsburgh Intern Conf on Surface Reactions 1948, 187-95	SURFACE PREPARATION BY ELECTRO-POLISHING	Charles L Faust

Essentially a detailed review and discussion of the literature concerning electropolishing, published since 1936 F describes in particular the different methods of electropolishing, the phys and chem properties of the surface obtained, and the various applications for industry (prepn of surfaces for electroplating) and in the lab In this last case electropolished surfaces are particularly advantageous for the study of the microstructures and of the electrochem potentials, and also as a starting point of corrosion studies (C A 42, 8679f)

(68A)

Comm. tech états et propriétes surface métaux, Journées étates surface (Paris) Oct , 1945, 37-9	THE STUDY OF METALLIC SURFACES BY ELECTROLYTIC METHOD THE PART OF THE BEILBY LAYER	A Grumbach

Polished and plane surfaces immersed in a liquid are covered by a layer of the polar solvent, and an electrostatic charge is produced The adsorbed liquid and the electrode behave like a condenser shunted with a great resistance In dil solns the discharge is complicated and in H_2SO_4 soln the change from one to the other form takes place when the two Raman lines at 450 and 985 cm^{-1} of the SO_4 ion appear These phenomena are observed as on the Beilby layer, no irregular discharges take place (C A 42, 3302e)

(69)

Compt rend 230, 1862-4 (1950)	CHEMICAL NATURE OF ELECTROLYTICALLY POLISHED METAL SURFACES AND ITS PRACTICAL IMPORTANCE	Pierre A Jacquet Marcel Jean

Surfaces of Cu, Zn, and Mg electrolytically polished in phosphoric acid soln can retain traces of a compd contg P Polished Fe in phosphochromic medium does not retain compds rich in P or Cr, but is covered with oxide Results are discussed from the point of view of certain properties peculiar to electrolytically polished metals (C A 44, 8797d)

PHYSICO-CHEMICAL REACTIONS OF SURFACES - Electrolytic Polishing

(70)

J Electrochem Soc Japan 18, 75-6 (1950), cf C A 45, 3258i	ELECTROLYTIC POLISHING II ELECTROLYTIC POLISHING FOR BASE-TREATMENT OF ELECTROPLATING	Kyoto Univ , Moto Kawasaki Norikatsu Kuwabara

Buff-polished and electropolished surfaces of metals (Cu, brass, carbon steel, and Ni) were electroplated with Ni or Cr, and the finished layers were compared Those on the electrolytically polished surfaces were less porous and more resistant to tearing than those of the buff-polished surfaces (C A 45, 7450d)

(71)

Rev Mét. 44, 87-90 (1947)	REAL PHYSICOCHEMICAL PROPERTIES OF METALLIC SURFACES DEVELOPED BY ELECTROLYTIC POLISHING	P Lacombe P Morize G Chaudron

Properly conducted electrolytic polishing and careful washing produce Al entirely free from any oxidic film on its surface This is shown by the soln potential of Al treated in this manner, which is -1 20 v in a 3% NaCl for pure Al and -0 70 v for Al coated with the heaviest oxide film which can be produced by exposing Al to air at room temp The drop of potential is proportional to the thickness of the oxide film, this permitted extension to oxidation at room temp of Mott's observation (C A 34, 4328^2) that oxidic film formation follows a logarithmic law at elevated temp The work has been extended to cover Zn, by using a bath of 185 cc H_3PO_4 in 315 cc C_2H_5OH at less than 2 5 v and washing with acetone and C_2H_5OH Clean Zn has a soln potential of -1 08 v , after 250 hrs in air it becomes -0 70 v following a log curve Fe polished electrolytically in a bath of 185 cc $HClO_4$ 765 cc Ac_2O, and 50 cc H_2O and washed with the utmost care still exhibited a film of oxide Corrosion of Al free from oxide by 10 N HCl follows a substantially straight line, as measured by H_2 evolution, but after being exposed to air it shows a pronounced passivity Distd H_2O attacks Zn which has been exposed to air in small localized areas, while Zn free from oxide is corroded uniformly resulting in a well-developed corrosion pattern within a few hrs (C A 42, 2183e)

(72)

Naturforsch u Med Deutschland 1939-1946 8, No 1, 102-8 (1947)	THE STRUCTURE OF THIN FILMS	Heinz Raether

A review, with bibliography, covering both amorphous and cryst films

Ibid , p 109-18 THE SURFACE STRUCTURE OF SOLIDS

Electron-diffraction expts and photographs made with the aid of the electron microscope give essential information regarding cold-worked surfaces They indicate that cold working always reduces the grain size and that it does not

produce an amorphous surface but rather a very finely cryst surface Results of studies of the properties of deformed surface films, especially their recrystn and oxidation, are reported The structures of electrolytically polished metal surfaces and tempered alkali halide surfaces are discussed Through Chem Zentr (Russian Zone Ed) 1948, II, 1155 (C A 44, 8722f)

(73)

J Electrochem Soc Japan 18, 70-4 (1950)	THE MECHANISM OF ELECTROLYTIC POLISHING I	Hitachi Central Research Lab , Tokyo, Seikichi Saito

Examns were made and curves were prepd of the relations between the voltage and current in electropolishing of W in NaOH solns of various concns at various temps The voltage-current plane had 3 distinct regions The surfaces of W obtained under the conditions corresponding to these 3 regions were rough, smooth and flat, and uneven, resp (C A 45, 7450b)

(74)

Ibid, p 223-7 cf C A 45, 3258i	THE MECHANISM OF ELECTROLYTIC POLISHING III	Seikichi Saito

Smooth polishing (like a mirror) is due to the uniform distribution of the anode current caused by the extremely pos characteristic of ion sheath, rough polishing is due to the irregular distribution caused by the neg characteristic, and the even polishing (like an eroded mirror) is due to the breakdown of the insulation of the ion sheath by the applied voltage (C A 45, 7450c)

(75)

Compt rend 224, 1102-3 (1947), cf C A 33, 1191[8], C A 39, 2258[8], Journées des états de surfaces 23, 40 (1945)	EXAMINATION OF ELECTROLYTICALLY POLISHED (METAL) SURFACES BY ELECTRON DIFFRACTION	Jean Jacques Trillat Moore Kranert, et al Taboury Bernard
Ibid, p 44		

Three metals were electrolytically polished with perchloric acid (for Fe, Al) and phosphoric acid (for Fe, Al, Cu) Numerous examns by the electron-diffraction method seem to prove the existence of an amorphous layer, situated immediately under the free surface of the metals The layer disappears after a longer electrolytic polishing, and the cryst structure becomes distinct The two solns produced a pronounced difference only with Al, phosphoric acid removing the amorphous layer better (C A 41, 4427i)

OXIDATION

(76)

Doklady Akad Nauk S S S R 61, 849-52 (1948)	ELECTRIC THEORY OF ADHESION OF FILMS TO SOLID SURFACES	B V Deryagin N A Krotova

A film of gutta-percha is made to adhere to the lower face of a solid plate (glass, Ni, Zn, steel) which can be rotated around a horizontal axis so as to form any desired angle α with the perpendicular, under the action of a load P suspended on the lower end of the film, detachment begins at a certain angle α_0 and proceeds at a rate v (in cm /sec) which increases with P and with α. If the work of detachment A is taken to be equal to the work of the falling load, $A = (P/b)(1 - \cos \alpha)$ Exptl plots of A as a function of v show an initial very rapid increase of A with v, and A of the order of magnitude of 10^5 ergs/sq cm , i e some 10^2 to 10^3 times the energy of adhesion of liquids to solids, calcd by the Dupré-Young equation from the surface tension and the angle of contact Neither the high value of A nor its increase with v can be ascribed to energy lost in the deformation of the film, calcn shows that these losses can only amt to a correction A theory that fits the observed facts can be developed on the assumption that almost all the work of detachment is spent to overcome electrostatic forces between opposite charges formed in the process of detachment The potential difference between the 2 surfaces, $V = 4\pi\sigma h$ (where σ = surface d of elec charge, h = distance between the surfaces) With v increasing, A tends to $A_0 = 2\pi\sigma h_c$, where h_c is the discharge distance', it is detd graphically, on a plot of V against ph (p = pressure), by the intersection with Paschen's curve of gaseous discharge, e g , for gutta-percha on glass, $h_c = 1 \times 10^{-4}$ cm , $\sigma = 1\ 3 \times 10^{-4}$ c g s e units This accounts for the fall of A with decreasing v, owing to leakage of elec charges, and leads, at very low v, to $A \sim v^4$, consistent with the exptl curves Further in agreement with the theory, v falls sharply with decreasing gas pressure p at const P, hence, at v const , A increases This is analogous to the increase of the work of cleavage of mica in a high vacuum and with the high potentials developed in this process, as observed by Obreimov (Proc Roy Soc (London) A127, 290, (1930) The elec nature of the work of detachment is further corroborated by the observed effects of irradiation with x-rays or radioactive Th (C A 43, 2842c)

(77)

Modern Packaging 23, No 7, 125 (1950)	MEASURING MINUTE SURFACE FILMS	Carnegie-Illinois Steel Corp J G Donelson

A hydrophil balance is used for a rapid check on the distribution of oil film on tin plate. (C A 44, 9906h)

(78)

J Electrochem Soc 94, 139-51 (1948)	ZONE OF METAL-PHASE CONSUMPTION IN GAS-METAL REACTIONS	Illinois Inst Technol Chicago Andrew Dravnieks Hugh J McDonald

It is shown by an analysis of the scale-growth process that the scale of even approx uniform compn formed in the reaction between gas and metal must consist of at least 2 layers One layer is formed by the outward migration of metal ions and electrons through the scale, the other forms under the scale in the zone of consumption of the metal phase The layers form under completely different conditions The inner layer is vital for the maintenance of metal transport to the bulk of the scale and grows at a gas pressure of the order of the dissocn pressure of the scale substance It is demonstrated that the inner layer will develop cavities A third layer may be formed in some secondary process, e g , that of recrystn It is therefore evident that the concept of a uniform process of scale growth is an oversimplification and fundamentally incorrect This conclusion is supported by an investigation on CuI scale The protective-film formation on Al and the accelerated growth of oxide films on metals at the beginning of oxidation are explained on the basis of the considerations presented above (C A 42, 8763e)

(79)

Metall 6, 285-91, (1952)	INFLUENCE OF ABSORPTION PHENOMENA ON THE OXIDATION OF METALS AT HIGH TEMPERATURES	Univ Greifswald, Ger H J Engell K Hauffe

A discussion of the mechanism involved in oxidation of metals at high temps The influence of the nature of the oxide layer formed (porosity, diffusion of ions or electrons through this layer, or layer of scale, d of the oxide layer), the lattice structure of the metal and the mode of entry of O into the lattice, the influence of skin formation on the formation of a thick oxide layer, and various other factors are considered 19 references (C A 46, 8585b)

(80A)

Pittsburgh Intern Conf on Surface Reactions 1948, 71-6	MECHANISM OF THE FORMATION OF FILMS ON METALS	U R Evans

The purpose is to present a picture of the mechanism of film formation on metals that explains the main exptl facts This picture leads to the four equations established by Vernon (C A 37, 6234g) The growth of films on metals proceeds in four successive stages (1) Attachment of O to the surface by chemisorption with formation of a two-dimensional layer of a solid

soln (2) Latteral growth during which the film (oxide) is in lateral compression This period is represented by the sigmoid curl at the origin of the oxidation-rate curve (3) Thickening of the film originating after the entire surface is covered The thickening of the film, translated by a parabolic law, is believed to result from the outward movement of cations and electrons This explains the fact that films that have poor electronic or ionic cond are protective (4) Periodic crack-heal growth, due to sudden cracking or blistering resulting from internal stress existing in the film The laws governing this last phase depend on the temp and on the nature of the film At high temps , plasticity will be preserved and cracks may not occur At lower temps cracks may occur in the outer layer overlying the inner compact layer According to the relative resistance of the two layers, the growth will obey either the parabolic or the rectilinear law At still lower temps blistering may take place leading to cracks parallel to the surface playing the role of a barrier Then the rectilinear law is replaced by a logarithmic relation and the parabolic by an asymptotic (C A 42, 8040d)

(81)

Trans Electrochem Soc 91, 24 pp (1947)(Preprint), cf C A 40, 4016[6]	THE MECHANISM OF OXIDATION AND TARNISHING	Cambridge Univ , Eng. U R Evans

The thickening of oxide (or sulfide) films can occur in different ways Outward migration of cations and electrons, normally by lattice defects, gives parabolic film growth, but mech breakdowns due to compressional stresses (of which good evidence exists) may lead to other equations It is shown that blistering (likely if adhesion is poor and cohesion good) should lead to rectilinear or logarithmic thickening according as the rifts in the blister walls do or do not admit O Flaking (which is rare but catastrophic) should lead to periodical recommencement of rapid oxidation Shear-cracking (likely if cohesion is poor and adhesion good) may produce parabolic, rectilinear, or intermediate forms The theory is applied to interpret the results of Vernon (C A 18, 964, 21, 1623, 25, 5667, 30, 1722[9]) and others, and particularly to explain why conditions prevailing at the time a specimen is first exposed decide the corrosion-rate, which often continues unchanged even if subsequently conditions fluctuate (C A 41, 2376b)

(82)

Finska Kemistsamfundets Medd 60, No 1, 4-19 (1951)	SURFACE FILMS ON METALS	Tek Hogskolan, Helsingfors, Finland H Grubitsch

A review with 29 references (C A 46, 7486f)

(83)

Metals Technol 13, No 7, Am Inst Mining Met Engrs, Inst Metals Div Tech Pub No 2068, 26 pp (1946)	AN ELECTRON-DIFFRACTION STUDY OF OXIDE FILMS FORMED ON IRON, COBALT, NICKEL, CHROMIUM, AND COPPER AT HIGH TEMPERATURES	E A Gulbransen J W Hickman

The literature on the electron-diffraction study of the oxidation of Fe, Co, Ni, Cr, and Cu is reviewed The app , prepn of specimens, exptl procedures, and the interpretation of the electron-diffraction data are discussed The following subjects were studied in the oxidation of Fe (1) vacuum-formed films at elevated temps , (2) the effect of surface prepn , (3) the low-temp oxidation of Fe, (4) the high-temp oxidation of Fe, (5) the effect of cooling atm on the oxides observed at room temp , (6) the effect of heating and cooling films of known thickness The oxidations of Co, Ni, Cr, and Cu were studied over a wide temp range and for times up to 1 hr The oxidation of Co indicates one lattice transformation between Co_3O_4 and CoO at 400° to 600° No lattice transitions occur in the oxides formed on Ni, Cr, and Cu Crystal growth and orientation effects were noticed, which indicate phys changes in the surface oxides of thin metals (C A 41, 358g)

(84)

Am Inst Mining Met Engrs , Inst Metals Div ,Metals Technol 14, No 6, Tech Pub No 2224, 17 pp (1947)	THIN OXIDE FILMS ON TUNGSTEN	E A Gulbransen W S Wysong

Vacuum microbalance measurements were made on the oxidation of W from room temp to 550° The effect of surface prepn , surface area, and pressure on the oxidation rate was also studied The reduction of the oxides was studied over the temp range of 500-700° and a H pressure of several cm The high-temp vacuum behavior of the W oxides was studied over the temp range of 600-1025° Room-temp film formation was found for specimens properly reduced and cooled in H atms Both thick and thin oxide films on W appear to be reduced at temps of 500° and higher (C A 41, 7190b)

(85)

Ibid , No 2226, 17 pp (1947)	THIN OXIDE FILMS ON MOLYBDENUM	E A Gulbransen W S Wysong

Vacuum microbalance measurements were made on the oxidation of Mo from 250 to 450° The effect of pressure, surface prepn , concn of inert gas in the lattice, cycling procedures in temp , and vacuum effect were also studied The reduction of the surface oxides was studied over a temp range of 500-600° The rates of evapn of a thick oxide film were studied at temps of 474-523° In vacuums of the order of 10^{-6} mm of Hg and at elevated temps an oxidation process was observed (C A 41, 7190a)

(86)

Ind Eng Chem 41, 1385-91 (1949), cf CA 36, 2824[6], 37, 2251[3], 40, 7134[3], 42, 7694b

KINETIC AND STRUCTURAL FACTORS INVOLVED IN OXIDATION OF METALS

Earl A Gulbransen

By a sensitive wt -gain method the oxidation of Fe, Mo, W, Al, and Mg was studied as a function of time, temp , pressure, and surface area At 400° the order of increasing rate of reaction is Mg, Al, W, Fe, and Mo No simple rate law fits all the data After a rapid initial period the parabolic law may be fitted to the data for many metals The rate law follows an exponential behavior, whereas the effect of pressure is small for most metals in the pressure range studied An electron-microscope study of stripped oxide films showed the film to consist of crystals of the order of 50 to 2000 A , depending on the temp and time of reaction The effect of the boundary zone between crystals on the rate of reaction is discussed The crystal structure of the oxide film was studied using the electron-diffraction method The several rate theories and the transition-state theory of oxidation are presented, and the oxidation results compared and tabulated The free energy of activation for the rate-limiting process varies from 36,040 cals per mole at 375° for Mo to 56,100 for 18-8 stainless steel at 650° (C A 43, 7309c)

(87)

Am Inst Mining Met Engrs , Inst Metals Div , Metals Technol 15, No 8, Tech Pub No 2483, 18 pp, (1948) cf C A 41, 3733i

OXIDE FILMS FORMED ON METALS AND BINARY ALLOYS AN ELECTRON-DIFFRACTION STUDY

J W Hickman

In general, it is impossible to predict the oxide that will be observed on the basis of the thermodynamic stabilities of the several possible oxides or of the sizes of the ions that may form Oxides of some of the elements are not observed in the outer surface of the oxide layer Among these are oxides of Si and Zr Some alloys show the presence of oxides of only one of the metals indicating that ions of the other metal have much lower rates of formation and diffusion in the temp region studied Other alloys show the presence of oxides of one of the metals at low temps , while oxides of the other metal appear at elevated temps In these cases the rates of formation and diffusion of the two metallic ions vary in a different manner with temp Complex oxides contg more than one metal do not form on the surfaces of most alloys Exceptions to this are alloys which contain Fe, Cr, or Ni (C A 43, 985f)

(88)

Iron Age 162, No 7, 90-4, No 8, 90-4, (1948)	METAL OXIDE FILMS AT ELEVATED TEMPERATURES	Westinghouse Research Labs , E Pittsburgh, Pa J W Hickman

Important factors in detg the chem and phys structure of the oxide film on the surface of an alloy are the rates of formation and diffusion of the various metal ions through the oxide lattice, the rate of diffusion of O atoms or mols through the oxide lattice, the thermodynamic stability of the oxide, the lattice type of the oxide and its resemblance to the metal or alloy lattice, the chem reactions which may occur in the oxide film between the several oxides or between metal ions or O atoms and the several oxides, the preoxidation treatment of the metal, such as annealing, polishing, or cleaning, and the rates of nucleation and growth of the oxide crystals The at geometry and compn of the outer layer of the surface film which is in contact with the gaseous atm are studied by means of reflection electron diffraction, where the electron beam probably samples no more than the outer 100 A of the film The growth, shapes, and sizes of the oxide crystallites are detd by light or electron microscopy Various Al alloys, Nichrome, Inconel, Stellite, Refractaloy, Kovar, Hypernik, mild steel, Hastelloy, and Z-Nickel were investigated In general the results show that it is not possible to predict which oxides will form on the surface of an alloy by considering the thermodynamic stability of the oxides, nor by considering the relative sizes of the metallic ions The most important factors are the relative rates of formation and diffusion of the metallic ions, and how they are influenced by temp An analytical method is desirable for analyzing the films while still present on the metal 30 references (C A 42, 7693a)

(89)

J Phys and Colloid Chem 52, 1186-97 (1948), cf C A 42, 5824a, 5826a, 43, 985f	AN ELECTRON-DIFFRACTION STUDY OF OXIDE FILMS FORMED ON HASTELLOY ALLOYS A, B, C, AND D	J W Hickman E A Gulbransen

Electron-diffraction techniques are used to study the structures of the oxides which form on the Hastelloy alloys A, B, C, and D in the temp range 300° to 900°. The structures observed are plotted as existence diagrams of the oxides on a time-temp scale The oxide, occurring on Hastelloy A, which is of the spinel type, is probably Fe_3O_4 Hastelloy B, which contains more Mo and less iron than Hastelloy A, oxidizes in a much more complicated manner NiO forms at low temps and at 800° while a spinel oxide, probably Fe_3O_4, forms at 700° and another spinel, which may contain Ni and Fe, forms at 900° Oxides of Mo, mainly MoO_2, form at 600° On Hastelloy C, probably Fe_3O_4 forms below 600° while Cr_2O_3 forms at 600° and 700° and a spinel oxide whose lattice parameter agrees with NiO Cr_2O_3 forms at 800° and 900° Hastelloy D which consists mainly of Ni, and Si with smaller quantities of Cu and Al forms Cu_2O up to 600° and NiO above this temp (C A 43, 1299e)

PHYSICO-CHEMICAL REACTIONS OF SURFACES - Oxidation

(90)

Metals Technol 14, No 3, Am Inst Mining Met Engrs, Inst Metals Div, Tech Pub No 2144, 17 pp (1947), cf C A 41, 79d	ELECTRON-DIFFRACTION STUDY OF OXIDE FILMS FORMED ON MOLYBDENUM, TUNGSTEN, AND ALLOYS OF MOLYBDENUM, TUNGSTEN, AND NICKEL	J W Hickman E A Gulbransen

The results of this investigation of thin oxide films are presented as existence diagrams of the oxides on a time-temp scale Heating and cooling expts are also included The study shows that (1) The oxide structures of thin film are identical with those of bulk oxides as detd by x-ray diffraction (2) The transition WO_3 to WO_2 on W occurs at lower temps for thinner films (3) Only oxides of Mo or W are obtained on the alloys 80 Mo-20 W, 93 Mo-7 Ni, and 93 W-7 Ni, this is in agreement with thermodynamic data for solid-phase reactions between NiO and W or Mo (4) The addn of Ni to Mo elevates the existence region of MoO_3 about 200° (5) The addn of W to Mo elevates the existence region of MoO_3 about 100° (6) The addn of Ni to W lowers the existence region of WO_3 about 100° (7) The O-W and O-Mo ratios increase with oxidation time at comst temp, as evidenced by the appearance of WO_3 and MoO_3 (8) The oxides Mo_4O_{11} and W_4O_{11} are not observed in the temp range 300° to 700° (C A 41, 3733i)

(91A)

Pittsburgh Intern Conf on Surface Reactions 1948, 142-56	INVESTIGATIONS OF GAS-METAL REACTIONS BY REFLECTION ELECTRON DIFFRACTION	J W Hickman

The structure of the outer layers of thin oxide films is studied by the reflection electron-diffraction method, the technique of which is described The results provide information with regard to ten different types of problems (1) Structural changes occur as oxidation proceeds at const temp The oxide compn of binary alloys varies during oxidation, one of the metals displaying a greater tendency to reach the surface and undergo oxidation (2) Reversible and irreversible transitions occur when oxide films on metals are heated and cooled, these are investigated in the case of Fe, Co, W, and Mo (3) Decompn of one oxide to form another occurs by loss of O, the results are relative to Cu oxides (4) Changes occur in oxide-crystallite size in regard to film thickness The diagram obtained for various alloys at different temps indicates that both chem compn and crystallite size may change as the oxide film builds up (5) With Ni and Cr solid-phase-reaction occurs on the surface of alloys when oxides are formed at low temp and heated in vacuum The reaction does not reverse when the specimens are cooled in the

vacuum (6) Changes in oxide-crystallite size occur as the temp is increased at const film thickness In particular it is shown that phys changes in the oxide film may occur even though no chem changes take place (7) Orientation is produced by substrata effect (8) Oxide film orientation is caused by growth effects It is shown that increased oxidation results in greater orientation (9) Existence diagrams of the oxides formed on metals and alloys are given as the function of time and temp (10) Diagrams relative to the rates of formation and diffusion of a number of metal ions in binary alloys are given (C A 42, 8130d)

(92)

Trans Electrochem Soc 91, 17 pp (1947) (Preprint) cf C A 41, 79d, 3733i	AN ELECTRON-DIFFRACTION STUDY OF OXIDES FORMED ON HIGH-TEMPERATURE OXIDATION-RESISTANT ALLOYS	Westinghouse Research Lab , E Pittsburgh, Pa J W Hickman E A Gulbransen

The electron-diffraction reflection technique is used to study the structures of the oxides which form on Alchrome-6, Worthite, stainless steels 301 and 446, and alloy S-588 in the temp range 300° to 900° Photographs of the oxides are taken at the temp of formation to eliminate the possibility of chem and phys changes which may occur upon cooling The structures found are plotted on existence diagrams as functions of time and temp Attempts are made to correlate the structures obtained with thermodynamic data reported by other workers The oxides on all of the alloys over the complete time-temp range consists of Cr_2O_3 or a spinel-type structure which may be a solid soln of 2 or more oxides Spectrographic analyses indicate that Ni is absent in the outer oxide layer There does not appear to be any unique mechanism for the oxidation of ferritic and austenitic stainless steels Complete or partial conversion of the oxide occurring on Alchrome-6 to γ Al_2O_3 as reported by other workers is not substantiated in this present study (C A 41, 4076a)

(93)

J Phys Soc Japan 8, 113-18 (1953) cf C A 44, 5300f	ELECTRON-DIFFRACTION STUDIES ON OXIDE FILMS FORMED ON METALS AND ALLOYS II SELECTIVE OXIDATION OF ALLOYS	Tokyo Inst Technol Goro Honjo

Surface oxidation products on Cu alloys contg 0 3% Be, 0 5% Al, 0 1% Mg, 7% Mn, and 7% Ni, and Fe with 13% Al subjected to varying oxidation conditions in the range from 300 to 900° at 10^{-4}-760 mm Hg pressure are studied with electron-diffraction methods In reduced air pressures the selective oxidation of the baser component generally takes place When the supply of the baser metallic ions toward the surface by diffusion is ample enough to consume the O atoms attacking the specimen surface, only the oxide of the

baser component is formed When the supply of O atoms to the surface overcomes that of the baser metallic ions as a result of the increase of air pressure, the oxide of the nobler component is also formed until at high air pressures the nobler component, having a much larger content in the alloys studied, becomes so abundant as to conceal the oxide of the baser component (C A 47, 5334b)

(94)

Chimie and industrie, 53, 222-33 (1945)	SURFACE CONDITIONS OF ALUMINUM AND ITS ALLOYS THE ANODIC OXIDATION FILM CONSIDERED AS A MEANS OF STUDYING SURFACE CONDITIONS	Paul Lacombe

The condition of Al surfaces can be considered from the geometrical, phys , or chem standpoint The latter two are reviewed from standpoints of (1) means of revealing the existence of the oxidation film, (a) by electrochem measurements of soln e m f , and (b) by isolation of the Al_2O_3 film, (2) growth, structure, and texture of the film, (a) by examg thin films by their interference colors, and (b) by examg thick films (thicker than 1μ) in polarized light, (3) applications of the film to the study of surface conditions, giving various examples of the use of anodic oxidation to show and magnify the surface condition of Al and its alloys revealing defects of mech and structural origin (C A 41, 70c)

(95)

Usine nouvelle 2, 9 (1946), Chem Zentr 1947, I, 205, cf C A 42, 3681e	ISOLATION OF THE OXIDE FILMS ORIGINATING IN THE ANODIC OXIDATION OF ALUMINUM ALLOYS	P Lacombe L Beaujard

The sepn of a gray film is observed when Al is electrolytically polished for the first time It is assumed that this phenomenon is concerned with the protective oxide film normally present on Al If the Al is previously exposed to anodic oxidation, films 10-20 μ in thickness can be obtained in the subsequent electrolytic polishing The upper limit for the film thickness is 150 μ These films are especially useful in investigating the structure of the surface of the underlying metal They also reveal information regarding the porosity of the surface film (C A 42, 8679d)

(96)

Steel Processing 32, 669, 676 (1946)	DISSOCIATION PRESSURES OF METAL OXIDES FORMED ON VARIOUS SOLID METALS	Westinghouse Research Lab , E Pittsburgh, Pa Benj Lustman

Dissocn pressures up to the m p. and extrapolations to the b p are given for oxides of Cu, Bi, Pb, Ni, Co, Fe, Mo, W, Zn, Cr, Si, Ti, Al, Mg, Be, and Ca as formed on solid metals Included are curves for the O_2 partial pressures in equil with $CO-CO_2$ and H_2-H_2O mixts that are typical of furnace atms such as "Endogas," "Exogas," and "Ammogas " (C A 41, 332h)

(97)

J chim phys 44, 172-80 (1947)	THE OXIDATION OF METALS	Univ Bristol, Eng N F Mott

The formation of oxide films on metals in contact with air is considered theoretically by taking into account the solubilities and mobilities of ions and electrons from the metals in the oxide film and the resultant fields (C A 42, 5317e)

(98)

Trans Faraday Soc 43, 429-34 (1947), cf C A 33, 9097[9], 34, 4328[4]	THEORY OF THE FORMATION OF PROTECTIVE OXIDE FILMS ON METALS III	Univ Bristol, Eng N F Mott

A new mechanism is proposed to account for the formation on metals of oxide films that grow to a limiting thickness It is assumed that (a) the work function is small enough to allow the thermionic emission of electrons from the metal into the conduction levels of the oxide If O is adsorbed onto the surface of the oxide and oxide ions are formed, a strong elec field will be set up in the oxide (b) The soly of metal ions in the oxide is at the temps considered too small for any passage of metal by diffusion Under these very strong fields, migration of ions can take place A theory based on these assumptions gives a limiting thickness which increases rapidly with temp up to a certain crit temp , which should be about 600°K for Al, above which the parabolic law should hold This mechanism is compared with M's previous theory based on tunnel effect, further exptl work is required to det which is correct (C A 42, 1471d)

(99)

Trans Australian Inst Metals 3, 67-70 (1950) Australasian Engr Dec 7, 1950, 53-6	THE KINETICS OF DECOMPOSITION OF GASES AT METAL SURFACES	Commonwealth Sci Ind Research Organisation, Melbourne M F R Mulcahy

In this review of the theory of metal-gas surface reactions, the results of published expts on the rate of deposition of C from CH_4 and of N from NH_3 are described briefly, together with a comparison of reaction rate with the diffusion rate in carburizing and nitriding processes 29 references (C A 46, 8480i)

(100)

J Appl Chem (London) 2, 550-4 (1952), cf C A 33, 5786[3], 39, 5234[2]	THE ISOLATION AND EXAMINATION OF FILMS FROM METAL SURFACES AN IMPROVED TECHNIQUE	Chem Research Lab., Teddington, Middlesex, Engl T J Nurse F Wormwell

A means of strengthening films stripped from metals was sought The object, such as oxide-covered steel, was immersed in 0 25-1% soln of Formvar in a mixt of 2 parts by vol of acetone and 1 part by vol of trichloroethylene for 1-2 min , removed, and allowed to drain for 5 min The film was then stripped in an anhyd deaerated soln of I in alc and washed in anhyd deaerated methanol The 0 5% soln of Formvar was adopted for general use but in some cases where electron-diffraction examn was necessary, 0 25% solns were used Applications of the technique were cited for oxide films on heated mild steel, the films produced on Fe or steel by industrial treatment, oxide films on polished stainless steel, and the oxide films on Cu, brass, Zn, Ti, Al, Al-Cu, and Al-Si alloys Three photographs of the films sepg from the base metal, an electron-diffraction pattern, and an optical photomicrograph of the phosphate film isolated from mild steel were given

(101)

Busseiron Kenkyû (Researches on Chem Phys) No 13, 7-14 (1949), cf Mott, C A 33, 9097[9], 34, 4328[4]	OXIDE LAYER ON THE SURFACE OF METALS	Hokkaido Univ , Sapporo Shôzô Shinohara

M 's theory of the theory of the rate of growth of protective oxide layer on metals is improved, in that S takes into account the image force in the case in which the logarithmic law holds (C A 47, 3070i)

(102)

J Chem Phys 18, 772-3 (1950)	PASSIVATION OF METALS	Ohio State Univ Rudolph Speiser F H Beck M. G Fontana E N Lassettre

Theoretical The passivation of some metals by films of, e g , O_2 or NO, and the stability of these films in a corroding medium is explained on the basis of the band theory of metals and surface thermodynamics (C A 44, 7204f)

(103)

Glass u Hochvakuum-Tech 1952, 109-10	THE ELECTRICAL MEASUREMENT OF SMALL AMOUNTS OF OXYGEN ON METALLIC SURFACES	Tech Univ , Berlin-Charlottenburg F Todt

0, 10^{-12} γ or less than 0 0001 part of an at layer, on the surface of noble metals can be measured by electrochem means The principle of the measurement depends on the condition that the current produced by a metal surface covered with O is detd against a practically unpolarizable anode By this method it is established that a smooth Pt surface exposed to air absorbs about 10 at layers of O, based on the surface geometry A practical application of the electrochem measurement of O consists in the simple recording of minutest amts of O in aq solns and in gases (C A 47, 3723c)

(104)

Rev inst franc pétrole et Ann combustibles liquides 2, 250-1 (1947), cf C A 41, 4376d	AN APPLICATION OF SECONDARY ELECTRON EMISSION TO THE STUDY OF THIN LAYERS	Centre Natl, Recherche Sci , Bellevue, France Jean J Trillat Charles Legrand

The emission of secondary photons produced by impact of x-rays on a thin layer of matter has been studied It is utilized to detect the presence of heterogeneous org or inorg layers on metal surfaces and to det their relative areas and vols (C A 42, 4046a)

(105)

Applied Sci Research B2, 352-60 (1952)	MEASUREMENTS OF THE FORMATION OF THIN TIN FILMS	Tech Phys ,Louvain, Belg A van Itterbeek L de Greve F Heremans

Sn films were sputtered in H, Ne, He, and A The films formed in H exhibited infinite resistance, but those formed in Ne, He, and A exhibited a finite resistance if they were not too thin The sp resistance of the films sputtered in He was approx ten times that of the films sputtered in Ne The rate of oxidation was followed by measuring the change in resistance with time after admission of O gas to a sputtered film The greatest increase in resistance occurred during the first few sec after admission of O and the rate of change of resistance depended on the O pressure Four electron micrographs of the Sn films at a magnification of 30,000 times are given The films appeared to consists of approx. spherical grains with individual diams of 200-2000 A (C A 46, 8448i)

STATES

(106)

Proc Cambridge Phil Soc 48, Pt 3, 457-69 (1952)	ELECTRONIC BOUND STATES AT THE SURFACE OF A METAL	Univ Liverpool, Engl G R Baldock

The tight-binding approximation is used to investigate the conditions under which bound states assocd with atoms in the surface of a metal may exist Modifications are required to produce bound states assocd with all of the atoms in the surface and bound states assocd with particular small groups of atoms, since most of the simple crystal structures do not exhibit surface states without modifications being applied No surface states are assocd with the following crystal surfaces if interactions between all nearest neighbors are neglected (1) the (100), (110), and (111) faces of the simple cubic lattice, (2) the (110) face of the body-centered cubic lattice (with next nearest neighbors included), (3) the (100) and (111) faces of the face-centered cubic lattice, (4) the (100) face of the body-centered cubic lattice (including next-nearest-neighbor interaction), (5) the (110) face of the face-centered cubic lattice, and (6) the (0001) and ($2\bar{1}\bar{1}0$) faces of the hexagonal close-packed lattice Surface states exist solely by virtue of the lattice geometry in the graphite and diamond lattices (C A 46, 9926d)

(107)

Tech moderne 38, 169-76, 223-8 (1946)	THE STATE OF METALLIC SURFACES	Paul Bastien C de Senneville

(C A 41, 6179d)

(108)

Rev mét 45, 61-7 (1948)	STATE OF SURFACE AND TRUE PHYSICOCHEMICAL PROPERTIES OF METALS	Georges Chaudron

General (C A 42, 7685f)

(109)

Discussions Faraday Soc 1950, No 8, 27-33	CONDITIONS FOR THE EXISTENCE OF SURFACE STATES	King's Coll , London C A Coulson G R Baldock

The mol modification of Bloch wave functions are used to study the existence of nonexistence of surface states on the boundary of a univalent metal for simple cubic models in 1, 2, and 3 dimensions Surface states may be induced by the perturbation caused by the approach of a polar or ionic group

These states are more easily produced close together than separately In certain noncubic systems, e g graphite, surface states exist even without any necessary changes in their Coulombic terms or resonance integrals on the boundary (C A 45, 9985e)

(110)

Proc Intern Congr Pure and Applied Chem (London) 11, 145-57 (1947)	SOME DEVELOPMENTS OF THE CHEMISTRY OF SOLIDS, 1912-1947	Chalmers Univ Technol , Gothenburg, Sweden J Arvid Hedvall

(In English) 24 references (C A 44, 4301g)

(111A)

Metal Interfaces - A Seminar, Am Soc Metals, Cleveland, O 1951, 1-19	ATOMISTIC THEORY OF METALLIC SURFACES	Bell Telephone Labs , Murray Hill, N J Conyers Herring
Ibid ,p 20-64	THEORY OF INTERNAL BOUNDARIES	Harvey Brooks
Ibid ,p 65-108	GRAIN SHAPES AND OTHER METALLURGICAL APPLICATIONS OF TOPOLOGY	Univ of Chicago Cyril Stanley Smith
Ibid , p 114-33	MEASUREMENT OF SOLID GAS AND SOLID LIQUID INTERFACIAL ENERGIES	Massachusetts Inst Technol , Cambridge Harry Udin
Ibid , p 134-50	MEASUREMENT OF SOLID SOLID INTERFACIAL ENERGIES	Kaiser Aluminum and Chem Corp , Spokane, Wash James B Hess
Ibid ,p 153-78	ENERGIES AND STRUCTURES OF GRAIN BOUNDARIES	Kaiser Aluminum and Chem Corp , Spokane, Wash K T Aust B Chalmers
Ibid , p 179-207	BOUNDARY MIGRATION DURING GRAIN GROWTH	General Elec Co , Schenectady, N Y R L Fullman
Ibid , p 208-47	INTERFACE MIGRATION IN RECRYSTALLIZATION	Univ Illinois, Champaign Paul A Beck

PHYSICO-CHEMICAL REACTIONS OF SURFACES - States

Ibid 248-68	STRESS RELAXATION ACROSS INTERFACES	Yale Univ A S Nowick
Ibid 269-95	PHASE TRANSFORMATIONS AT INTERFACES	General Elec Co , Schenectady, N Y Alfred H Geisler
Ibid 299-311	MECHANICAL EFFECTS OF INTERFACES	Univ Toronto Bruce Chalmers
Ibid 312-35	METAL SURFACE PHENOMENA	Massachusetts Inst Technol , Cambridge Herbert H Uhlig

(C A 46, 8430d)

(112)

Trans N Y Acad Sci 12, 245-56 (1950)	ROLE OF IONIC DEFORMATION IN SURFACE CHEMISTRY	W A Weyl

Asymmetric Coulombic force fields exist at surfaces and interfaces The polarizing effect of the asymmetric field can be expected to alter the electron d distribution of the ions so that the chem behavior of the ions has directional properties On the basis of Fajan's rules for ionic polarization (C A 25, 2367, 37, 817[6]) rules are postulated for predicting qual changes in the properties of ions and metal atoms at interfaces The rules are applied to the explanation of heterogeneous catalysis and other surface phenomena (C A 44, 9774c)

PHYSICO-MECHANICAL REACTIONS OF SURFACES

FRICTION

(113)

Proc Roy Soc (London) A212, 508-12 (1952)	EFFECT OF SURFACE STRUCTURE, COMPOSITION, AND TEXTURE ON FRICTION UNDER BOUNDARY CONDITIONS	Thornton Hall, Glasgow, Scotland F T Barwell

The coeff of friction of surfaces lubricated under boundary conditions may be profoundly affected by such factors as the degree of working of the substrate material, the nature of the oxide film, and the degree of roughness of the surface Expts are described wherein the frictional behavior of surfaces of stainless steel specimens prepared in various ways was compared The worked surface layers increase the value of the coeff of friction, but the effect of surface texture is of predominant importance The effect of different oxide films is best illustrated by reference to pure Al, the surface of which has been oxidized under different environmental conditions The constitution of the oxide film formed is modified, with a consequent effect on boundary friction Data are reported for stainless steel, with castor oil lubricant, methods of finish were, resp , anodic polish, buffed, emery abraded, ground, anodic pitted (C A 46, 8447d)

(114)

Ann N Y Acad Sci 53, 805-23 (1951)	INFLUENCE OF SURFACE FILMS ON THE FRICTION ADHESION AND SURFACE DAMAGE OF SOLIDS	Univ Cambridge, Engl F P Bowden

A review is given of effect of films on surfaces cleaned in vacuo by heat Introduction of O_2, H_2O or caproic acid vapor reduces friction Caproic acid plus O gives a lower coeff of friction (I) than does the acid alone Cl compds lower I but by heating metal to 300-400° Cl is driven off and I increases Although H_2S does not reduce I as much as Cl, the FeS films are stable up to over 800° Variations in oxide films det their friction-reducing properties If the oxide film is harder than the underlying metal, it will not protect the surface from adhesion Air or O reduce friction on diamonds (C A 46, 2876b)

(115)

Research (London) 3, 383-4 (1950)	FRICTIONAL PROPERTIES OF POROUS METALS CONTAINING MOLYBDENUM DISULFIDE	Univ Cambridge, Engl F P Bowden

Tabulated data show the coeff of friction and its variation with temp for Cu contg MoS_2 and for sintered Mo The Cu shows a small coeff of friction (μ = 0 13) after repeated sliding and even at 300° μ = 0 14, with Mo contg MoS_2 μ = 0 07 even at 400° - the effect is similar to porous metal impregnated with a low-friction plastic (C A 45, 3188f)

(115A)

Oxford Univ Press, London, Eng 1950	THE FRICTION AND LUBRICATION OF SOLIDS	Cambridge Univ F P Bowden D Tabor

Chapter

I	Area of Contact Between Solids
II	Surface Temperature of Rubbing Solids
III	Effect of Frictional Heating on Surface Flow
IV	Friction and Surface Damage of Sliding Metals
V	Mechanism of Metallic Friction
VI	Action of Bearing Alloys
VII	Friction of Clean Surfaces Effect of Contaminant Films
VIII	Friction of Non-Metals
IX	Boundary Friction of Lubricated Metals
X	Mechanism of Boundary Lubrication
XI	Action of Extreme Pressure Lubricants
XII	Breakdown of Lubricant Films
XIII	Nature of Contact Between Colliding Solids
XIV	The Nature of Metallic Wear
XV	Adhesion Between Solid Surfaces The Influence of Liquid Films
XVI	Chemical Reaction Produced by Friction and Impact
	Appendix Some Typical Values of Friction
	Index

(C A 45, 1759f)

(116)

Proc Roy Soc (London) A188, 329-49 (1947)	HOT SPOTS ON RUBBING SURFACES AND THE DETONATION OF EXPLOSIVES BY FRICTION	Univ Melbourne, Australia F P Bowden M A Stone G K Tudor

The local temp at the surface of sliding solids may reach a high value even under comparatively gentle conditions of sliding With metals the surface temp can be measured by using 2 different metals as a thermocouple, the temp depends on the load, speed, and thermal cond of the metals With nonmetals, which are poor thermal conductors, the high temps occur more readily The thermoelec method cannot be used with nonconductors, but if one or both of the surfaces is of transparent material, such as glass or quartz, the hot spots may be observed visually or recorded photographically Expts with surfaces of different m ps show that the hot spots first become visible when the temp is about 520-570° Hot spots of this temp may occur on glass or quartz when the load is about 1000 g and the sliding speed as low as 1 or 2 ft/sec These local surface temps play an important part in the chem decompn which accompanies the rubbing of solids Expts show that the detonation of a liquid

explosive, such as nitroglycerin, by friction is due to the development of local high temps on the surface of the sliding solids Under the conditions of these expts the temp of the hot spots necessary to cause the explosion of nitroglycerin is about 480° The effect of grit on the incidence of hot spots with soft metals is studied with Pb, Sn, Zn, Au, Cu, Ag, aloxite slider, with abrasive pastes Data are diven for load and speed necessary to cause explosion of nitroglycerin for mild steel on mild steel (turned), mild steel on mild steel (lapped), mild steel on chrome-molybdenum, 18% W steel on chrome-molybdenum, carbon steel on chrome-molybdenum, cast iron on mild steel (lapped) Effect of thermal cond on incidence of explosion is studied with silica, constantan, steel, Ni, W Incidence of hot spots and explosions with the following metal sliders on glass is studied 80 Au-20 Sn, 80 Au-20 Pb, 75 Au-25 Te, 73 Ag-27 Sn, 70 Ag-30 Sb, 80 Ag-20 As, 50 Au-50 Cd, 92 Au-8 Al, constantan, Ni, Fe, W The velocity gradient may be of the order of 10^9 sec^{-1} These high pressures and high rates of shear, however, do not produce an explosion unless the local surface temp rises to about 500° These results illustrate how difficult it is to bring about the decompn of nitroglycerine by direct mech means Although the nitroglycerin is rubbed violently and ground at very heavy loads and high speed, it fails to explode unless the temp of the surfaces is raised to a sufficiently high value Under the conditions of these expts it is apparently necessary that the mech energy should first be degraded into heat The local hot spots on the surfaces then bring about the decompn of the explosive (C A 41, 3628c)

(117A)

Symposium on Properties of Metallic Surfaces (Inst Metals, London) 1952, 197-212	THE INFLUENCE OF SURFACE FILMS ON THE FRICTION AND DEFORMATION OF SURFACES	Cambridge Univ , Engl F P Bowden D Tabor

The interaction between metal surfaces is crucially dependent on the surface films with which they are covered In the absence of all contaminating films, gross seizure occurs and sliding is impossible The smallest quantities of gases or vapors greatly reduce the interaction This decrease is partly due to chemisorbed films and partly to van der Waals adsorption Similar, though less marked, effects are observed with nonmetals The physically adsorbed films are only one or two mol layers in thickness, and the heavier adsorption often observed with water is due to the presence of hygroscopic impurities on the surfaces The friction and surface damage of inert metals immersed in an electrolyte may be greatly affected by small changes in the interfacial potential, largely because of the protective properties of electrodeposited gas layers The oxide film normally present on most metal surfaces can also provide considerable protection, particularly at light loads, the behavior depending primarily on the relative mech properties of the oxide and the substrate At high speeds of sliding, high-temp flashes are generated at the regions of contact, and the softened or molten material is smeared over the surfaces to form the Beilby layer Recent work

suggests that the stability of the Beilby layer may be due to the presence of minute occlusions of impressed oxide, and because of its extreme hardness the layer may offer considerable protection to the underlying metal during sliding Boundary lubricant films also act as protective films when they are in the solid state The protection diminishes when they melt, and deteriorates further when they desorb For effective protection at higher temps , solid films of higher m ps must be used Films of soft metals, polytetrafluoroethylene, MoS_2, and metal sulfides and chlorides are particularly suitable for this purpose (C A 47, 2570h)

(118)

Proc Roy Soc (London) A208, 311-25 (1951)	FRICTION OF CLEAN METALS AND THE INFLUENCE OF ADSORBED FILMS	Univ Cambridge, Engl F P Bowden J E Young

An exptl study of the frictional behavior of degassed metal surfaces An app is described, in which friction can be measured at any desired temp up to 1200° or more either in vacuo or in a particular gas When sufficiently clean metals are allowed to touch, even at room temp , complete seizure occurs Over the real area of contact the specimens adhere with the bulk strength of the metal, and this area increases greatly with continued sliding or attempted sliding Various gases and vapors were adsorbed on the clean specimens, and their influences on friction detd These sp contaminants are most effective as lubricants where they can react with the metal to form a solid and chemically attached film which is several mol layers thick Otherwise the friction remains very high, although seizure is prevented Phys adsorption may occur in addn , with a significant reduction in the friction The results support the view that the friction of metals is due mainly to adhesion at the points of real contact, and is governed by the extent to which even the thinnest of surface films can reduce this metallic contact If it were not for the presence of random contamination, seizure would occur with most solids even under mild conditions of sliding It is difficult to reach the necessary standard of cleanness This conclusion also shows that a temp coeff of friction for clean metals can have little meaning, since seizure occurs at all temps Whenever a surface layer was adsorbed onto the clean surfaces (with the possible exception of H), complete seizure no longer occurred The friction remained high, and only rarely was it reduced to the value observed when the surfaces are cleaned in the atm It seems that surfaces exposed for some time to the atm acquire a layer of contamination, the chem and phys structure of which is different from that produced in any of these expts on admitting specific contaminants Oxygen did not reduce the friction between clean iron surfaces below $\mu = 2\ 0$ when first admitted, although several mol layers of oxide would be formed On Pt, where the oxide layer, is formed at all, is very thin, the friction remains extremely high Only on U, where the attachment is very strong, does the oxide film confer appreciable surface protection Similar behavior is shown by other permanent gases The conclusion follows that adsorbed monolayers or even multilayers of the permanent gases, do not reduce the friction to the low values commonly observed (C.A 46, 5398i)

(119)

Proc Roy Soc (London) A208, 444-55 (1951)	FRICTION OF DIAMOND, GRAPHITE, AND CARBON AND THE INFLUENCE OF SURFACE FILMS	Univ Cambridge, Engl F P Bowden J E Young

An exptl study of the frictional behavior of diamond, graphite, and C which have been outgassed in vacuo The removal of surface films that are normally present causes a large increase in the friction The admission of a small amount of O, water vapor, or other contaminant reduces the friction Both phys adsorption and chem adsorption are important With clean graphite surfaces there is strong adhesion at the interface, so that when sliding takes place slip and shearing occurs beneath the surface C and graphite have a neg temp coeff of friction The low friction normally observed with diamond is due to the presence of adsorbed O and other gases The friction of clean diamond on diamond is high, and the shear strength at the interface is comparable with the shear strength of diamond Large-scale seizure does not occur because the deformation of the diamond in the region of contact is elastic and the real area of contact necessarily remains small The exptl arrangements are described in detail The behavior of graphite is not significantly different from that of hard C, which does not exhibit an obvious lamellar structure The pressure of water vapor necessary in these expts to give a low friction on clean graphite was much less than that found necessary to reduce the wear This is probably a kinetic effect When the adsorbed gas films normally present are removed from the surface of diamond, the friction rises from about 0 05 to a value of about 0 5 (C A 46, 6889f)

(120)

Proc Roy Soc (London) A212, 485-8 (1952)	FRICTION OF DIAMOND, GRAPHITE, AND CARBON THE INFLUENCE OF ADSORBED FILMS	Univ Cambridge, Engl F P Bowden J E Young G Rowe

Further expts confirm the conclusions presented in C A 46, 6889f The mechanism of friction for nonmetallic solids is generally similar to that proposed for metals (C A 46, 8462g)

(121)

Proc Roy Soc (London) A189, 88-102 (1947)	KINETIC BOUNDARY FRICTION	Natl Phys Lab , Teddington, Eng J R Bristow

Expts on sliding friction and relaxation oscillation are described Curves of coeff of friction against velocity are given Results are given for (a) a series of ethyl esters of satd fatty acids for two pairs of sliding surfaces, (1) hard steel on hard steel, and (2) phosphor bronze on hard steel,

at room tem , (b) a mineral oil contg addns of various percentages of oleic acid, with sliding surfaces of (1) steel on steel, and (2) brass on hard steel at room temp , (c) for (1) ethyl palmitate lubricating the sliding of tin on hard steel and for (2) a mineral oil used as lubricant for steel sliding on hard steel, at various temps The esters used are ethyl formate, ethyl acetate, ethyl propionate, ethyl valerate, ethyl enanthate, ethyl caprylate, ethyl pelargonate, ethyl laurate, ethyl palmitate At high speeds, the friction falls continuously with increasing mol wt for hard steel sliding on hard steel, and for phosphor bronze on hard steel no max is shown even at very low speeds The coeffs of kinetic boundary friction are continuously reduced by increasing addns of oleic acid to the mineral oil, the oleic acid having good properties as a boundary lubricant, and the mineral oil-poor properties The effect of addns of fatty oil is greatest at low concns The effect shown of the decreasing effect of addns of oleic acid at higher speeds has not so far been satisfactorily explained The effect of temp on kinetic boundary friction for various surfaces and lubricants appears to be somewhat complicated (C A 42, 1477b)

(122)

U S Patent 2,574,318 Nov 6, 1951	LOW-FRICTION ALUMINUM ALLOY	Vereinigte Deutsche Metallwerke A -G Hans Burkhardt

Easily workable and machinable alloy having sliding-friction characteristics very similar to those of leaded bronze is made by alloying Al with Ca 1 5% and Fe 2% In addn , the alloy may contain Si 1 5%, Zn 2% max , and Cu, Mn, Pb, and Mg 1% max (C A 46, 1950f)

(123)

Nucleonics 1, No 4, 38-50 (1947)	RADIOACTIVE TRACERS IN FRICTION STUDIES	Mass Inst Technol Cambridge J. T Burwell, Jr

The basic processes of friction can be advantageously investigated by making radioactive the softer of the two components, the procedure is said to be superior to the taper-sectioning method (Bowden, Moore, and Tabor, J Applied Phys 14, 80 (1943)), particularly in regard to weld-point detection Four methods of activating the friction specimen are described exposing it to a high-energy beam from an accelerator, electroplating, then fusing on a layer of isotopic metal, mixing in the isotope during the foundry operation, exposing the finished specimen to thermal neutrons in a pile. Each process has advantages and disadvantages The traces left on the harder surfaces by the radioactive specimen take the form of lines or tracks according to radio autographs The total amt of metal left behind as welds may be measured by Geiger-Müller equipment to give estimates as low as 0 00012 γ (C A 42, 1864d)

(124)

Nucleonics 6, No 1, 34-7 (1950)	RADIOCHROMIUM PLATING FOR FRICTION STUDIES	Mass Inst of Technol, John T Burwell, Jr S F Murray

In using radiochromium for friction studies, one of the surfaces is made radioactive and the other surface is examined for evidence of radioactivity at the end of the expt Piston rings can be plated with a thin layer of material contg radiochromium, and transfer of metal to the cylinder walls can be studied by the radiotracer method Radiochromium was oxidized to CrO_3, the plating bath component, with $HClO_4$ Details of prepg CrO_3 as well as plating bath compn and plating conditions are offered Test results indicate that most metal transfer occurs near the upper limit of the ring's path (C A 45, 47g)

(125)

Metal Progress 60, No 3, 69-74 (1951)	RADIOACTIVE TRACERS REVEAL FRICTION AND WEAR OF METALS	Mass Inst of Technol Cambridge J T Bruwell C O Strang

One of 2 rubbing surfaces of metals or alloys is made radioactive and the other surface is examd after rubbing with a Geiger counter or by contact with an x-ray film Expts with a hard Cr-plated steel, SAE 1020, 1119, and 4027 steels, cast iron, and carburized steels, with and without lubrication, are described Hardness improves wear resistance with similar metals, but chem compn is more important with dissimilar metals (C A 45, 9439f)

(126)

U S Patent 2,419,252 Apr 22, 1947	PREVENTION OF SEIZURE OF METAL PARTS	General Motors Corp Wilfred A Bychinsky, et al

Seizure of metal part surfaces held in engagement at high pressure is prevented by applying a paste contg 300 g ZnO and 540 g dibutyl phthalate (C A 41, 4434d)

(127)

Proc Roy Soc (London) A187, 430-9 (1946)	KINETIC FRICTION IN OR NEAR THE BOUNDARY REGION I APPARATUS AND EXPERIMENTAL METHODS	B Chalmers P G Forrester E F Phelps

There are two methods of obtaining relatively pure boundary friction to ensure that the amt of lubricant present is only sufficient to provide a boundary film, or to control conditions of load, speed, and contact area so that little or no opportunity is given for fluid film formation The relative advantages of the two methods are discussed, and app is described in

which the second method is used In this app one specimen is driven at a fixed velocity and a second specimen is applied to it by a dead load The force required to restrain the second specimen is measured by balancing against a variable dead load, instability being suppressed by fluid damping A direct reading of coeff of friction is obtained by a null method Reproducibility of detns is generally within 10%, the limiting factor being the accuracy with which exactly similar surfaces can be reproduced

Ibid, p 439-63	II THE INFLUENCE OF SLIDING VELOCITY AND OTHER VARIABLES ON KINETIC FRICTION IN OR NEAR THE BOUNDARY REGION	Tin Research Inst London P G Forrester

The causes underlying changes of friction with sliding velocity were studied The method adopted was to measure the friction of several different combinations of materials under three different conditions dry, with excess of various lubricants, and with thin films of various lubricants applied by two different methods The expts show that changes in friction with velocity can be derived from at least three sources Certain combinations of materials show, when unlubricated, a decrease in friction with increasing velocity, this tendency may remain in a modified form even when a lubricant is added Various hypotheses to explain this tendency are discussed With a boundary film of lubricant present, friction may increase with increasing velocity, and the evidence suggests that this change is due to partial destruction of the boundary film, the rate of which destruction rises with increasing sliding speed When there is excess of lubricant, fluid film effects may occur even with restricted areas of contact and sliding speeds as low as 0 5 cm/sec , such fluid film effects bring about a decrease in friction with increasing velocity This tendency is most marked when one component is a soft metal, and may well explain the good antifriction properties of the Babbitt and similar alloys A brief investigation is also made of the effects of surface finish and of continual sliding or running in, and the results obtained are discussed in the light of information gained from the expts on sliding velocity Friction velocity curves for the following unlubricated systems are reported Babbitt/steel, hard steel/bronze, steel/steel, Cd-Ni/steel Expts are reported for lubrication tests using medicinal paraffin and I C E (crankcase) as nonpolar lubricants and also using strongly polar oleic acid, with the above metal combinations Friction-velocity curves are reported for rubbed films with excess lubricant for Sn and Sn alloys contg 1, 2, and 3% of Sb Effects of running in are studied The effect of the surface finish is examd A decrease in friction is shown by certain unlubricated combinations when velocity rises The fact that the tendency is most marked when one component is a soft metal of low m p suggests that it may be assocd with reduction in shear strength of the metal with increasing temp For the combinations of metals tested, the effect of surface finish is wholly through its effect on the lubricant film, for the friction of the unlubricated surfaces is independent of surface finish The surface finish of the plate has much more effect in the combination Babbitt sliders/steel plate than in the combination hard-steel sliders/bronze plate This is not unexpected, for in the latter case the contour of the contact area is controlled by that of the steel surface rather than by that of the bronze Practical implications are discussed (C A 41, 3338e)

(128)

Vestnik Akad, Nauk S S S R 1948, No 5, 28-31	PROBLEMS OF FRICTION OF SOLIDS AND LUBRICATION	B V Deryagin

(C A 44, 7052f)

(129A)

Comm tech états et propriétés surface métaux, Journées états surface Paris, Oct , 1945, 235-6	THE PART OF CHEMICAL REACTIONS IN THE PHENOMENA OF FRICTION AND WEAR	C H Desch

A summary (C A 42, 3298c)

(130A)

Ibid , p 92-4	THE STRUCTURE OF GLIDING SURFACES	G I, Finch

A short review (C,A 42, 3298f)

(131)

Proc Phys Soc London, 63B, 465-83 (1950)	THE SLIDING SURFACE	Imperial Coll , G I Finch

A general survey of recent work Emphasis is laid on the oxide layer and on the oil as purveyor of oxidant to the high-temp zone of solid-to-solid sliding contact Without the oxide layer and oil-borne oxidants, whose interaction is confined to regions of high temp , sliding under boundary conditions would be practically impossible The bearing surface is discussed in detail Electron-diffraction patterns are discussed for Cu single crystal, Fe single crystal, α-Fe, austenitic steel, cast iron, graphite, Fe oxide film, γ-Fe_2O_3 and cuprous oxide Interboundary lubricant films are discussed 55 references (C A 45, 1759a)

(132)

Phys of Lubrication, Brit J, Applied Phys , Suppl 1, 79-82, (1951)	SURFACE WELDING AND THE EXTREME-PRESSURE LUBRICANT	Imp Coll Sci Technol , London G I Finch R T Spurr

When two surfaces are brought into contact the surface oxide films prevent intermetallic welding The films may be ruptured by sliding the surfaces over each other, or by applying sufficient pressure to cause plastic flow at the interface The ease with which surfaces weld on sliding depends upon their rigidity and the nature and thickness of the surface films Extreme-pressure additives react with the surface oxide to form a compd which is more fusible than the metal If the local temp rises sufficiently during sliding, this compd melts and smears over the surface, and acts as a temporary lubricant (C A 45, 4916c)

(132A)

Chemical Publishing Co , Brooklyn, N Y 1950 | FRICTIONAL PHENOMENA | The Detroit Edison Co Andrew Gemant

Part A Frictional Processes in General
- Chapter I Review of the Concept of Friction in Physics and Engineering
- Chapter II Outline of the Mathematical Treatment of Frictional Processes

Part B Frictional Processes in Gases
- Chapter III Theory and Experimental Facts
- Chapter IV Adsorption of Sound Waves and of Supersonics
- Chapter V Sound-Absorbing Materials

Part C Frictional Processes in Liquids
- Chapter VI Theory and Experimental Facts
- Chapter VII The Measurement of the Viscosity of Liquids
- Chapter VIII Viscosity of Colloidal Solutions Applications to Synthetic Polymers
- Chapter IX Structural Viscosity
- Chapter X The Flow of Fluids
- Chapter XI Applications of Liquid Viscosity to Electrical Insulating Liquids, Particularly in High-Voltage Cables
- Chapter XII Lubrication

Part D Frictional Processes in Solids
- Chapter XIII The Plastic Flow of Solids
- Chapter XIV Correlation Between Elastic Moduli and Viscosity of Liquids and Plastics
- Chapter XV Engineering Applications of the Plastic Flow of Solids
- Chapter XVI Internal Friction in Solids
- Chapter XVII Engineering Applications of the Internal Friction of Solids
- Chapter XVIII Reduction of Vibrations by Use of Materials of High Damping Capacity
- Chapter XIX Stress-Dependent Plastic Resistance and Damping Capacity of Alloys
- Chapter XX External Friction of Solids
- Chapter XXI Engineering Applications of External Friction

Index

(C A 45, 942c)

(133)

Natl Advisory Comm Aeronaut Tech Note 1461, 37 pp (1948) | INFLUENCE OF CRYSTAL PLANE AND SURROUNDING ATMOSPHERE ON SOME TYPES OF FRICTION AND WEAR BETWEEN METALS | Univ Virginia Charlottesville Allan T Gwathmey Henry Leidheiser, Jr G Pedro Smith

The effect of crystal plane on dry static friction was detd between 2 single crystals of Cu The pull required to sep a spherical crystal resting on a flat face was measured at room temp after previously heating the crystals in

H_2 to 500° to remove any oxide present on the surfaces The coeff of friction between the (100) faces was greater than 100, and that between (111) faces was approx 25 The difference between the coeffs of friction for the 2 sets of faces was attributed largely to the digging-in and greater area of contact with the (100) faces Under similar exptl conditions the coeff of friction varied between 35 7 and 56 0 with polycryst specimens Exposure of the surfaces to air lowered the coeffs of friction to approx 1 The strength of adhesion between 2 crystals placed in contact, as detd from the area of contact and the vertical pull required to disengage the crystals, was roughly equal to the tensile strength of bulk Cu The effect of the surrounding atm on wear between 2 dry polycryst Cu surfaces was detd by measuring the time required for a Cu sphere to wear through a film of Cu previously electrodeposited on a cylindrical steel rotor The stms used were H_2 and N_2 contg 0 2% O_2 In an atm of H_2 at 300° the sphere wore through the Cu film in about 10 sec , whereas in the N_2-O_2 mixt the sphere did not wear through the film in 90 min Expts were conducted to det the effect that difference in roughness caused by corrosion on various crystal faces had on wear The times required for several faces of a Cu crystal previously etched in stearic acid at 185° to wear through a Pb film in mineral oil at room temp were measured The (110) face, which became rough on etching in stearic acid, wore through the Pb film in excess of 200 times as fast as the (111) face, which remained smooth on etching The effect of atm on wear through a Pb film by a polished Cu sphere in mineral oil at room temp was also studied In an atm of H_2 the sphere wore through the film approx 200 times as fast as in an atm of air It was also observed that the depth of recrystn of the surface of a spherical Cu single crystal as a result of quenching from 800 to 900° into water at room temp differed on the various crystal faces The metal in the (100) region recrystd into many small crystals to a great depth, whereas the remainder of the surface remained monocryst (C A 42, 8041c)

(134)

Australasian Engr Aug , 1952, 46-56 — BEARING METALS — M E Hargraves

Review of friction, thermal, mech , and chem properties of bearing metals and discussion of various types in use (C A 47, 2656c)

(135)

Die Technik 2, 72-6 (1947) Chem Zentr 1947 I, 382 — NEW KNOWLEDGE OF FRICTION, LUBRICATION, AND WEAR — Materialprufungsamt, Berlin-Dahlem, Ger E Kindscher

The importance of the resistant, amorphous Beilby films produced by polishing is discussed and the effect of very brief, local "temp blitzes" in increasing wear is explained The processes of frictional oxidation, which occurs even at the lowest temps and which is important as regards the aging of the

oil, is also discussed An attempt is made to set the limits of the various lubrication zones in terms of quant data Complete lubrication at a coeff of friction of 0 001-0 005, partial lubrication at 0 005-0 1, and limiting lubrication at 0 1-0 3 The presence of polar mols and mol associates satd by residual valence forces is considered essential for limiting lubrication, while the behavior of the viscosity with changes in pressure and temp is the most essential factor to be considered in complete lubrication (C A 42, 9144a)

(136)

Zavodskaya Lab 13, 71-7 (1947) SURFACE FRICTION V A Kislik

Steel specimens were subjected to sliding friction (without lubrication) and examd for microhardness at depths up to 100 μ from the surface Steel with a ferrite-pearlite structure having a low C content showed progressive increase in hardness from the core to the surface due to cold work In martensitic steel the hardness at the surface decreased due to annealing by the heat of friction In steel with a ferrite-pearlite structure having a high C content, max hardness was obtained at a depth of 12 μ as a result of heating above the crit temp followed by rapid cooling (C A 42, 3713e)

(137)

Welding J (N Y) 27, 515s-20s (1948) THERMAL RESISTANCE OF METAL CONTACTS W B Kouwenhoven J H Potter

The effects of pressure (195 to 2955 lb per sq in), temp , and surface roughness (3 to 4150 micro-in) on the thermal resistance of a steel to steel (0 22% C) contact were investigated. The thermal resistance decreased with temp in a manner which was essentially exponential The rate of decrease was greater for rougher surfaces while for very smooth surfaces, the thermal resistance was practically independent of pressure In the absence of corrosion and at const pressure, the thermal resistance was unchanged by increases in temp (C A 43, 533f)

(138)

Natl Advisory Comm Aeronaut , Tech Note No 2460, 26 pp (1951) FORMATION OF SULFIDE FILMS ON STEEL AND EFFECT OF SUCH FILMS ON STATIC FRICTION Lewis Flight Propulsion Lab , Cleveland, O Erva C Levine Marshall B Peterson

Steels contg less than 0 035% S were used The min temps at which Fe sulfide was formed on heated specimens in cetane solns contg 0 1% free S by wt were 700°-375°F The calcd rate of film formation on steel in a soln of 0 5% S in cetane was approx 1 8 x 10^5 A / sec in the temp range 1000°-1100°F Static friction data were obtained with clean dry steel (coeff of static friction, 0 79) and for steel coated with sulfide films of various thicknesses Dry film thicknesses of 5000A or greater were found necessary

to prevent surface welding completely and to produce relatively low friction (coeff of static friction, 0 32-0 39) Welding was appreciably reduced with film thicknesses of the order of 3400 A , although friction was reduced only slightly Thin sulfide films were, therefore, somewhat effective in reducing friction even though complete prevention of welding was not obtained (C A 46, 2463e)

(139)

U S Patent 2,622, 993 Dec 23, 1952	ANTIFRICTION COATING FOR METAL SURFACES	Robert W McCullough Clyde K Hanyen

The lubricating properties of metal surfaces are enhanced by subjecting an inorganic disulfide, diselenide, or ditelluride (I) and metal packed with this compd to a pressure of 1000-10,000 lb /sq in , temps of 300-1000°F , for 1-7 hrs After cooling, excess I is brushed off It is essential that surface first be cleaned thoroughly as this facilitates combination with the disulfide In a specific example, a cold-rolled steel surface was packed with MoS_2 and subjected for 5 hrs to a pressure of 40,000 lb/sq in at 540°F Although, MoS_2 is preferred practically any I contg a metal from Groups IV(b), VI(b), VII(b), or VIII(b) of the periodic table can be used The process may also be applied to Cu and bronze (C A 47, 2974b)

(140)

Proc. Roy Soc (London) A202, 224-43 (1950)	ADHESION OF SOLIDS AND THE EFFECT OF SURFACE FILMS	Cambridge Univ J S McFarlane D Tabor

Expts show that with clean hard surfaces in dry air the adhesion is negligibly small In moist air appreciable adhesion may be observed, owing to the surface tension of a thin film of adsorbed water The surface-tension forces due to thin films of liquid trapped between solid surfaces may be very large Under certain conditions the viscosity of the liquid may also be important The absence of adhesion between clean hard surfaces is not due to the nonformation of metallic junctions Expts show that it is due to the released elastic stresses that break the junctions one by one as the load is removed With very soft metals (Pb or In), marked adhesion is observed in air, if the surfaces are freed of grosser contaminants If the surfaces are covered with oxide films of appreciable thickness, the amt of metallic interaction is diminished with a corresponding reduction in the adhesion Lubricant films have a similar effect Those materials that are most effective in reducing the adhesion are also most effective, as boundary lubricants, in reducing the friction Adhesions on glass are given for thin films of H_2O, glycerol, decane, octane, alc , benzene, aniline, castor oil Adhesions are given for hard steel against mild steel, Cu, Cd, Al, Sn, Pb, In (without lubricants) and with lubricants (paraffin oil, lauric acid) for In, Pb, Sn, Cd If two solid surfaces are to adhere to each other, they must be brought together over a large area of real

contact without the application of great stresses, since the surfaces may otherwise tend to sep elastically when the stresses are removed The two bodies will then stick together with a force detd by the nature of the surfaces or the surface films. The intrinsic adhesion may be great, as with In and steel, or weak, as with In and "Teflon" Surface films that may modify the interaction of the metals at their interface may exert a profound effect on the strength of adhesion (C A 45, 6007d)

(141)

Proc Roy Soc (London) A202, 244-53 (1950)	RELATION BETWEEN FRICTION AND ADHESION	Cambridge Univ J S McFarlane D Tabor

Simultaneous measurements were made of the friction and adhesion of steel sliding on In in air Both the normal and tangential stresses play a part in the deformation of the metallic junctions formed at the interface The detailed behavior of the junctions during the early stages of the sliding process may be expressed quantitatively There is good agreement between the theoretical relation and the exptl observations The results emphasize the reality of the cold welding process which occurs at the points of intimate contact when metal surfaces are placed together The metallic junctions so formed are responsible both for the friction and the adhesion observed Lubricant films diminish the amt of metallic contact and so lead to a reduction in the friction and adhesion Data are also given for steel sliding on Pb and Sn Lubricants studied include paraffin oil and lauric acid In contrast to paraffin oil, the fatty acid monolayer produced a great reduction in the amt of metallic adhesion across the interface (C A 45, 6007i)

(142A)

Comm tech états propriétés surface métaux, Journées états surface (Paris) Oct , 1945 179-86, cf C A 41, 590a	THE RELATION OF THE FRICTION COEFFICIENT AND THE SURFACE CONDITION	A Marcelin

Description of the improved rotative and alternative frictiographs which make observable the different stages min liquid film, stratofilm, and hydrodynamic friction The alternative machine is more appropriate for the detn of the min liquid film or for the comparison of different lubricants or finishes (C A 42, 3557f)

(143)

Lubrication Eng 5, 75-82 (1949)	THE FRICTION OF DRY AND LUBRICATED SURFACES	Gulf Res and Dev Co F Morgan M Muskat D W Reed

The work of Bowden and Leben (Proc Roy Soc (London) A169, 371 (1939), C A 34, 6867[4]) has been extended by use of a similar app A math analysis of the stick-slip problem is given, and the coeffs of friction are calcd Results of various earlier workers obtained by other methods are confirmed (C A 44, 6108g)

(144)

O N E R A (Office natl Études et recherches aéronaut.) Rapport Tech No 36, 86 pp (1948)	FRICTION AND WEAR	J Pomey

A comprehensive review covering generalities on friction and wear, hydrodynamic lubrication, unctuous friction, seizure, and dry friction 77 references (C.A 43, 6816f)

(145)

Kolloid-Z 111, 83-95 (1948)	PHYSICAL PROBLEMS OF FRICTIONAL RESISTANCE I RELATION BETWEEN THE FRICTIONAL COEFFICIENT AND THE NORMALLY APPLIED LOAD	Rembert Ramsauer

(Cf C A 43, 6879d) According to the Coulombic law, the frictional coeff (μ) is independent of the load (ρ) acting normal to the bearing surface Actually, μ is a function of ρ, with increasing ρ, the value of μ generally decreases and only at high values of ρ does it become const Instances are known where μ increases initially Analysis shows that at low values of ρ the deformation of surface roughness is elastic, at high values of ρ, it is plastic (C A 44, 5669c)

(146)

Ibid., p 145-55	PHYSICAL PROBLEMS OF FRICTIONAL RESISTANCE II ENERGY CONSIDERATIONS IN FRICTIONAL RESISTANCE	

The work involved in moving a surface with respect to another is the sum of the work required to deform elastically and plastically the surface roughness plus a work term which is similar to that involved in the slippage of shear planes

in crystals In the case of metallic faces in vacuo the surface atoms approach within crystal distances, so that for a tangential strain appreciable forces must be overcome. The reduction in friction caused by a lubricant is due to the reduction in shear strength of the surfaces With increasing order of lubricant mols , the shear strength decreases Ordering is promoted by adsorption on the surfaces Beyond this adsorbed film and depending on the strength of the intermol forces, other ordered layers are produced having a quasicryst condition with favored glide planes parallel to the surface Any tendency of the liquid mols. to assoc or to orient under the influence of an applied tangential force disturbs this ordering action of the surface forces (C A 43, 6879d)

(147)

Kolloid-Z 112, 26-35 (1949)	PHYSICAL PROBLEMS OF FRICTIONAL RESISTANCE III WEAR AND FRICTIONAL RESISTANCE	Univ Oldenburg Rembert Ramsauer

The amount of wear at the interface of two rubbing surfaces is not simply related to the frictional loss When the frictional losses are high, the degree of wear may be small and vice versa. A liquid lubricant may actually increase the amount of surface wear - the more so, if surface-active materials are added to the liquid above certain concns This phenomenon is discussed in terms of surface-tension forces (C A 44, 6231c)

(148)

Seifen-Ole-Fette-Wachse 77, 35-7, 55-7 (1951)	NEW RESULTS IN THE FIELD OF FRICTION RESEARCH	Rembert Ramsauer K L Wolf

The relations between friction coeff and normal load were studied as well as the energy balance in the friction process (C A 45, 6007h)

(149)

Doklady Akad Nauk S S S R 83, 443-6 (1952)	THE LAW OF STATIC FRICTION	S B Ratner

Exptl detns of the friction coeff μ, defines by $F = \mu N$ (where F = friction force, N = force applied in pressing one solid against the other), for different resins on steel, an Al alloy, and on plexiglas, show a linear increase of μ as a function of $1/N$ The data can be represented by $\mu = a + (b/N)$ The const $a = \mu_\infty$ is the min value of the friction coeff at $N \rightarrow \infty$ or $N \gg b$ The exptl equation can be written $F = F_0 + \mu_\infty N$, where $F_0 = b$ is the min force acting in the absence of a load, i e , at $N = 0$, $F_0 = \mu_0 N_0$, with N_0 designating the normal force of adhesion between the solids at zero N Hence, $F = \mu_0 N_0 + \mu_\infty N$, and $\mu = \mu_\infty + (\mu_0 N_0/N) = \mu_\infty + (F_0/N)$ Friction is

thus composed of one const term, depending on adhesion, and a term proportional to the applied load N, the coeffs μ_0 and μ_∞ are distinctly different, and, consequently, Polosatkin's formulation $F = \mu (N_0 + N)$ is incorrect, as is the formula of Thirion (C A 42, 7562b) $1/\mu = (1/\mu_0) + A N$, which does not fit the present exptl results (C A 46, 8462d)

(150)

Zhur Tekh Fiz 17, 537-42 (1947) — MOLECULAR THEORY OF FRICTION — V S Shchedrov

Considerations of mol interaction between projecting parts of 2 surfaces lead to a formula in which the friction coeff is represented as a function of several parameters characterizing the roughness of the surface, the elasticity, and of parameters depending on the mol structure of the surface In particular, friction increases with the height of the mol field of the surface and with the coeff of mol interaction, and decreases with increasing modulus of elasticity, relative roughness, and Poisson's ratio Whereas the qual predictions are consistent with the exptl results of Kragel'skiĭ (Ibid 13, 145 (1943)), the exponents are different This, evidently, is due to the mixed mol -mech nature of actual friction (C A 44, 3334d)

(151)

J Applied Phys 22, 177-84 (1951) — DRY METALLIC FRICTION AS A FUNCTION OF TEMPERATURE BETWEEN 4 2°K and 600°K — Arthur D Little, Inc; I Simon; H O McMahon; R J Bowen

Coeffs of static friction of 6 metals (Fe, Ni, Cu, Pb, Sn, and Zn) were measured at temps ranging from liquid He up to room conditions (and in two cases above this) Shear strengths and hardnesses of these metals were measured over the same range of temps In spite of the generally large variation of both of these latter quantities with temp , their ratio is in most cases dependent, to only a slight extent, on temp , following rather closely the change of the static-friction coeff with temp This fact tends to substantiate the adhesion theory of friction proposed by Bowden (Ibid 14, 80 (1943), Nature 164, 1089 (1949)) (C A 45, 3677a)

(152)

Ital Patent 465,752 Sept 24, 1951 — ANTIFRICTION AND HIGH-RESISTANCE ALLOY — Società per azioni Italiana leghe e metalli

The compn contains Cu 50-90, Ni 0 5-27, Sn 1-16, Fe 0 4-6, Pb 0 3-50, Mo-Ti-Ta 1-10, Si 1-9, Cr 0 1-5, Sb 0.3-1 8, Sn 0 5-3, Bi-Mn-Ag-As 0 001-1% An example contains Cu 68, Ni 10, Sn 2, Fe 1, Pb 12, Mo-Ti-Ta-Cr 2, Si 2 7, Sb 0 5, Bi 0 3, Mn 0 1, Zn 1 39, Ag 0 008, and As 0 002% Cu is first alloyed with Ni, Fe, Mo, Ti, Ta, Si, Cr, and Mn, and then the other metals are added (C A 47, 93d)

(153)

Rept Inst. Sci Tech 1, 50-9, (1947)	THE TWO KINDS OF BOUNDARY FRICTION	Tokyo Univ Norimune Soda

In ordinary friction observed at lower pressure there exist oriented or unoriented films of uni- or multimol layers, whereas in the 2nd kind of friction whose coeff is higher than the ordinary one, the adsorbed mols have lost their properties as films The second kind of boundary friction was found at higher pressure exerted perpendicularly at the boundary surface In ordinary friction, the boundary surface is scarcely injured, while in the 2nd kind it wears out The max loading allowed for smooth lubrication is the upper limit for the region of ordinary friction, which is found to be 300-400 kg/sq.cm for ordinary lubricant oils and is about 100 times the limiting value accepted at present (C A 45, 3587c)

(154)

Ôyô Butsuri (J Applied Phys) 20, 159-60 (1951), Cf. C A 45, 6373d	A RELATION BETWEEN THE THICKNESS OF MOLECULAR FILMS AND THE TRANSITION TEMPERATURES OF FRICTION	Univ Tokyo Norimune Soda Yukio Miyagawa

The mech transition temps T were measured of built-up films of Ba stearate on steel with various nos. n of layers T increases as n increases until T reaches the max temp 200° at n = 9 At least 10 layers are necessary for the boundary lubrication This may be because the apparent 10 layers correspond to the effective monolayer owing to roughness of the substrate surface T in the case of Cu reaches its max at 100° with n = 5. Thus, the larger the coeff of sliding friction, the lower is the mech transition temp (C A 46, 5922c)

(155)

Rept Inst Sci Tech 2, 49-57, (1948)	THERMAL LIMITATION IN THIN-FILM LUBRICATION OF OILS	Univ Tokyo Norimune Soda Yukio Miyagawa

Three kinds of transition temps were found for sliding friction of metallic surfaces lubricated with thin films of normal aliphatic acids of C_4-C_{16} At the lowest one T_n smooth sliding changes to stick-slip, which is due to the disappearance of orientation of adsorbed mols (preceding abstr.) The second one T_o, where stick-slip changes to smooth sliding, is concluded to be due to the oxidation of the lubricant oil and the formation of an orientated film of the oxidation product At the highest one T_d smooth sliding changes again to stick-slip, increasing the amplitude with temp and at last it changes to irregular and fluctuating friction characteristic of dry metallic friction For lower aliphatic acids the second transition temp T_o is located nearer to T_m than to T_d, while for higher homologs it approaches T_d (C A 45, 6373e)

(156A)

Festschr Paul Schläpfer 1950, 142-56 (English summary)	FRICTION AND LUBRICATION	Grutlistrasse 50, Zurich, Switz H Stager K Frey

The various existing theories on the nature of friction and lubrication were reviewed and the influence of the mol shape on the formation of the oil film was discussed An appl was described for testing the behavior of lubricants under an addnl impact shock The results showed that a considerable difference with regard to the orientation of mols existed between paraffin base and naphthene base mineral oils It was found also that the coeff of friction did not vary in relation to the viscosity but seemed to depend on the orientation of the mols. in the oil film (C A 46, 718a)

(157)

Metal Finishing 48, No 9, 66-70 (1950)	DESIGNATION OF METALLIC SURFACES	Welding Research Council George Stroman Helmut Thielsch

Methods used in measuring and rating metallic surface characteristics are discussed Wear, friction, abrasion, lubrication, corrosion, fatigue, strength, notch sensitivity, optical properties, and adhesion of coatings are influenced by surface roughness 19 references (C A 44, 99061)

(158)

Australia, Council Sci Ind Research, Bull No 212, 38 pp (1947)	THE FRICTIONAL PROPERTIES OF LEAD-BASE AND TIN-BASE BEARING ALLOYS THE ROLE OF THE MATRIX AND HARD PARTICLES	D Tabor

Expts on Sn-base and Pb-base alloys with "stick-slip" friction-testing equipment showed that the basic frictional and wear properties are not greatly affected by the presence of hard particles, whether measured at room or elevated temps , or with clean or lubricated surfaces, although they may give better phys and mech properties in actual use Alloys tested were Sb 15, Cu 0 5, Sn 6, Pb 78 5% compared with Sb 10, Sn 3, Pb 87% (Pb-rich solid soln with duplex Pb-Sn-Sb matrix), and pure Pb, Sb 6 5, Cu 4 2, Sn 89 2, Ni 0.1% compared with Sb 7, Cu less than 0 4%, Sn remainder, and pure Sn Frictional work is absorbed in shearing soft metal films which weld momentarily to the surface of the steel shaft (C A 46, 7975a)

(159)

J Inst Petroleum 34, 743-73 (1948), B.I.O.S. Final Rept No 1610	FUNDAMENTAL WORK ON FRICTION, LUBRICATION, AND WEAR IN GERMANY DURING THE WAR YEARS	E D Tingle

An outline is given of fundamental German work on friction and lubrication during the years 1939-1945 (C A 43, 2416b)

(160)

Metal Ind (London) 75, 68-70, 73, 89-91, 112-13 (1949) — SURFACE REACTIONS OF METALS EFFECT ON WEAR, FRICTION, LUBRICATION, AND FINISHING — G Tolley

The behavior and performance of any metal in service may well depend upon its surface Surface reactions of metals are classified as physicochem and physicomech The first class includes catalysis, absorption, elec properties of surfaces, and corrosion, the second includes mech wear, lubrication, friction, and mech polishing Several methods are described for detg surface roughness and active surface area The great variation in surface area for the different methods is notable With reference to the surface anodizing by different processes, the H_2SO_4 process obviously gives a much more porous and uneven surface than the CrO_3 method Sealing with steam closes up the majority of the pores and gives the lowest figure for specific surface The roughness of electrodeposits was also investigated A further review is given of the effect of surface condition on corrosion inhibitors, high-temp oxidation, friction, and lubrication (C A 43, 7769c)

(161)

Trans. Faraday Soc 46, 93-7 (1950) — IMPORTANCE OF SURFACE OXIDE FILMS IN THE FRICTION AND LUBRICATION OF METALS I DRY FRICTION OF SURFACES FRESHLY EXPOSED TO AIR — Cambridge Univ E D Tringle

A smooth shallow track on the metal surface was made by a cutting tool of WC The slider used in the detn of friction passed over this track immediately behind the cutting tool so that the interval between exposure of the metal and measurement of friction was very short With unlubricated surfaces the oxide film generally produces a marked reduction in friction even though the period of exposure to the atm of a freshly cut surface is only a few sec With subsequent growth of the film there is further reduction but the effect is less marked The thin layer of oxide immediately adjacent to the surface plays a more significant part in reducing the friction than the thicker layers of oxide above it

Ibid, p 97-102 — II FORMATION OF LUBRICATING FILMS ON METAL SURFACES

A diamond-edged cutting tool made a smooth shallow track on the lower Cu surface under a pool of the lubricant soln The combined action of water and atm O on the surface of a reactive metal is often able to produce a penetrable film which will react with a fatty acid to give an effective lubricating layer The lubricating properties of long-chain fatty acids on metals are divided They may lubricate metals which form a thick permeable layer of oxide capable of reacting with fatty acids to form a soap, or they may lubricate metals whose oxides, although probably capable of reaction with fatty acid, are formed on the surface as tough, compact skins, or they lubricate metals which form no oxide film or only a very thin film (C A. 44, 6613h)

(162)

Proc Roy Soc (London) A201, 109-24 (1950)	SURFACE DEFORMATION AND FRICTION OF METALS AT LIGHT LOADS	Cambridge Univ , England J R Whitehead

The interaction of sliding metals when the normal load between them is very small was studied A new app is described which enables friction to be measured, under controlled conditions of sliding, down to loads of a few mg The deformation of the sliding surfaces has been studied by light and electron microscopy Exptl results on electrolytically polished Cu reveal a departure from Amontons' law when the normal load is less than a few g A corresponding change is observed in the deformation within the track of sliding At light loads the friction is low and the damage is slight This is attributed to the effect of the thin film of oxide formed by contact with the atm A thicker film of oxide, formed by heating in air, reduces the friction at heavy loads Results of observations on Cu surfaces prepd in various ways show that the influence of surface roughness upon friction is not great The friction of Ag on Ag and of Al on Al is const and Amontons' law holds over the whole range of loads It appears that the thin film of oxide on Al is penetrated, even at the lightest loads The difference in behavior of the various metals is attributed to the contrasting properties of their oxides Sapphire and diamond show that the coeff of friction is low and const for these nonmetals Friction data are given for Cu on electrolytically polished Cu, steel on electrolytically polished Cu, Ag on Ag, Al on Al, Cu on Cu bounded by (a) lauric acid, (b) octacosanoic acid The preliminary exptl results of sliding Cu on Cu lubricated by a monolayer of a long-chain polar compd show a departure from Amontons' law such that the friction becomes greater at the lighter loads The effect appears to increase with the length of the mol chain for the two compds. studied The departure from Amontons' law suggests the presence of a small force addnl to the "true" frictional force This may be a measure of the forces of adhesion between the surface films of lubricant The coeff of friction is greater at very light loads (C A 44, 7737d)

(163)

Erdol u Kohl 4, 9-17 (1951)	FRICTION, LUBRICATION, WEAR SUMMARY OF RESULTS PUBLISHED BETWEEN 1944 AND 1948	R Wiebe

72 references (C A 45, 4435i)

(164)

Proc Roy Soc (London) A212 450-2 (1952)	INFLUENCE OF OXIDE FILMS ON METALLIC FRICTION	Univ Cambridge, England R Wilson

The mechanism of metallic friction, in air, was investigated for loads ranging from 0 003 to 10,000 g on Pt, Au, Ag, Cu, Sn, Pb, Zn, Cd, Mg, Al, and Cr With most metals the natural oxide layer is sufficient to prevent metallic contact at very small loads The degree of protection depends on surface roughness, the thickness of the oxide film, the relative hardness of the oxide and the metal substrate, etc (C A 46, 8462f)

LUBRICATION

(165)

Proc Roy Soc (London) 191A, 243-52 (1947)	AN ELECTRON-DIFFRACTION STUDY OF THE HEATING OF STRAIGHT-CHAIN ORGANIC FILMS AND ITS APPLICATION TO LUBRICATION	K G Brummage

Thin films of normal paraffins, fatty acids, and esters have been examd by electron diffraction during heating upon a variety of metal surfaces In all cases the films lost their orderly condensed structure at a comparatively low temp , leaving expanded films of individual mols Evidence has been obtained of the formation of metallic soaps when fatty acid films are deposited upon reactive surfaces such as Cu, Cd, and mild steel The film materials studied are tetratriacontane, triacontane, tetracosane, behenic acid, stearic acid, palmitic acid, cetyl palmitate, ethyl stearate, and methyl stearate Base metals used are Al, Cd, Cu, Ni, Ag, mild steel, and stainless steel Conclusions (1) It has been demonstrated that disorientation at a characteristic temp is general in thin films of normal paraffins, fatty acids, and esters deposited on metals (2) The results show that the disorientation temp is invariably lowest for a monolayer quantity deposited on a given surface and increases with thickness to a steady characteristic value, which may be above or below the m p. of the material constituting the film (3) The high disorientation temps. of fatty acids deposited on Cd, Cu, and mils steel are due to the formation of soap films (4) The difference between the thick-film disorientation temp and the m p of a given substance depends on its mol wt and upon its nature, that is, whether it is a paraffin, a fatty acid, or an ester. (5) The metals studied can be divided into two groups, depending upon the thick-film disorientation temps of fatty acids (or their soaps) deposited upon them. In the first, comprising Al, Cd, Cu, mild steel, and stainless steel, the fatty acids or soaps become disorientated in thick films at temps below their m ps., like the paraffins Upon Ni and Ag, their disorientation temps., are above their m ps as with esters (6) The measured disorientation temps. correlate well with the discontinuity in smooth friction often observed in Bowden-Leben friction app It is thus confirmed that this discontinuity corresponds to the change of the lubricant film structure from a condensed to an expanded state (7) The reasons for the dependence of disorientation temp upon film thickness, and of thick-film disorientation temp upon film constitution and substrate metal are unknown (C A 42, 5216h)

(166)

Trans Am Soc Mech Engrs. 70, 401-8 (1948), cf Trans Am Soc Mech Engrs 61, 633-41 (1939)	BOUNDARY LUBRICATION II INFLUENCE OF ADSORBED MOISTURE FILMS ON COEFFICIENT OF STATIC FRICTION BETWEEN LUBRICATED SURFACES	Bell Telephone Labs , Murray Hill, N J W E Campbell E A Thurber

Extraordinarily high values of the coeff of static friction between steel surfaces lubricated with straight-chain normal hydrocarbons (heptane to decane)

are shown to be due to a film of adsorbed moisture at the solid-liquid interface The coeff. of friction of a highly refined paraffin-base oil applied to surfaces in equil with a dry and moist atm are 0 35 for the dry and 0 6 for the moist surface Friction measurements are recorded for 4 fundamentally different lubricant types on steel, brass, and glass in equil with dry air and air of 75% relative humidity, resp The friction is invariably raised from 40 to 70% by the high humidity, this effect is especially pronounced with glass These results explain many of the discrepancies in the literature among oiliness results obtained by the static-friction method, and indicate that the humidity of the atm plays a significant part in the mechanism of boundary lubrication (C.A 42, 4336a)

(167)

Proc Roy Soc (London) A212, 459-62 (1952)	FORMATION OF LUBRICANT AND OTHER FILMS ON CLEAN METAL SURFACES A STUDY BY ELECTRON DIFFRACTION	R Courtel

Report on electron-diffraction aberrations on surfaces ground in vacuo With Fe the vapors of fatty materials are absorbed and form oriented films With Ce an oxide is formed which has not hitherto been isolated (sesquioxide Ce_2O_3 cubic) By observing the oxides and their structural changes, it is also possible to det , in certain cases, the surface temp developed by grinding Details are given of an app in the course of construction This app contains a separate prepn chamber so that the action of certain sulfurized compds , especially on clean surfaces, can be studied at different temps (C A 46, 8842c)

(168)

Ind Eng Chem 42, 1837-41 (1950)	BOUNDARY LUBRICATION OF STEEL BLENDS OF ACIDS, ESTERS, AND SOAPS IN MINERAL OIL	Acton Tech Coll , London William Davey

Blends in mineral oil of acids, including naphthenic, stearic, palmitic, oleic, myristic, and capric, and esters, including ethyl stearate, palmitate, oleate, myristate, and tristearin, tripalmitin, triolein, and castor oil, and soaps including Na, Al, Zn, Ni, Co, Mn, Fe, Sn, and Pb naphthenates, Na, Ca, Mg, Al, Zn, Ni, Co, Mn, Fe, Sn, Cu, and Pb stearates, Na, Ca, Mg, Al, Zn, Ni, Fe, Sn, Cu, and Pb oleates, and Na, Al, Zn, and Cu palmitates were studied by means of the four-ball machine. In addn combinations of some of the soaps with S, and preformed films of FeS, Pb, PbS, $PbSO_4$, Cu, and CuS, alone and in combination with several of the acids, were tested Blends of acids show better boundary lubricating properties than esters, having less tendency to seizure and better recovery from seizure These data are correlated with the results of heating the acids and esters with Fe powder, in that the acids all react with Fe while acid-free esters do not Effective boundary lubrication at high loads by soap blends depends on the metal present in the soap rather than

the acid Metal interchange, iron + metal soap = metal + iron soap is the proposed mechanism The tests indicate that metal interchange will occur only if the metal in the soap is less electropos than Fe Boundary lubrication is effected by esters and soaps by phys adsorption at the surface to give a film which reduces both coeff. of friction and wear at low loads Fatty acids react chemically with steel surfaces to give tightly bound Fe soap films capable of resisting seizure and reducing wear. Esters show anomalous behavior on steel, and although some chem reaction is possible, under extreme conditions, this factor is unlikely to play a major part in lubrication under ordinary conditions In the presence of S, a sulfide film is formed, which facilitates adsorption of the polar compds and gives a lower coeff of friction and lower wear Under heavy loading conditions breakdown of the film occurs with increased wear or even welding of the surfaces. In the presence of S, Pb and Cu soaps give sulfide films which lower the tendency of seizure and reduce wear, friction is reduced by the adsorbed soap Cf following abstr (C.A 44, 11075e)

(169)

Compt rend acad sci U R S S 54, 137-40 (1946)(in English)	A TRIBOMETRIC METHOD OF MEASURING ADSORPTION ON A SOLID SOLUTION INTERFACE APPLICATIONS TO THE STUDY OF THE LUBRICATING ACTION OF ADSORBED LAYERS	B Deryagin M Smolinanskiĭ

The surface-active substances stearic acid, palmitic acid, myristic acid, caproic acid, octyl alc , and cetyl alc were deposited in a thin film of paraffin oil from a benzene soln upon a smooth plate The coeff of friction of the surface of the plate was then measured by means of a slider supported by three steel needles The detd coeff of friction was a measure of the quantity of active agent adsorbed on the plate Variations in the thickness of film of paraffin oil between 10^{-6} and 10^{-3} cm and in the initial concn of surface-active agent were made at 12-15° The data for the above materials were found to fall on continuous curves representing the Langmuir isotherm Traube's rule was closely followed by the fatty acids (C A 41, 2625h)

(170)

S African Ind Chemist 2, 212-16, (1948)	FRICTION, FLUID LUBRICATION, AND EXTREME-PRESSURE BOUNDARY	P. J de Kadt

The history of the development of theories of lubrication is reviewed Types of extreme pressure (E.P.) lubricants are discussed The most successful E P. additives are S compds. with active H atoms the type of mineral oil used as a vehicle is of no importance Pure hydrocarbons are poor lubricants Cetyl sulfonic acid is a perfect lubricant with a coeff. of friction of 0 06 up to 125° Values of this order are given by 2-mercapto- and 2-thiocyanopalmitic acids up to 250-300° and by oleic acid up to 120°, while 8,9-dithiocyanostearic acid, which has an initial coeff of 0 08, gives on heating a value of 0.02 up to less than 400° E.P lubricants interact with the metal surfaces

to form a chemisorbed film (distinct from the original lubricant) which should have a high softening point, be relatively insol in mineral oils and neither hard nor cryst , have a high breakdown temp , and sufficient load-carrying capacity to prevent seizure of the metals (C A 45, 4029d)

(171)

Lubrication Eng 8, 285 (1952)	LUBRICATING PROPERTIES OF MOLYBDENUM DISULFIDE	Mass Inst Technol Cambridge I -Ming Feng

The lubricating ability of MoS_2 is related to its crystal structure It is shown by electron microscopy to have a laminar structure similar to graphite Coeffs of sliding friction of MoS_2 in thin films and in compressed pellets were detd to be about 0 20 X-ray diffraction results for a completely randomly oriented powder specimen are given. X-ray results for thin rubbed films show oriented laminas, the orientation increasing with rubbing pressure (C A. 47, 1451h)

(172)

Phys of Lubrication Brit J Applied Phys , Suppl 1, 34-5 (1951)	THE BOUNDARY LAYER	Imp. Coll Sci, and Technol , London G. I Finch

The present state of knowledge of the liquid and solid boundary layer is reviewed The function of the boundary layer is to replace the oxide-layer component of friction by one of still lower value The structure of the oil boundary layer is discussed, as are the effects of heat and sliding on this structure, particularly on the orientation of the lubricant mols Solid lubricants of the layer lattice type depend for their functioning on a large ratio of surface area to particle mass and have on their surfaces firmly adhering liquid or gaseous adsorbed layers (C A 45, 4915b)

(173)

French Patent 862,120 Feb 27, 1941	SEMICOLLOIDAL MOLYBDENITE AS A METAL LUBRICANT	Michael J Galvin

(C A 42, 6108c)

(174)

Mech Eng. 73, 892-6 (1951)	BEARINGS, LUBRICANTS, AND LUBRICATION	J C Geniesse

A digest of 1950 literature with 72 references (C A 46, 718b)

(175)

Natl Advisory Comm Aeronaut , Tech Note No 2628, 16 pp (1952), cf Godfrey and Nelson, C A 43, 6816g	BONDING OF MOLYBDENUM DISULFIDE TO VARIOUS MATERIALS TO FORM A SOLID LUBRICATING FILM I THE BONDING MECHANISM	Lewis Flight Propulsion Lab , Cleveland, O Douglas Godfrey Edmond E Bisson

Air drying and heating of a mixt of MoS_2 powder and some liquid vehicles cause the decompn. and polymerization of the vehicles The resin product binds the particles of MoS_2 together and to the surface to be lubricated MoS_2 is bonded to steel, Al, brass, stainless steel, and glass by the use of vehicles such as asphalt-base varnish, silicones, glycerol, ethylene glycol, polyglycol ether, and corn sirup but not by the use of a light petr oil vehicle The reduction of Fe_2O_3 formed by preheating steel in air, to Fe_3O_4 by corn sirup improves the lubricating properties of the solid film Electron diffraction patterns indicate distinct preferred orientation of MoS_2 in dusted, built-up, or resin-bonded films which have been rubbed (C A 46, 5303a)

(176)

Ibid No 2802, 16 pp	BONDING OF MOLYBDENUM DISULFIDE TO VARIOUS MATERIALS TO FORM A SOLID LUBRICATING FILM II FRICTION AND ENDURANCE CHARACTERISTICS OF FILMS BONDED BY PRACTICAL METHODS	Douglas Godfrey Edmond E Bisson

To form a solid film lubricant MoS_2 can be bonded to metal with resin-forming liquid vehicles For bonding thinned asphalt-base varnish, silicon varnish and glycerol are recommended, they give just as satisfactory results as corn sirup The new type varnish-forming products contain grease solvents like naphtha or xylene and do not require such thorough cleaning before application as corn sirup which contains water Application by brushing is followed by air drying, infrared drying, and oven curing Bonding does not depend on any special surface finish Friction and endurance tests showed excellent lubricating qualities of films 0 0002-0 0005 in thick At low sliding speeds asphalt-varnish bonded films were somewhat inferior (C A 47, 2469e)

(177)

Ibid No 1882, 28 pp	OXIDATION CHARACTERISTICS OF MOLYBDENUM DISULFIDE AND EFFECT OF SUCH OXIDATION ON ITS ROLE AS A SOLID-FILM LUBRICANT	Douglas Godfrey Erva C Nelson

Expts were conducted with an app that caused a spherical rider to slide in a spiral path on a rotating disk at velocities between 50 and 8,000 ft per min and a load of 269 g (126,000 lb/sq in , initial Hertz surface stress) A coating of MoS_2 serving as a high-temp solid-film lubricant maintained low

coeff -of-friction values during its oxidation to MoO_3 as long as an effective subfilm of MoS_2 remained Films of MoO_3 alone produced very high friction The rate of oxidation and phase changes occurring to MoS_2 while being heated to various temps were investigated by x-ray diffraction MoS_2 began to oxidize slowly in air at 750°F, the rate increasing steadily and becoming high at 1050°F In vacuum MoS_2 maintained its original structure at 1000°F (C A 43, 6816g)

(178)

Trans Faraday Soc 45, 631-5 (1949) LUBRICATION OF METAL SURFACES BY MONO- AND MULTIMOLECULAR LAYERS E B Greenhill

Lubricating layers of stearic acid, Et stearate, octadecyl alc , and the stearates of Cu and Ag were deposited by the Langmuir-Blodgett method (C A 30, 1633^2) on a flat metal surface and the friction between this surface and a clean slider of the same metal was detd Where a metal can be lubricated by a soln of one of these compds in paraffin oil, 1 or 3 deposited layers suffice, where a paraffin soln does not provide lubrication more than 3 layers are necessary This indicates that where paraffin solns do effect lubrication the sliding surfaces are only sepd by the monolayer adsorbed on each surface The results for Pt and Ag show that metal stearates are more effective lubricants than stearic acid itself Breakdown of lubrication occurs at the bulk m p except with stearic acid on a reactive metal Here, lubrication persists up to a temp equal to the softening point of the appropriate metal soap (C A 43, 9424c)

(179)

Nature 159, 403 (1947) LUBRICATING PROPERTIES OF MOLECULAR LAYERS OF STEARIC ACID AND CALCIUM STEARATE ON METAL SURFACES Univ , Melbourne, Austr J N Gregory J A Spink

From 1 to 21 mol layers of Ca stearate and stearic acid were deposited on Pt, Cu and stainless steel, from 0 0001 M $CaCO_3$ at pH 6 These layers contained 60% soap and 40% acid The coeff of friction k was detd. at various temps, on these surfaces On Cu, there is an increase in k at the m p of stearic acid The liquid acid reacts to form Cu stearate, and k falls to its original low value There is a permanent increase in k at and above the softening point of Cu stearate On stainless steel there is an increase in k at and above the softening point of Ca stearate, there are no changes at the m p of stearic acid or of ferric stearate On Pt, there is a temporary increase in k at the temp at which β,α phase changes occur, followed by a permanent increase at and above the m p of the acid, these results were also obtained with layers of palmitic and octacosanoic acids In general, each fluctuation in k corresponds to a phase change The min. no of layers required for lubrication varies with the metal it is 1 for stainless steel, 3 for Cu, and 5 for Pt Ca stearate does not lubricate Cu or Pt (C A 41, 4693g)

(180)

Australian J Sci Research, Ser A, 1, 85-97 (1948)	LUBRICATION OF METAL SURFACES BY SILICONE FILMS SYNTHESIS AND ANALYSIS OF CHLOROSILANES	J N Gregory Marjorie J. Newing

Mono-, di-, and tri-isoamylchlorosilanes, and monocetylchlorosilane, were prepd with the aid of Grignard reagents Methods for the analysis of silanes were developed Silicone films were prepd on polished metal surfaces from mono- and di-ethyl- and mono- and di-isoamylchlorosilanes Monocetylchlorosilane was unsatisfactory. The films could not be obtained by direct adsorption The metal surface must first have adsorbed water Cu, mild steel, Ag, and Pt were examd The silicone layers reduced the coeff of friction to values characteristic of good boundary lubrication even up to 200°. The addn of paraffin destroyed the wear resistance of the film on Ag but increased it on Pt The films on Cu and mild steel were not affected Silicone films are not self-repairing after breakage The adherence of the films may depend on attachment to the metal by residual fields of force from the O atoms Lubrication on Cu and steel is better than on Ag and Pt This may depend on some degree of chem reaction between the O and the metal Cross-linking in the silicone film makes for tenacity and thermal stability The hydrocarbon part of the mol is turned outwards from the metal surface and is water-repellent 15 references (C A 43, 7219d)

(181)

Proc Roy Soc (London) A212, 516-19 (1952)	VARIATION WITH LOAD OF THE COEFFICIENT OF FRICTION AND METALLIC TRANSFER UNDER CONDITIONS OF BOUNDARY LUBRICATION	Assocd Elec Inds Ltd , Aldermaston, Berks, Engl W Hirst M Kerridge J K Lancaster

Data are reported for Cu surfaces, lubricated with 1 and 5 monolayers of stearic acid 82 references (C A 46, 8839h)

(182)

Natl Advisory Comm Aeronaut , Tech. Note 2366, 35 pp. (1951)	FRICTION AT HIGH SLIDING VELOCITIES OF OXIDE FILMS ON STEEL SURFACES BOUNDARY-LUBRICATED WITH STEARIC ACID SOLUTIONS	Lewis Flight Propulsion Lab , Cleveland,O. Robert L Johnson Marshall B Peterson Max A Swikert

The lubrication of a heavily loaded pin (up to 194,000 psig Hertz) on a rotating steel disk (linear velocities up to 7000 ft per min) by cetane contg. 0 1 to 0 5% stearic acid was studied Films of Fe_3O_4 and Fe_2O_3, 1000 A thick were applied to the disk by heating in an O-deficient atm and in air With clean steel and Fe_2O_3 coated steel lubrication failure was obtained at 3000 ft

per min With Fe_3O_4 speeds greater than 7000 ft. per min, did not cause failure Clean steel and oxide-coated surfaces covered by rubbed films of stearic acid withstood sliding velocities greater than 7000 ft per min As the total load on the pin was increased from 169 to 1543 g the max sliding velocity obtainable without lubrication failure generally decreased (C A 45, 7343d)

(183)

Stahl u Eisen 72, 1212-16 (1952) BOUNDARY-FRICTION LUBRICANTS Martin Kuhn

Lubrication in the field of liquid and boundary friction is explained through the formation of conforming momomol films The lubricating action of similar materials in the range of very high pressures and temps at the limiting friction is ascribed to the formation of broken films which result from the decompn of the originally used material in its dissocn at high temp and in the reaction at the metal surface Theoretical aspects of the reciprocal action of lubricant and carrier as well as of the effect of chem structure of lubricants and diluents on lubricating properties are discussed briefly The importance of such boundary-friction lubricants in metal cold-forming is pointed out (C A 47, 24691)

(184)

U S Patent 2,420,886 May 20, 1947 APPLICATION OF SOLID LUBRICANT COATINGS TO SURFACES Westinghouse Electric Corp. Carthrae M Laffoon, Jr

See Can 437, 017 (C A 40, 7147^5) (C A 41, 6400f)

(185)

Phys of Lubrication, Brit J Applied Phys, Suppl 1, 35-8 (1951) SCUFFING TEMPERATURES OF BOUNDARY LUBRICANT FILMS Shell Refining and Marketing Co Ltd Chester, Engl T B Lane

A 2-ball testing machine is described and exptl data obtained with it are presented to confirm Blok's postulate that lubrication fails when the temp in the contact area reaches a value characteristic of the lubricant and sliding system Test data presented for 5 mineral oils ranging in viscosity from 8 to 148 centistokes at 60° indicate that the failure temp increases with viscosity (C A 45, 4915d)

(186)

U S Patent 2,619,458 Nov 25, 1952 | SOLID LUBRICANT | Westinghouse Elec Corp Byron V McBride

Addn of 0.2-25% of 1 or more hexavalent Cr compds (I) to disulfides, selenides, and telurides of Mo, W, and Ti inhibits bearing metal against corrosion The I include $Na_2Cr_2O_7$, $K_2Cr_2O_7$, H_2CrO_4, $ZnCrO_4$, and $(NH_4)_2CrO_4$ The mixt can be applied as an aq suspension which included both a suspension and wetting agent or as a suspension in a solvent, such as xylol A suitable mixt is MoS_2 100, methylcellulose 2, wetting agent 1 1/2, $Na_2Cr_2O_7$ 1, and H_2O 100 parts (C A 47, 2479d)

(187)

Research (London) Suppl , Surface Chemistry 1949, 223-31 (in French) (Engl summary) | BOUNDARY FILMS THE SOLID/SOLID BOUNDARY AND THE LUBRICATING FILM | A Marcelin

Similarities and differences between boundary films at liquid-gas, gas-gas, and solid-solid boundaries are discussed Solid-solid boundaries, e g , a layer of lubricating oil between metal surfaces, are studied by means of 3 types of app a frictiograph with rotary movement, a frictiograph with alternating rectilinear movement, and a microfilometer Corresponding to the properties of liquid-gas and gas-gas boundary films, the solid-solid boundary film may appear in 3 different stages (1) A thick layer ensures perfect hydrodynamic lubrication This thick layer gets progressively thinner under increasing load or decreasing speed until it reaches a min crit thickness of about 1 μ The min liquid film, corresponding to the 2nd stage, is remarkable for its stability when the relative speed of the metal surfaces becomes extremely small or even zero, the film can resist pressures up to 100 kg/sq cm without being crushed When the crit load is passed, the min liquid film suddenly collapses But even after collapse, i e , with a coeff friction higher than that of the min liquid film, lubrication is provided by means of stratofilms formed by the superposition of one or more double layers of mols It is only in the region of stratofilms, i.e , in the 3rd stage, that wear and tear of metallic surfaces takes place The multiplicity of stratofilms is shown to correspond closely to the appearance of black spots in soap bubbles (gas-gas boundary) (C A 43, 8799d)

(188)

Phys. of Lubrication, Brit J Applied Phys Suppl 1, 52-4 (1951)	A STUDY OF BOUNDARY LUBRICANT FILMS BY ELECTRON DIFFRACTION	Univ Cambridge, Engl J W. Menter

Exptl work reported on the orientation and structure of thin films of long-chain hydrocarbon compds on metal surfaces and the effect of temp indicate, when correlated with the behavior of sliding surfaces lubricated by the same compds , that good boundary lubrication occurs only when there is a closely packed solid film of oriented mols on the surface (C A 45, 4915a)

(189)

Ôyô Butsuri, J Applied Phys. 21, 215-19 (1952)	EFFECT OF ATMOSPHERES ON THE BOUNDARY LUBRICATION	Univ Tokyo Yûzaburô Nagai Hiroshi Miyazaki

Coeffs of the boundary friction of quenched steel surfaces lubricated with refined spindle oil (d_4^{30} = 0 852 and n_D^{30} = 1 4661) are measured in various gases by the use of the pendulum-type oiliness tester (Soda and Miyata, C A 42, 1728d) The values of f at room temp are 0 48 in air at 1 atm pressure, 0 18 in air at 1-2 mm Hg, 0 23 in CO_2, 0 23 in H_2, and 0 36 in N_2 O_2 shows the same f as air The temp variation of f is examd. and the adsorption of gases on the boundary surface is discussed. (C A 46, 11658d)

(190)

Japan Pátent 36 Jan 11, 1950	SOLID LUBRICANT	Fusatoshi Nozawa

A solid lubricant suitable for use with metals is prepd by mixing bentonite 40-60, Al powder 10-15, talc 30-5, solid fat 20-5, and metal soap 3-5 parts and molded by heating (C A 46, 8848i)

(191)

Chemie, Ing , Tech 21, 216-18 (1949)	THE EFFECT OF THE LUBRICANT UPON THE ENERGY AND MATERIAL LOSSES IN BOUNDARY LUBRICATION	R Ramsauer K L Wolf

Exptl data are presented which show that the addn of interfacial active agents to lubricating oils will decrease friction but increase the material losses (C A 43, 7675g)

(192)

J Chem Soc Japan, Ind Chem Sect 54, 363-5 (1951), cf C A, 47, 3551a	THE OILINESS OF LUBRICANTS X THE COEFFICIENTS OF STATIC FRICTION OF MONO- AND MULTILAYERS OF DIBASIC ESTERS	Tokyo Inst Technol Toshio Sakurai

The coeffs of Static friction of a steel surface covered with successive monolayers of higher dibasic esters, sebacate, adipate, have been detd The coeffs μ of ester mono-layers are generally higher as compared with the case in which the surface of steel is lubricated sufficiently As the thickness of successive layers of lubricants increases, the μ value decreases and becomes const when the thickness becomes 5-7 mol layers The test of stripping has been carried out for the nine mol layers of palmitic acid (I) and of diododecyl sebacate (II) I has a greater resistance to stripping than II It is expected that II also can build up film sufficiently strong as lubricating oil (C A 47, 5673f)

(193)

Ann N Y Acad Sci 53, 862-9 (1951)	PHYSICALLY AND CHEMICALLY ADSORBED FILMS IN THE LUBRICATION OF GRAPHITE SLIDING CONTACTS	Gen Elec Co , Schenectady, N Y Robert H Savage

S summarizes the behavior of graphite as a lubricant The friction of clean graphite in a vacuum is high The chief requirement for lubrication is a "separating mol " which is physically adsorbed on a C atom O increases the attraction for H_2O on graphite so that the H_2O mol can be used more efficiently (C A 46, 2876a)

(194)

J Applied Phys 19, 1-10 (1948)	GRAPHITE LUBRICATION	Gen Elec Co , N Y Robert H Savage

The slipperiness of graphite depends not only on the crystal structure but also on adsorption films, especially water, which cover the C atoms and provide surfaces of low cohesion In a vacuum graphite brushes seize upon a moving base of Cu or graphite and wear away as a fine dust This wear and accompanying high friction are instantly stopped by condensible vapors at pressures below 5 mm Hg These substances, such as H_2O, C_6H_6, or NH_3, apparently cover the graphite with a reversibly adsorbed film, sensitive to the temp and pressure at the surface Under conditions of optimum coverage the graphite friction may be accounted for as the heat of cohesion of water monolayers attached to the C atoms and undergoing successive makes-and-breaks From the observations made in expts the area of mol contact is estd to be 4×10^{-6} sq cm under a real pressure of 2×10^4 kg /sq cm The wear dust of unlubricated graphite shows a unique adsorptive power at room temp for N_2 and CH_4, and a greater adsorption for H_2 than that of activated charcoal by 5 orders of magnitude (C A 42, 2753i)

(195A)

Science Museum, London, 1946	QUARTERLY BIBLIOGRAPHY OF LUBRICATION NO 55, 66 pages	Science Library Current Bibliography Series No 2

(C A 41, 6700g)

(196)

Petroleum Processing 4, 1003-8 (1949)	SULFURIZED EXTREME-PRESSURE LUBRICANTS AND CUTTING OILS I. LITERATURE SURVEY	Helen Sellei

A review covering (1) the theoretical background of boundary lubrication, (2) suggested mechanisms of the lubrication process with sulfurized lubricants, (3) historical development of sulfurized oils and S compds with particular reference to their use in extreme-pressure lubricants and cutting oils 98 references (C A 44, 315c)

(197)

Engineering 165, 505-7 (1948)	COLLOIDAL GRAPHITE IN ASSEMBLY LUBRICATION	E A Smith

A film of graphite on rubbing surfaces of machinery being assembled promotes wedge formation and spreading of oil, protects against metal pickup, controls running-in wear, sustains higher loads, and lowers initial friction (C A 42, 6098d)

(198)

German Patent 806,005 June 11, 1951 Cl 7b, 4_{50}	LUBRICANT FOR THE EXTRUSION OF METALS	Societe anon dite Comptoir industriel d'étirage et profilage de métaux Jacques Séjournet, inv

When a curved draw-plate or container is used in the high-temp extrusion, particularly wire drawing, of high-melting metals or alloys, plate glass, since it shatters when applied to curved surfaces, gives uneven lubrication A satisfactory lubricant consists of elements of foam glass combined with the plate glass, preferably with part or all of the foan glass applied between the draw-plate and the plate glass Cf C A 45, 2846g. (C.A 47, 93b)

(199)

Rept Inst Sci Tech (Univ Tokyo) 4, 176-89 (1950)	FRICTION OF UNI- AND MULTIMOLECULAR LAYERS	Norimune Soda Yukio Miyakawa

The kinetic frictions of uni- and multimol layers of stearic acid and Ba stearate deposited by the Langmuir-Blodgett technique (Y-deposition) are measured for various loads, temps curvatures of sliders, and combinations of rubbing materials The friction decreases with the increase of the number of layers, as is well known, but the min number of layers sufficient for the satn of lubricating action and the limiting value of the friction largely depend on the curvature of the slider and the kinds of rubbing materials For uni- and trimol layers Coulomb's rule holds in the whole region of the pressure from 110 to 230 kg / sq mm , whereas for 5 or more mol layers the frictional coeff increases abruptly at the pressure of 150-170 kg /sq mm , though on either side of this point Coulomb's rule is applicable (cf CA 45, 3587c) Moreover, the rates of increase of friction and wear of mol layers during repetition of sliding are discussed, and it is computed that the layer worn by friction is not repaired by the supply from the surrounding layers The mech transition temp of mol layers measured by the stick-slip method (cf CA 45, 6373d) is found to increase with the number of layers (C A 45, 7408h)

(200)

Blast Furnace Steel Plant 40, 1184-9 (1952)	THE UGINE-SÉJOURNET EXTRUSION PROCESS	Vanadaium Corp of America, N Y, Jerome Strauss

In this process for the production of bars, shapes, and tubes of steel by hot extrusion, the lubricant used is glass in the fibrous or woven form and contg SiO_2 60-72, Al_2O_3 4-5, CaO 8-14, and Na_2O 8-14% Oxides must be removed from the billets by heating in a salt bath just before extrusion Such metals as low-metalloid Fe, 20Cr-9Ni stainless steel, high-purity Mo, Ti metals and alloys, S 816, and others have been extruded successfully by this process (C.A 47, 88a)

(201)

Proc Roy Soc (London) A212, 498-505 (1952)	BOUNDARY AND EXTREME-PRESSURE LUBRICATION MECHANISM OF BOUNDARY LUBRICATION	Univ Cambridge, Engl D Tabor

The most effective lubrication is provided by a solid boundary film that possesses a close-packed strongly oriented structure When the film melts, a marked increase in friction and metallic interaction occurs Fatty acids are generally more effective than hydrocarbons or alcs , since they can react with the surface to form metallic soaps of relatively high m ps This

chem attack generally occurs via the metal oxide film on the surface The soap formation and the difference between a physically adsorbed and a chemically formed layer were investigated by radioactive methods At the m p of the lubricant film a marked increase in pick-up and friction occurs At still higher temps. a second deterioration in lubricating properties occurs, corresponding to the desorption of the lubricant film Although the surface is flooded with a lubricant the friction and surface damage are comparable with that observed with unlubricated surfaces These effects are reversible on cooling and correspond to changes in the structure and orientation of boundary films. A schematic summary of pick-up results is given for palmitate, palmitic acid, cetyl alc , cetane, and silicone (C A 46, 8839i)

(202)

Research (London) Suppl , Surface Chemistry 1949, 217-22 (in English and French)	SURFACE ATTACK OF METALS BY FATTY ACIDS AND THE FORMATION OF LUBRICATING LAYERS	D Tabor E D Tingle

On nonreactive metal surfaces, such as Ag or Pt, fatty acids are no more effective as boundary lubricants than paraffins or alcs of corresponding chain length, they produce a low coeff of friction only when solid, and a marked increase in friction and surface damage is observed above their bulk m p On reactive metals, on the other hand, friction and surface damage remain low up to the melting or softening point of the metallic soap formed at the surface These exptl results are not in agreement with the classical view, according to which the efficacy of a lubricant is detd by the strength of bonding of the adsorbed lubricant mols at the metal surfaces Since a solid nonpolar hydrocarbon is more efficient than a molten fatty acid on a nonreactive metal, it must be assumed that laterial adhesion between the lubricant mols is of primary importance in providing lubrication Phys adsorption of the mol at the metal surface can be of only secondary importance The results of the friction studies also elucidate the mechanism of the formation of lubricating soap films by chem reaction between fatty acids and metals Friction expts on surfaces from which the oxide film has been removed indicate that this reaction does not occur directly with the metal even in the case of electroneg metals. The reaction also does not take place in presence of oxide films but in the absence of water Adequate soap formation requires the presence of water during the formation of the oxide film The most likely explanation is that water forms a hydroxide or some other compd which is readily penetrated and attacked by the acid (C A 43, 8799g)

(203)

Ind Eng Chem 41, 938-43 (1949)	ANTISEIZURE PROPERTIES OF BOUNDARY LUBRICANTS	R E Thorpe R G Larsen

The antiseizure properties of boundary lubricants, which usually depend on the shearing of chemically bound films of the rubbing surfaces, are evaluated by measuring the variation of the kinetic coeff of friction with speed by means of the 4-ball method of Beeck, Givens, and Smith (C A 35, 1684^4) For effective lubricants, the coeff of friction is independent of sliding velocity at speeds of 0 1 to 8 cm/sec , or else decreases slightly with increasing speed Examples are oils contg chemically reactive polar mols such as tritolyl phosphate Poor boundary lubricants, which do not contain such mols , are characterized by high coeffs of friction that often increase at low sliding velocities to values characteristic of unlubricated surfaces The magnitude of the coeff of friction under non-seizing conditions is largely detd. by the thickness of the adsorbed films of oil between the rubbing surfaces. Measurements of contact resistance and metal pickup indicate that the degree of metal-to-metal contact is reduced to very small values with effective boundary lubricants (C A 43, 5933a)

(204)

Bull, assoc franç techniciens pétrole No 69, 17-44 (1948)	MOLECULAR ADSORPTION AND THE STATE OF THE LUBRICATED SURFACE	J J Trillat

A review of recent research on the adsorption of lubricating films showing the influence of the mol structure of the oil (especially when modified by additives such as oleic or stearic acids) and the phys and chem properties of the metal surface 19 references (C A 43, 1953b)

(205)

Doklady Akad Nauk S S S R 68, 325-8 (1949)	NEW PRINCIPLE OF EVALUATION OF THE EFFECTIVENESS OF LUBRICATING MATERIALS IN THE WORKING OF METALS UNDER PRESSURE	S Ya Veĭler L A Shreĭner

A steel ball of 6 316 mm diam is pressed repeatedly through an oblique cylindrical 6 200-mm bore in a metal sample (Cu or brass), and the load P is measured as a function of the penetration h, with and without lubricant Curves of P against h show a max P_m The values of P diminish with each following pass, and the max becomes flatter If P_m is plotted against the no n of consecutive passes, the descending curve, obtained in the presence of a lubricat (5% soln of a soap contg 59% fatty acids), is found to lie considerably below that obtained without lubricant, thus, at n = 1 (1st pass), P_m = 80 and 138 kg , resp The effect is evidently detd not only by

a decrease of friction but also by increased ease of plastic deformation in the surface layer, owing to the presence of surface-active substances After a certain no of passes, P_m becomes const , this takes place, in the absence of a lubricant, after 14 passes, and, in its presence, after 5 This indicates that, with a surface-active substance, the process of plastic flow in the surface layer is completed sooner (C A 44, 3141)

(206)

Eng and Boiler House Rev 65, 314-19 (1950) — CARBON AS AN ENGINEERING MATERIAL — A E Williams

New type of C is now available which make possible the construction of different components, which hitherto have been generally made of metal It lends itself to sulf-lubricating bearings for both high and low speed, pump seals, heat exchangers, tower packing, C linings, piston rings, and carbon vanes for use in compressors and pumps Each of these applications is described (C A 45, 327e)

MECHANICAL POLISHING

(207)

Bull acad sci U R S S , Classe sci tech 1947, 341-8, cf Schulze and Hanemann, C.A 36, 3134[2] — THE VARIATION OF THE MICROHARDNESS OF METALS IN RELATION TO THE DEPTH OF PENETRATION OF THE INDENTER AND TO THE CONDITION OF THE SURFACE LAYER — A A Bochvar, O S Zhadaeva

The object of the work was to increase the precision of microhardness testing of metals and to investigate the work-hardening effect of polishing various metals and alloys Tests were made on 99 98% Al, electrolytic Cu, remelted Zn single crystal, Sn, Pb, Cd, 32%-Zn α brass, and 42%-Zn β brass by using loads of 1, 2, 5, 10, 20, 50, and 100 g on the Khrushchov and Berkovich app with confirming tests on the Hanemann-Zeiss microhardness tester Shiny surfaces suitable for testing were obtained on cast specimens by casting the melts on a polished slab Mech, polishing was done on a file, emery paper, and by using Al_2O_3 on a polishing wheel In plots of microhardness (kg/sq mm) vs indenter load for all specimens and all conditions the hardness was found to increase to a max and then to decrease with increasing load Plots of microhardness vs depth of the indent showed a similar behavior The microhardness of a given metal tended to be lower in the cast condition than after mech polishing or after the metal had been deformed and annealed Electropolishing gave lower microhardness than did mech polishing It is concluded that if the microhardnesses of different metals are to be comparable, the indenter load must be high and the surface prepn must be suitable The standard

diagonals of 5, 10, and 20 μ recommended by Schulze and Hanemann failed to give const values when used with the present data The factors that caused anomalous hardness values at low indenter loads are (1) work-hardening of the surface layers produced by mech polishing, (2) possible breaking up of the surface as a result of its mode of crystn , of surface oxidation, of deformation, or of recrystn , (3) the difference in the stress condition of exterior and interior layers of metal in the microhardness-testing process The data on microhardness vs load are given in the table where the various specimens are identified by the nos (1) Al, cast, unpolished, (2) Al, cast, Mech polish, (3) Al, wrought, annealed 4 hrs at 400°, unpolished, (4) Cu, cast, unpolished, (5) Cu, cast, mech polish, (6) Cu, wrought, annealed 1 hr at 700°, cleaned on emery paper, and electropolished, (7) Zn, cast, unpolished, (8) Zn, cast, mech polish, (9) Sn, cast, unpolished, (10) Sn, cast, mech polish, (11) Pb, cast, unpolished, (12) Pb, cast, mech polish, (13) Cd, cast, unpolished, (14) Cd, cast mech. polish, (15) α brass, wrought, annealed, electropolished, (16) same, except mech polish, (17) β brass, wrought, water quenched, after 3 hrs at 850°, electropolished, (18) same, except mech polish (C A 42, 11661)

(208)

J recherches centr natl recherche sci (Paris) 1947, 147-51, Compt rend 225, 731-3 (1947)

STUDY OF SURFACE STRUCTURES BY MEANS OF X-RAYS

Centre natl recherche sci , Bellevue, France Charles Legrand

The thickness of cryst material that is effective in the diffraction of x-rays (observed in reflection) depends on the angle of incidence It is shown from theoretical considerations that the thickness is of the order of 10 μ for α = 60°, 7 μ for 30°, and 1 4 μ for 3° The mounting used is a modification of that of Brentano (C A 31, 2475[4]) Results are given for three samples of a stainless steel differing only in the treatment of one surface At 30° incidence no difference could be observed between samples that were (a) ground, (b) polished with corundum, (c) polished with chrome green At 3° the lines are widened increasingly as the polish is made finer corresponding to more and more pronounced cold-working of the surface (C A 42, 5295d)

(209)

Z Physik 124, 258-63 (1948)

STRUCTURE CHANGES OF CRYSTAL SURFACES PRODUCED BY WORKING, DEPENDENCE ON THE HARDNESS

Karl H Leise

The relation is studied between the hardness of nonconducting crystals and the change in the structure of their surface when polished, as inferred from electron-diffraction photographs The crystals studied include LiF, NaCl, KBr, harder substances than these (calcite, tourmaline, and beryl), and softer ones (gypsum, talc, graphite, AgCl, and TlBr) The harder crystals maintain the character of their surfaces, the softer ones show marked changes, becoming covered with a fine-grained layer These results do not support the Beilby theory (C A. 43, 4071i)

(210)

J Electrodepositor's Tech Soc 28, Advance Copy No 1, 8 pp (1952)	PHYSICAL AND CHEMICAL CHANGES WHICH ACCOMPANY THE POLISHING OF METALS	Univ Cambridge, Engl A J W Moore

The theory of mech polishing is discussed The presence of an amorphous metal surface layer after polishing is explained by the presence of occluded oxide to inhibit grain growth (C A 46, 5504a)

(211)

Ôyô Butsuri (J Appl Phys)21, 314-18 (1952)	ELECTRON DIFFRACTION AND MICROSCOPE STUDY ON THE CRYSTALLIZATION OF POLISHED METAL SURFACES	Kyûshû Univ , Fukuoka Kôzô Nonaka Kazutake Kôhra

Beilby layers of Cu, Ni, and Au and their crystn process with the heat-treatment are studied by the use of electron diffraction and microscope In the diffraction pattern of the Beilby layer of each metal, a new halo of spacing 3 8 to 4 0 A is observed besides the 2 haloes so far reported The halo pattern changes to the Debye ring pattern by the heat-treatment in vacuo, the process being classified into several stages according to the pattern and the crystn curves are obtained as a function of time of heat-treatment at various temps There exists a relaxation time for the crystn of the Beilby layer and the crystn proceeds rapidly above a temp , 60-70° for Cu, 300° for Ni, and below 250° for Au The crystd layers are identified with Cu_2O, NiO, and Au, resp The oxidation of Cu and Ni is observed at the polishing process before the formation of the Beilby layer The crystn of the polished layer occurs irrespectively of the existence of the oxides (C A 47, 2658c)

(212)

Busseiron Kenyû (Researches on Chem Phys No 30, 57-62 (1950)	ELECTRON-DIFFRACTION STUDY OF THE RECRYSTALLIZATION OF POLISHED SURFACES OF METALS I COPPER	Kyûshû Univ Fukuoka Kôzô Nonaka Kazutake Kôhra

Copper was polished with emery paper from 0 to 0000, with Al_2O_3 suspension, and finally with deer-leather For the surface polished only with Emery paper 000 to 10 min , 5 diffraction rings of pure polycryst Cu are obtained For the surface polished by the above procedure, immediately after the polishing, 2 diffuse halos are observed, spaced at 2 26 A and 1 25 A , resp After 21 hrs , the halos are weakened and the faint (110) diffraction ring of Cu_2O appears After 46 hrs , (110), (200), and (220) are rather strong and (111), (311), and (222) are weak, fiber patterns being observed in (110) and (200) After 94 hrs , (111) becomes stronger and (110) and (200) fiber patterns become much stronger After 142 hrs , the Debye rings become broader and the (111) fiber pattern appears strong In the latter 2 cases, weak lines with

spacings 1 91-1 93 A and 1 73-1.68 A which are assigned as those of CuO appear The spacings of these lines coincide with the x-ray data of Cu_2O The appearance of diffraction lines of CuO may be due to oxidation by air remaining in the camera (vacuum of the order of 10^{-2} to 10^{-3} mm Hg) or to the exposure to air during replacement of photographic plates The relation of Beilby layer to inner fiber structure and oriented growth are discussed (C A 46, 8586d)

(213)

Metaux and corrosion 22, No 257, 2-17 (1947)	THE STRUCTURE OF THE MECHANICALLY AND ELECTROLYTICALLY POLISHED SURFACE	H Raether

The polished surface of metals has been discussed on the basis of the examn with x-rays and with electron microscope The mechanically polished surface showed the presence of oxides whereas the electrolytically polished surface did not This review on the subject merely brings out factors of interest in studying the surface of metals (C A 41, 5422h)

(214)

Mikroskopie 5, 101-6 (1950)	THE STRUCTURE OF MECHANICALLY AND ELECTROLYTICALLY POLISHED SURFACES	Natl Off Aeronaut, Paris Heinz Raether

Electron diffraction and electron microscopy show that mechanically polished metal surfaces consist of distorted cryst material increasing in grain size with depth, but are not "amorphous" as proposed by Beilby (Aggregation and Flow of Solids, 1921, (CA 16, 1177)) Nonmetallic substances, depending on their hardness and plasticity, undergo little or no distortion or subdivision of their surfaces, which appear rough because of fine particles being broken off in polishing Electrolytically polished metals are locally almost plane, but can be coated by a film oxide formed during or immediately after polishing Such films also form on mechanically worked surfaces, and have been incorrectly interpreted as evidence of an amorphous layer (C A 44, 7209b)

(215)

Z Physik 124, 286-308 (1948)	THE STRUCTURE OF MECHANICALLY WORKED SURFACES AND THEIR PROPERTIES (THE QUESTION OF THE SO-CALLED BEILBY LAYER)	Heinz Raether

The structures are studied by means of electron diffraction For metals the increasing diffuseness of the diffraction pattern with cold working is evidence that very small surface crystals are produced by working and that there is no amorphous layer The properties of metallic surfaces are interpreted from this point of view For insulating crystals, the softer the crystal

the greater is the extent of formation of a ploycryst surface layer during polishing Electron microscopic observations show that highly polished metallic surfaces are smooth while the polished surfaces of insulators have a relatively rough texture (C A 43, 4199a)

(216A)

Comm tech états et propriétés surface métaux, Journées états surface (Paris) Oct , 1945, 40-3	THE BEILBY LAYER COMPARISON OF ELECTROSTATIC AND ELECTRONIC PROOFS OF ITS EXISTENCE	F J Taboury

A mechanically polished plain metallic surface immersed in a soln contg very few ions shows a spontaneous electrostatic charge and discharge similar to a shunted condensor (cf preceding abstr) The single discharge oscillation of nonoxidizable metals is different from that of oxidizable metals in the cold This behavior is considered as proof for a polar electroadsorbed layer of the electrolyte. The Beilby layer, produced by mechanically polishing a monocrystal, is shown by electronic diagrams to be homogeneous and nonoriented (C A 42, 3302f)

MECHANICAL WEAR

(217A)

Ibid ,p 73-81	THE SUPERFICIAL HARDENING OF ALUMINUM AND IRON BY ABRASION THE USE OF X-RAY REFLECTION FOR THE STUDY OF SURFACE CONDITIONS	J Bénard P Lacombe G Chaudron

The study of metal surfaces with reflected x-rays has the advantage over and against the electronic beam in that it works on a certain thickness of the metal The Debye-Scherrer rings are easily observed on an Al foil of 5 μ thickness The Laue spots of a monocrystal disappear after mech polishing, and only the Debeye-Scherrer rings with intensifications in cross section become visible Gradual electrolytic polishing makes the rings fade until the spots reappear The depth effect of coarse grinding material is 20 to 30 μ, and the transition from the unoriented surface goes through an oriented zone, a transition zone, and to the unaltered crystal (C A 42, 3681e)

PHYSICO-MECHANICAL REACTIONS OF SURFACES - Mechanical Wear

(218)

J Electrochem Soc 94 No 2, 14N-16N (1948) PROPERTIES OF METALLIC SURFACES R M Burns

A review of lubrication and wear, corrosion, oxidation and tarnishing, and catalysis, in relation to properties of metallic surfaces (C A 43, 80g)

(219)

Phys of Lubrication, Brit J Applied Phys Suppl 1, 69-78(1951) PHYSICAL CHANGES IN RUBBING SURFACES ON SCUFFING Natl Phys Lab, Engl D Clayton C H M Jenkins

Cast iron surfaces rubbing against steel develop a thin layer of a "white constituent" when scuffing occurs or is approached This appears to contain cementite and a quenched high-C ferritic phase developed from austenite resulting from the high temp developed by rubbing In wear tests the scuffing load for castor oil for a ball running on 3 piston-ring segments was about 500 kg compared with 250 kg. for plain mineral oil There was no difference when the free fatty acid (1 6%) was carefully neutralized and the soap removed, thus the glyceride was the effective lubricant Addn of 1% ricinoleic acid to plain mineral oil has no effect on the scuffing load The only additive giving an increase of scuffing load was 1% of a trio ether At low loads benefits in wear reduction were shown by tritolyl phosphate and triphenylarsine Pretreatment of the surfaces with HNO_3 showed no improvement in scuffing load, but phosphating increased the scuffing load by about 50% (C A 45, 4915d)

(220)

Nature 162, 71-2, (1948) STRUCTURE OF ABRADED SURFACES C S I R Aeronaut Lab, Melbourne J B Dance D J Norris

The effect of abrasion on the hardness and microstructure of surface and subsurface layers of metals was detd. For a Cr-Mo steel, heat-treated to a uniform sorbitic structure and to an av. bulk hardness of Knoop 340, abrasion caused an increase in hardness in the surface layers to a depth of 3 5-6 μ according to degree of abrasion Max hardness, at a depth of 1 5 μ, was Knoop 400 Hardness increase diminished progressively from a depth of 1 5 μ to the surface Examn of taper sections (x 2500) revealed a layer, corresponding in thickness to the depth of "softening" in which a modification of the original structure of the steel was evident Plastic deformation cannot be responsible for all the "softening" effects observed The probable cause of "softening" was tempering due to heat of abrasion A series of severely

abraded α-brass samples (35% Zn) annealed to 240° showed a layer of fine crystallites (0 5-1 μ) at the surface extending to a depth of 1-2 μ followed by deformed layer to a depth of 35 μ Samples annealed at 249° caused an increase in depth of layer of fine crystallites indicating recrystn Since fatigue cracks normally start at the surface, the recryst and deformed layers produced by surface grinding should be removed before testing (C A 42, 76851)

(221)

Ann N Y Acad Sci 53, 919-35 (1951)	INFLUENCE OF ROUGHNESS AND OXIDATION ON WEAR OF LUBRICATED SLIDING-METAL SURFACES	Shell Refining and Marketing Co Ltd, Chester, Engl C B Davies

By employing a machine in which a pin tipped with sintered W carbide was held against a rotating flat steel ring and employing a medicinal oil as a lubricant, the rate of wear in the first 5 min of a 30-min test was higher than during the remainder of the test It was assumed that iron oxide particles, which were found in the used oil, protected the wearing surface by a mech process of filling up irregularities in the working surface Addn of either oleic acid 2 5, olive oil 2 5, metal solfonate 1 0, or tritolyl phosphate 1 0% resulted in the same wear pattern By using moderate potentials between the 2 surfaces and employing refined lubricating oil, the rate of wear could be varied with the potential Wear was increased when the soft steel ring was made the cathode and decreased when it was made the anode Tests run with reduced air pressure showed abrupt increase in wear when the pressure dropped to 110 mm Hg With an atm of N similar effects were obtained These tests indicate that either oxide or nitride coatings protect steel against wear in the presence of lubricants (C A 46, 3251f)

(222)

J Applied Phys 23, 1011-19 (1952)	METAL TRANSFER AND WEAR	Mass Inst Technol, Cambridge I.-Ming Feng

A new theory of metal transfer and wear is suggested Metal transfer and wear take place at points of actual contact The interfaces of the high spots that actually make contact are roughened as the result of plastic deformation when they carry normal load The mech interlocking effect of these roughened interfaces is the primary cause of metal transfer and wear Owing to the mech. interlocking effect of the roughened interface, and the strainhardening that accompanies plastic deformation, the application of a tangential force will break one of the pair of the contacting high spots a certain distance away from the interface rather than at the original interface A secondary cause of metal transfer is the adhesion or the diffusion process If the adhesive force is very weak and the diffusion process is not rapid enough to cause the sheared-off peak of the high spot to become a blob of transferred metal, the small piece of metal sheared from the high spot can leave as a loose wear particle

This proposed theory explains the welding of the sheared-off peak to its opponent high spot as the consequence of friction, whereas, in the "welding" theory of friction, welding is considered as the cause of friction Most metallic surfaces in ordinary atm are always covered by a surface film The effect of surface contamination on metal transfer, wear, and the shear component of friction is discussed Difficulties encountered in applying the "welding" theory to explain the friction of and metal transfer between contaminated surfaces where metallic adhesion is absent, are obvious Exptl support of this new theory includes as direct evidence (1) the roughening of the interface as the result of the plastic deformation, (2) the perfect matching at the roughened interface, which gives a strong mech interlocking effect, and (3) a definite region of severely strain-hardened metal near the interface (C A 46, 11064h)

(223)

Doklady Akad Nauk S S S R 86, 345-7, (1952)	WEAR RESISTANCE OF DIFFUSIONAL CHROME PLATES	Inst. Phys Chem Acad Sci ,U S S R , Moscow N S Gorbunov V P Lazarev

Iron and steel articles thermally coated with Cr, by the method described by Izgaryshev and Sarkisov (Zhur. Obshchei Khim 22, 321 (1939)) showed, in dry friction, a wear about 1/3 that of the uncoated samples, and a distinct improvement of microhardness. (C A 47, 460h)

(224)

Metal Progress 55, 842-8 (1949) cf C A 42, 8742a	ABRASIVE WEAR OF METALS	Roy D Haworth, Jr

The effects of alumina, quartzite, sand, feldspar, Fe pyrites, slate and coke, speed, pressure, impact, moisture, and heat on the wear of hard steel and cast Fe are given Corrosion warrants further investigation (C A 43, 5721a)

(225)

Trans Am Soc Metals, Preprint No 42, 36 pp (1948)	THE ABRASION RESISTANCE OF METALS	Armour Res Found Chicago, Ill R D Haworth, Jr

Description and operation are given of new equipment which dets the resistance of metals to wet or dry abrasion Wt -loss data for C and alloy steels and Fe-Cr alloys contg 2 to 31% Cr show (1) in the absence of impact, C content is the most effective alloying element, (2) dry abrasion is more serious than wet

abrasion, (3) the degree of angularity of the abrading material affects the extent of abrasive wear markedly, (4) hardness of the microconstituents of the metal relative to the abrading material together with size, distribution, and quantity of the hard phases in the structure are detg factors, (5) hot hardness may be an addnl important factor for dry abrasion, (6) over-all hardness is not significant, and (7) carburizing, nitriding, siliconizing, and cold-working do not improve resistance to wet or dry abrasion (C A 42, 8742a)

(226)

Repts Casting Research Lab., Waseda Univ (Tokyo) No 3, 20-2 (1952)	WEAR PROPERTIES OF SPHEROIDAL GRAPHITE CAST IRON	Fusao Hayama

Different types of cast iron were investigated for friction weight loss Spheroidal cast iron showed good properties (C A 46, 9487g)

(227)

Rev tech luxembourg 40, 126-47 (1948)	THE FIGHT AGAINST WEAR AND ABRASION BY SPECIAL CAST STEELS WITH HIGH WEARING STRENGTH	Aciéries électriques Arbed, Dommeldange A Hencks J Biren

The mechanism of wear is discussed under the headings of wear by dry and wet rolling, gliding, rolling and gliding, and by impact and cavitation The various factors inherent in the steel, as structure, hardness, chem compn , and the behavior of the different alloy steels to mitigate wear, are treated in detail (C A 42, 81361)

(228)

Z Metallkunde 40, 365-7 (1949)	THE NATURE AND DETERMINATION OF WEAR IN SLIDING FRICTION	Otto H Hummel

Equipment is described for detg the effect of chem compn of material, its surface prepn and temp developed during testing upon wear Data for brass and 3 kinds of bronze are given (C A 44, 1388c)

PHYSICO-MECHANICAL REACTIONS OF SURFACES - Mechanical Wear

(229)

Natl Advisory Comm Aeronaut Tech Note No 2758, 30 pp (1952)	WEAR AND SLIDING FRICTION PROPERTIES OF NICKEL ALLOYS SUITED FOR CAGES OF HIGH-TEMPERATURE ROLLING-CONTACT BEARINGS I ALLOYS RETAINING MECHANICAL PROPERTIES TO 600°F	Lewis Flight Propulsion Lab Cleveland, O Robert L Johnson Max A Swikert Ed E Bisson

Investigation of wear, friction, and surface failure properties of dry surfaces and of boundary-lubricated surface of "L" nickel, Monel, wrought Monel, cast Monel, modified "H" Monel, "S" Monel, Invar, Ni-Resist 3, and Nichrome V sliding on hardened S A E 52100 steel were conducted at room temp The alloys investigated may be useful as possible cage materials for high-temp rolling-contact bearings of high-speed turbine engines Desirable operating properties of all the materials studied could be assocd with the development on the rider surface of a naturally formed film which x-ray diffraction patterns indicated was predominately Ni oxide High-temp operation in air would accelerate formation of the beneficial surface film, in consequence, the best of these materials could perform will in cages of high-temp rolling-contact bearings Pretreatment to form a surface film before operation would probably be beneficial On the basis of wear and friction properties Ni-Resist 3, modified "H" Monel, and Invar were the best of the materials studied in this investigation although they did not perform as well as nodular iron Of these materials, Ni-Resist 3 showed the best film-formation properties The first two materials have thermal expansion coeffs approaching that for steel, Ni-Resist 3 being less than and modified "H" Monel being greater than that for S A E 52100 Cast modified "H" Monel showed the inconsistent performance characteristic of Monel which results from erratic surface film formation In general, cast Monels have better friction and wear properties than the wrought form of these metals Annealed "L" nickel performed very well at light loads but had insufficient yield strength for operation with the heavy loads

Ibid , No 2759, 29 pp (1952)	II ALLOYS RETAINING MECHANICAL PROPERTIES ABOVE 600°F

Investigation of wear, friction, and surface failure properties of boundary-lubricated surfaces of cast Inconel, wrought Inconel X, Nimonic 80, Refractalloy 26, Discaloy, beryllium nickel, and heat-treated beryllium nickel sliding on hardened S A E 52100 steel were conducted at room temp Desirable operating properties of all the materials studied were assocd with the development on the rider surface of a naturally formed dark film identified by x-ray diffraction as being predominantly nickel oxide It is probable that these films prevented mass surface welding with all material combinations of this investigation High-temp operation in air would accelerate the formation of the beneficial surface film A pretreatment to form a surface film before operation would probably be of value Cast Inconel was the best material in most of the expts performed It was not subject to surface failure at the most severe conditions and evidenced desirable low wear characteristics It has

good high-temp phys properties, and a coeff of thermal expansion that approaches that for steels These properties make cast Inconel appear attractive for cages of rolling-contact bearings Nimonic 80 was one of the better materials under all types of operation Because its thermal exapnsion coeff, of 7 34 x 10^{-6} is greater than that for steels, Nimonic 80 may be best suited for inner-race riding cages of rolling-contact bearings Beryllium nickel, Refractalloy 26, and Discaloy showed signs of incipient failure at some time during the wear runs (C A 46, 11075g)

(230)

Liteĭnoe Proizvodstvo 1952, No 2, 23 WEAR RESISTANCE OF HIGH-SILICON IRON V B Lyadskiĭ

Samples of perlitic iron both alloyed and unalloyed, with a total C content of 2 33-3.32 and Si content of 1 78-4 59%, were tested for wear resistance The test involved rotating a specimen under a 10-60 kg/cm sq load against a stationary specimen of identical iron The loss of wt during 10 min represented wear Most resistant was an alloyed iron contg C 2 92, Si 1 78, Cr 0 6, and Ni 2 94% A very close second was an unalloyed specimen contg C 2 33 and Si 4 59% The wear of the moving part was greater than of the stationary (C A 46, 7017f)

(231)

Nature 170, 1029-30 (1952) AUTORADIOGRAPHY OF METAL SURFACES USING A RADIOCHEMICAL METHOD Mass Inst Technol, Cambridge E Rabinowicz

The different chem reactivities of the various metal components toward a radioactive substance that forms a localized radioactive reaction product on the metal surface was used for the autoradiographic study of metal surfaces Expts were made with amyl iodide soln (specific activity 1 5 mc /g) contg I-131 and free I_2 Ag, Cr, Pb, and Cu reacted most strongly with the I_2 (~ 200 atomic layers absorbed), indium, tungsten carbide, and brass reacted less vigorously (~ 50 at layers), Al, Bi, Ni, Sb, Sn, Cd, and mild steel produced thinner films (~ 15 at layers), Zn and Ti took up only three atomic layers. The friction track of Cu on mild steel was studied as follows Amyl iodide was placed on the surface, allowed to remain 15 sec , and washed with cold water, a 2-day exposure made with "No Screen X-Ray" film The Cu wear fragments transferred to the steel retained the active I and appeared on the film as black circular patches along the wear track, while the background due to the steel, which did not retain I, was nearly invisible Since only the surface was activated, good resolution was achieved (C A 47, 4813e)

PHYSICO-MECHANICAL REACTIONS OF SURFACES - Mechanical Wear

(232)

Phys of Lubrication, Brit J Applied Phys, Suppl 1, 82-5 (1951)	AN INVESTIGATION OF SURFACE DAMAGE WITH RADIOACTIVE METALS	Cambridge Univ E Rabinowicz

Exptl autoradiographical data reported show that when a radioactive metal hemisphere slides over a nonradioactive metal surface, metal transfer takes place in the form of discrete fragments and that well-lubricated surfaces give less transfer than clear surfaces by factors of 400 or more On heating well-lubricated surfaces, both the coeff of friction and the amt. of metal transfer increase markedly at the m p of the surface film The metal transfer, however, in contrast to the friction, is sensitive also to temp. change below the surface film's m p This is explained as due to the softening of the surface film near its m p Examples are shown of some cases in which large nonradioactive fragments picked up on the radioactive slider prevent the transfer of radioactive fragments (C A 45, 4915h)

(233)

Proc Phys Soc (London) 64A, 939-40 (1951)	A STUDY OF METAL TRANSFER DURING SLIDING USING RADIOACTIVATION ANALYSIS	Cambridge Univ Dept Phys Chem E Rabinowicz

A Cu surface was slid over a steel surface, and as a result some Cu fragments were transferred to the steel The steel specimen was then activated in a nuclear pile and within a few hrs of its removal from the pile an autoradiograph was made of its surface The autoradiograph showed a light fogging corresponding to radiation from the Fe in the steel, and a few intensely black spots produced by the Cu fragments adhering to the steel surface If the method is to be successful, there must be a large difference in the specific activities of the two metals Here the difference is by a factor of more than 4,000 It also proved possible to detect the steel fragments transferred to the Cu surface during sliding The Cu surface was also activated in the pile, and an autoradiograph was obtained some two weeks after its removal from the pile By this time the activity due to the Cu had practically disappeared while that of the steel had been reduced but little (C A 46, 10068f)

(234)

Natl Advisory Com Aeronaut, Tech Note No 1492, 57 pp (1948)	AN INVESTIGATION OF FRETTING CORROSION UNDER SEVERAL CONDITIONS OF OXIDATION	Mass Inst Technol, Cambridge B W Sakman B G Rightmire

Fretting corrosion tests were made with paired metal specimens in air, in vacuum, in O_2, and in He under identical conditions of load and slip With nearly all of the materials tested there was less damage in vacuum than in air and less in an inert atm than in O_2 In no case was the damage in vacuum

greater than in air, although in most cases the friction force in vacuum was greater than in air Results were interpreted to mean that chem action is of primary importance in fretting corrosion effects and that oxide formation does not give any protection to the metals but rather increases the rate of wear The following pairs of metals were included in the tests phosphor bronze-mild steel, Sn-mild steel, Al-Al alloy, Pb-mild steel, and mild steel-alloy steel (C.A 42, 7223e)

(235)

Metalloberflache A6, No 7, 120-4 (1952)

ELECTROCHEMICAL REACTIONS IN FRICTIONAL SYSTEMS AT ELEVATED TEMPERATURES AND THEIR EFFECT UPON THE WEAR OF FACTORY MACHINES

Aachen, Ger
H Schiffers

The degree of wear in lubricated frictional systems (e g , packing glands) at elevated temps (300-500°) depends upon the compn of the metals or alloys used in the system The fat used as lubrication is partly hydrolyzed to give the corresponding fatty acid, which in turn reacts with the iron to give a ferrous soap This soap serves as electrolyte in a cell formed by the metals rubbing against each other, and whenever the ratio of their oxidation-reduction potentials is not unity, electrochem corrosion takes place which in turn increases the mech wear In arranging systems it is, therefore, suggested that the alloy having the greater soln pressure be selected for the component which can be replaced cheapest The use of alloy bushings for cast-iron cylinders is not desirable unless there is a temp difference In this case the Nernst equation should be taken into account Exptl evidence shows that the method of manuf affects the electrochem behavior of the alloy Elec isolation of the poles prevents electrochem wear (C A 46, 11079e)

(236)

Metal Finishing 44, 420-2, 428, 476-8 (1946)

PROPERTIES OF THE (ELECTRO) PLATE

Cleveland Graphite Bronze Co , Cleveland
H J Sedusky
J B Mohler

A discussion of factors affecting the wear and corrosion resistance, ductility, hardness, and cryst structure of electrodeposited metals Methods for detg tensile strength, hardness, wear, ductility, adhesion, porosity, and corrosion resistance are described Tensile-strength measurements are preferred over direct hardness measurements Wear is measured by a machine which consists of 2 abrasive wheels, under a definite load, which revolve in opposite directions through frictional contact with the rotating specimen and exert a combined abrasive, compressive, and twisting action twice in each revolution of the specimen holder. Wear rate is detd either by depth of penetration or loss in wt 12 references (C A 41, 33i)

(237)

U S Patent 2,563,764 Aug 7, 1951	PREVENTION OF CORROSIVE WEAR OF MOVING METAL PARTS	Shell Development Co. Aaron Wachter Nathan Stillman

The corrosive wear of metal parts normally subjected to frictional contact is prevented by introducing into the proximity of the metal parts a fluid, gas, liquid, or grease contg an org N-base nitride salt having a vapor pressure of at least 0 00002 mm Hg at 21° The org base may be the nitride salt of a primary, secondary, or tertiary amine, a quaternary ammonium base, one of the other onium bases such as sulfonium, or a mixt of 2 or more of these It is practical to use a nitride salt of an amine, the hydrocarbon radicals of which are different, or of an amine contg a plurality of amino groups The media used in conjunction with the inhibitor should yield an aq phase of pH 7 or higher upon contact with H_2O A basic-acting agent is added to counteract any acidity In a particular application, 0 05 g dicyclohexylammonium nitrite is mixed with 45 ml of a white highly refined mineral oil in 4 oz oil sample bottles Distd H_2O 5 ml is added to the oil and a 5 in length of cold-rolled steel rod is cleaned and placed in the bottle In the control, the amine-nitrite salt is omitted The bottles are rotated end over end at 60 r p m for 24 hrs at 150°F The rod from the dicyclohexylammonium nitrite test shows no rust while the control rod in the oil and H_2O alone shows numerous rust blisters (C A 45, 8964b)

(238)

U S Patent 2,433,311 Dec 23, 1947	METAL-SURFACE TREATMENT	Tide Water Associated Oil Co Stanley P Waugh

The treating compn described is composed of a S base (I) and a salt of an ester of a sulfodicarboxylic acid as the reaction promoter, and is used to treat a steel surface to produce thereon a uniform, adherent sulfide coating I may be made up of mineral oil contg small amts of S, sulfurized tall oil (II), sperm oil or vegetable oils (i e cottonseed), and alkyl or aryl sulfides (i e dibenzyldisulfide) Examples of the salts that may be used include the alkali metal and alk earth metal salts or other metal salts, such as Al, of the alkyl and particularly the dialkyl esters (i e lauryl, amyl, and octyl) of sulfodicarboxylic acids Best results have been obtained when the compn was slightly acidic, which can be produced with oleic acid Thus, 100 Pale oil (contg 0 8% S) 99 is mixed with Na dioctylsulfosuccinate (III) 1% To 50 cc. of this compn 5 cc of H_2O is added, and the soln heated to 200°F A piece of steel drill rod immersed and allowed to stand a few min in this soln shows a dark, adherent uniform coating on removal Another compn is made up of H_2O 5 cc and 50 cc of a mixt of sulfurized 100 Pale oil (contg 0 8% dissolved S) (IV) 89, sulfurized sperm oil (contg 9 5% noncorrosive S)10,

and III 1% This compn likewise produces a uniform sulfide film on steel surface, but one more adherent than obtained using the previous compn A third compn includes H_2O 5 cc and 50 cc of a mixt contg IV 89, III 1, and II 10% The coating produced with this compn is the most uniform and adherent These compns can be used in quenching operations Varying proportions of H_2O (as high as 80%) may be used Expts are described showing the improvement in load-carrying capacity gained by surface treatment of rubbing surfaces of machine parts intended for high-unit-load operations, the corrosion-resistant properties imparted to metal surfaces, and the penetrative effect or wear resistance accomplished by this treatment

INDEXES

PUBLICATION INDEX

The numerals following each entry are abstract numbers, and the letters succeeding the abstract numbers are indicative of book references

BOOK	ABSTRACT
Adam, Neil K The Physics and Chemistry of Surfaces London University Press, 1941	43A
Alexander, A E Surface Chemistry An Introduction to Its Principles and Applications New York Longmans, Green and Company, 1951	43B
American Society for Metals Metal Interfaces A Seminar Cleveland The Society, 1941	111A
Bowden, F. P , and Tabor, D The Friction and Lubrication of Solids London Oxford University Press, 1950	68A, 115A,
Commission technique des états et propriétés de surface des métaux Journées des états de surface Paris Éditions de l'office professionnel général de la transformation des métaux, 1945	129A, 130A, 142A 216A, 217A
Faraday Society Surface Chemistry New York Interscience Publishers, Inc , 1949	49A
Festschrift Paul Schlapfer Solothurn, Switz Verlag Vot-Schild A G , 1950	156A
Gemant, Andrew Frictional Phenomena Brooklyn Chemical Publishing Co , 1950	132A
Gregg, S J The Surface Chemistry of Solids New York Reinhold Publishing Corp , 1951	50A
Harkins, William D The Physical Chemistry of Surface Films New York Reinhold Publishing Corp , 1952	50A
Institute of Metals Symposium on Properties of Metallic Surfaces London The Institute, 1952	2A, 58A,
International Conference on Surface Reactions Pittsburgh Corrosion Publishing Co , 1948	67A, 80A, 91A, 117A
Lewis, Winifred. Thin Films and Surfaces Brooklyn Chemical Publishing Co , 1950	53A
Science Museum, London Quarterly Bibliography of Lubrication, No 55 ("Science Library Current Bibliography," Series No 2) London The Museum, 1946	195A
Vlaamse Acad Wetenschap , Belg , Verhandel Grenslaagverschijnselen (Symposium), 1947, 38-61	61A

JOURNAL	ABSTRACT
Acad sci Paris, Compt rend 224, 1102-3 (1947)	75
——— ——— ———, ——— ——— 225, 731-3 (1947)	208
——— ——— ———, ——— ——— 230, 1862-4 (1950)	69
——— ——— ———, ——— ——— 233, 409-10 (1951)	32

JOURNAL	ABSTRACT
Akad nauk S S S R Comptes rendus (Doklady) 54, 137-40 (1946)	169
——— ——— ——— ——— Doklady 61, 849-52 (1948)	76
——— ——— ——— ——— ——— 68, 325-8 (1949)	205
——— ——— ——— ——— ——— 83, 443-6 (1952)	149
——— ——— ——— ——— ——— 86, 345-7 (1952)	223
——— ——— ——— ——— Izvestiia Otdelenie khimicheskikh nauk, 1948, 50-6	20
——— ——— ——— ——— ——— ——— teknicheskikh nauk, 1947, 341-8	207
Am Chem Soc, J 68, 1941-52 (1946)	52
——— ——— ———, ——— 70, 2925-30 (1948)	46
——— ——— ———, 70, 3830-7 (1948)	9
——— ——— ———, 71, 791-7 (1949)	47
——— ——— ———, 74, 3556-61 (1952)	44
——— Electroplaters' Soc, Proc 34, 340-1 (1947)	65
——— ——— ———, ——— 35, 215-21 (1948)	64
——— Ink Maker 26, No 1, 25-7, 59 (1948)	11
——— Inst Mining Met Engrs, Inst Metals Div, Metals Technol 13, No 7, Tech Pub No 2068, 26 pp (1946)	83
——— ——— ——— ——— ——— ——— ——— ——— ——— ——— ——— 14, No 3, ——— ——— No 2144, 17 pp (1947)	90
——— ——— ——— ——— ——— ——— ——— ——— ——— ——— ——— 14, No 6, ——— ——— No 2224, 17 pp (1947)	84
——— ——— ——— ——— ——— ——— ——— ——— ——— ——— ——— 14, No 6, ——— ——— No 2226, 17 pp (1947)	85
——— ——— ——— ——— ——— ——— ——— ——— ——— ——— ——— 15, No 8, ——— No 2483, 18 pp (1948)	87
——— Soc Mech Engrs, Trans 70, 401-8 (1948)	166
——— ——— Metals, Preprint No 42, 36 pp (1948)	225
Ann N Y Acad Sci 53, 805-23 (1951)	114
——— ——— ——— ——— 53, 862-9 (1951)	193
——— ——— ——— ——— 53, 919-35 (1951)	221
Appl Sci Research B2, 352-60 (1952)	105
Arch Metallkunde 2, 46-9 (1948)	19
Arkiv Kemi, Mineral Geol A21, No 17, 26 pp (1946)	12
Assoc franc techniciens pétrole, Bull, No 69, 17-44 (1948)	204
Australia, Council Sci Ind Research, Bull No 212, 38 pp, (1947)	158
Australian Chem Inst, J and Proc 14, 268-85 (1947)	43
——— Engr Aug 1952, 46-56	134
——— Inst Metals, Trans 3, 37-40 (1950)	24
——— ——— ———, ——— 3, 67-7 (1950)	99
——— J Sci Research, Ser A, 1, 85-97 (1948)	180
Blast Furnace Steel Plant 40, 1184-9 (1952)	200
Brit J Applied Phys., Phys of Lubrication, Suppl 1, 34-5 (1951)	172
——— ——— ———, ——— ———, Suppl 1, 35-8 (1951)	185
——— ——— ———, ——— ———, Suppl 1, 52-4 (1951)	188
——— ——— ———, ——— ———, Suppl 1, 69-78 (1951)	219
——— ——— ———, ——— ———, Suppl 1, 79-82 (1951)	132
——— ——— ———, ——— ———, Suppl, 1, 82-5 (1951)	232

JOURNAL	ABSTRACT
Bull acad sci U R S S , Classe sci tech 1947, 341-8	207
____ ____ ____ ____ , ____ ____ Chim 1948, 50-6	20
____ assoc franç techniciens petrole, No 69, 17-44 (1948)	204
____ Chem Soc Japan 17, 61-3 (1942)	37
____ ____ ____ ____ 24, 200-2 (1951)	54
____ ____ ____ ____ 24, 274-8 (1951)	57
Busseiron Kenyû (Researches on Chem Phys) No 13, 7-14 (1949)	101
Cambridge Phil Soc , Proc 48, Pt 3, 457-69 (1952)	106
Casting Research Lab , Waseda Univ (Tokyo), Repts No 3, 20-2 (1952)	226
Chem Soc Japan, Bull 17, 61-3 (1942)	37
____ ____ ____, ____ 24, 200-2 (1951)	54
____ ____ ____, ____ 24, 274-8 (1951)	57
____ ____ ____, J , Ind Chem Sect 54, 363-5 (1951)	192
____ ____ J 1952, 1736-44	1
____ ____ 1949, (Suppl Issue No 2), S259-74	5
____ Zentr 1947, I, 205	95
____ ____ 1947, I, 382	135
____ ____ 1948 II, 1155	72
Chemie, Ing , Tech 21, 216-18 (1949)	191
Chimie and industrie 53, 222-33 (1945)	94
Compt rend , Acad sci Paris 224, 1102-3 (1947)	75
____ ____, ____ ____ ____ 225, 731-3 (1947)	208
____ ____, ____ ____ ____ 230, 1862-4 (1950)	69
____ ____, ____ ____ ____ 233, 409-10 (1951)	32
____ ____, ____ ____ U R S S 54, 137-40 (1946)	169
Die Technik 2, 72-6 (1947)	135
Discussions Faraday Soc 1950, No 8, 18-27	51
____ ____ ____ 1950, No 8, 27-33	109
Doklady Akad Nauk S S S R 61, 849-52 (1948)	76
____ ____ ____ ____ ____ 68, 325-8 (1949)	205
____ ____ ____ ____ ____ 83, 443-6 (1952)	149
____ ____ ____ ____ ____ 86, 345-7 (1952)	223
Electrochem Soc , J 94, 139-51 (1948)	78
____ ____, ____ 94, No 2, 14N-16N	218
____ ____, ____ 97, 71-4 (1950)	29
____ ____, Japan, J 18, 70-4 (1950)	73
____ ____, ____ ____ 18, 75-6 (1950)	70
____ ____, ____ ____ 18, 223-7 (1950)	74
____ ____, Trans 91, 17 pp (1947)	92
____ ____, ____ 91, 24 pp (1947)	81
Electrodepositors' Tech Soc , J 26, No 4, 8 pp (1950)	15
____ ____ ____, ____ 28, No 1, 8 pp (1952)	210
Engineering 165, 505-7 (1948)	197
Eng and Boiler House Rev 65, 314-19 (1950)	206
Erdöl u Kohl 4, 9-17 (1951)	163

JOURNAL	ABSTRACT
Faraday Soc., Discussions 1950, No 8, 18-27	51
——— ——, ——— 1950, No 8, 27-33	109
——— ——, Trans 43, 429-34 (1947)	98
——— ——, ——— 45, 631-5 (1949)	178
——— ——, ——— 46, 93-7 (1950)	161
——— ——, ——— 47, 900-8 (1951)	45
Federation Paint and Varnish Production Clubs, Offic Dig No 333	60
Finish 7, No 6, 27-30 (1950)	17
Finska Kemistamfundets Medd 60, No 1, 4-19 (1951)	82
Glass u Hochvakuum-Tech. 1952, 109-10	
Govt Research Repts, Selected (London) (Powder Metallurgy) 9, 1-21 (1951)	38
Ind Eng Chem 41, 938-43 (1949)	203
——— ——— ——— 41, 1385-91 (1949)	86
——— ——— ——— 42, 1837-41 (1950)	168
Inst Chem Engrs, Trans (London) and Soc Chem Ind (London), Roads and Bldg Materials Group, Advance Copy, Feb 4, 1947, 27-33	4
——— Petroleum, J 34, 743-73 (1948)	159
——— Sci Tech, Rept (Tokyo Univ) 1, 50-9 (1947)	153
——— ——— ———, ——— ——— 2, 49-57 (1948)	155
——— ——— ———, ——— ——— 4, 176-89 (1950)	199
Intern Congr Pure and Applied Chem, Proc (London) 11, 145-57 (1947)	110
Iron Age 162, No 7, 90-4, No 8, 90-4 (1948)	88
J Am Chem Soc 68, 1941-52 (1946)	52
——— ——— ——— 70, 2925-30 (1948)	46
——— ——— ——— 70, 3830-7 (1948)	9
——— ——— ——— 71, 791-7 (1949)	47
——— ——— ——— 74, 3556-61 (1952)	44
——— Appl Chem (London) 2, 550-4 (1952)	100
——— ——— Phys 19, 1-10 (1948)	194
——— ——— ——— 21, 721 (1950)	41
——— ——— ——— 22, 177-84 (1951)	151
——— ——— ——— 23, 1011-19 (1952)	222
——— Chem Phys 17, 1004-5 (1949)	7
——— ——— ——— 18, 772-3 (1950)	102
——— ——— Soc 1949, (Suppl Issue No 2), S259-74	5
——— ——— ——— 1952, 1736-44	1
——— ——— ——— Japan, Ind Chem Sec 54, 363-5 (1951)	192
——— chim phys 44, 172-80 (1947)	97
——— Electrochem Soc 94, No 2, 14N-16N (1948)	218
——— ——— ——— 94, 139-51 (1948)	78
——— ——— ——— 97, 71-4 (1950)	29
——— ——— ——— Japan 18, 70-4 (1950)	73
——— ——— ——— ——— 18, 75-6 (1950)	70
——— ——— ——— ——— 18, 223-7 (1950)	74
——— Electrodepositors' Tech Soc 26, No 4, 8 pp (1950)	15
——— ——— ——— ——— 28, No 1, 8 pp (1952)	210

JOURNAL	ABSTRACT
J Inst Petroleum 34, 743-73 (1948), B I O S Final Rept No 1610	159
Metals 4, Trans 657-60 (1952)	8
Phys Chem (U S S R) 21, 161-2 (1947)	39
and Colloid Chem 51, 644-7 (1947)	10
52, 969-75 (1948)	31
52, 1186-97 (1948)	89
53, 1466-7 (1949)	30
Soc Japan 6, 135-8 (1951)	53
8, 113-18 (1953)	93
recherches centr natl recherche sci (Paris) 1947, 147-51	208
Research Natl Bur Standards 46, 51-5 (1951)	6
Kolloid-Z 111, 83-95 (1948)	145
, 145-55 (1948)	146
112, 26-35 (1949)	147
Kunststoffe 38, 74-6 (1948)	16
Liteĭnoi Proizvodstvo 1952, No 2, 23	230
Lubrication Eng 5, 75-82 (1949)	143
8, 285 (1952)	171
Mech Eng 73, 892-6 (1951)	174
Metal Finishing 44, 420-2, 428, 476-8 (1946)	236
48, No 9, 66-70 (1950)	157
49, No 5, 54-61 (1952)	27
Ind (London) 75, 68-70, 73, 89-91, 112-13 (1949)	160
Progress 55, 842-8 (1949)	224
56, 225-7 (1949)	22
60, No 3, 69-74 (1951)	125
Metall 4, 359-65 (1950)	13
6, 285-91 (1952)	79
Metalloberfläche A6, No 7, 120-4 (1952)	235
Metallurgia 38, 71-4 (1948)	23
Metals Technol 13, No 7, Am Inst Mining Met Engrs , Inst Metals Div , Tech Pub No 2068, 26 pp (1946)	83
14, No 3, , 2144, 17 pp (1947)	90
14, No 6, , 2224, 17 pp (1947)	84
14, No 6, , 2226, 17 pp (1947)	85
15, No 8, , 2483, 18 pp (1948)	87
Métaux, corrosion, usure 19, 12-17 (1944)	18
et corrosion 22, No 257, 2-17 (1947)	213
Mikroskopie 5, 101-6 (1950)	214
Modern Packaging 23, No 7, 125 (1950)	77
Monthly Rev Am Electroplaters' Soc 34, 430-41 (1947)	65

JOURNAL	ABSTRACT
Natl Advisory Comm Aeronaut, Tech Note No 1461, 37 pp (1948)	133
——— ——— ——— ———, ——— ——— ——— 1492, 57 pp (1948)	234
——— ——— ——— ———, ——— ——— ——— 1882, 28 pp (1949)	177
——— ——— ——— ———, ——— ——— ——— 2366, 35 pp (1951)	182
——— ——— ——— ———, ——— ——— ——— 2460, 26 pp (1951)	138
——— ——— ——— ———, ——— ——— ——— 2628, 16 pp (1952)	175
——— ——— ——— ———, ——— ——— ——— 2758, 30 pp (1952)	229
——— ——— ——— ———, ——— ——— ——— 2802, 16 pp (1952)	176
Nature 159, 403 (1947)	179
——— 162, 71-2 (1948)	220
——— 163, 441 (1949)	59
——— 170, 1029-30 (1952)	231
Naturforsch u Med Deutschland 1939-1946 8, No 1, 102-8 (1947)	72
Naturwissenschaften 34, 313-14 (1947)	33
N Y Acad Sci, Ann 53, 805-23 (1951)	114
——— ———, ——— 53, 862-9 (1951)	193
——— ———, ——— 53, 919-35 (1951)	221
——— ———, Trans 12, 245-56 (1950)	112
Nucleonics 1, No 4, 38-50 (1947)	123
——— 6, No 1, 34-7 (1950)	124
Offic Dig Federation Paint and Varnish Production Clubs, No 333, 650-70 (1952)	60
O N E R A (Office natl Études et recherches aéronaut), Rapport Tech No 36, 86 pp (1948)	144
Ôyô Butsuri (J Applied Phys.) 20, 159-60 (1951)	154
——— ——— (——— ———) 21, 215-19 (1952)	189
——— ——— (——— ———) 21, 314-18 (1952)	211
Petroleum Processing 4, 1003-8 (1949)	196
Phys of Lubrication, Brit J Applied Phys, Suppl 1, 34-5 (1951)	172
——— ——— ———, ——— ——— ———, ——— 1, 35-8 (1951)	185
——— ——— ———, ——— ——— ———, ——— 1, 52-4 (1951)	188
——— ——— ———, ——— ——— ———, ——— 1, 69-78 (1951)	219
——— ——— ———, ——— ——— ———, ——— 1, 79-82 (1951)	132
——— ——— ———, ——— ——— ———, ——— 1, 82-5 (1951)	232
——— Soc Japan, J 6, 135-8 (1951)	53
——— ——— ———, 8, 113-18 (1953)	93
——— ——— (London) Proc, 62A, 639-48 (1949)	36
——— ——— (———) ———, 63A, 444-57 (1950)	42
——— ——— (———) ———, 63B, 465-83 (1950)	131
——— ——— (———) ———, 64A, 939-40 (1951)	233
Proc Am Electroplaters' Soc 35, 215-21 (1948)	64
——— Cambridge Phil Soc 48, Pt 3, 457-69 (1952)	106
——— Intern Congr Pure and Applied Chem (London) 11, 145-57 (1947)	110
——— Phys Soc (London) 62A, 639-48 (1949)	36
——— ——— ——— (———) 63A, 444-57 (1950)	42
——— ——— ——— (———) 63B, 465-83 (1950)	131
——— ——— ——— (———) 64A, 939-40 (1951)	233

JOURNAL	ABSTRACT
Proc Roy Soc (London) A187, 430-9 (1946)	127
—— —— —— (——) A188, 329-49 (1947)	116
—— —— —— (——) A189, 88-102 (1947)	121
—— —— —— (——) A191, 243-52 (1947)	165
—— —— —— (——) A201, 109-24 (1950)	162
—— —— —— (——) A202, 224-43 (1950)	140
—— —— —— (——) A202, 244-53 (1950)	141
—— —— —— (——) A204, 514-24 (1951)	55
—— —— —— (——) A204, 525-33 (1951)	56
—— —— —— (——) A208, 311-25 (1951)	118
—— —— —— (——) A208, 444-55 (1951)	119
—— —— —— (——) A212, 450-2 (1952)	164
—— —— —— (——) A212, 485-8 (1952)	120
—— —— —— (——) A212, 498-505 (1952)	201
—— —— —— (——) A212, 505-8 (1952)	48
—— —— —— (——) A212, 508-12 (1952)	113
—— —— —— (——) A212, 516-19 (1952)	181
Rept Inst Sci Tech (Tokyo Univ) 1, 50-9 (1947)	153
—— —— —— —— (—— ——) 2, 49-57 (1948)	155
—— —— —— —— (—— ——) 4, 176-89 (1950)	199
Repts Casting Research Lab, Waseda Univ (Tokyo) No 3, 20-2 (1952)	226
Research (London) 3, 383-4 (1950)	115
—— (——), Suppl, Surface Chemistry 1949, 205-16	50
—— (——), —— —— —— 1949, 217-22	202
—— (——), —— —— —— 1949, 223-31	187
Rev inst franç pétrole et Ann combustibles liquides 2, 250-1 (1947)	104
—— mét 42, 305-7 (1945)	21
—— —— 44, 87-90 (1947)	71
—— —— 45, 61-7 (1948)	108
—— tech luxembourg 40, 126-47 (1948)	227
Roy Soc (London), Proc A187, 430-9 (1946)	127
—— —— (——), —— A188, 329-49 (1947)	116
—— —— (——), —— A189, 88-102 (1947)	121
—— —— (——), —— A191, 243-52 (1947)	165
—— —— (——), —— A201, 109-24 (1950)	162
—— —— (——), —— A202, 224-43 (1950)	140
—— —— (——), —— A202, 244-53 (1950)	141
—— —— (——), —— A204, 514-24 (1951)	55
—— —— (——), —— A204, 525-33 (1951)	56
—— —— (——), —— A208, 311-25 (1951)	118
—— —— (——), —— A208, 444-55 (1951)	119
—— —— (——), —— A212, 450-2 (1952)	164
—— —— (——), —— A212, 485-8 (1952)	120
—— —— (——), —— A212, 498-505 (1952)	201
—— —— (——), —— A212, 505-8 (1952)	48
—— —— (——), —— A212, 508-12 (1952)	113
—— —— (——), —— A212, 516-19 (1952)	181

JOURNAL	ABSTRACT
Seifen-Ole-Fette-Wachse 77, 35-7, 55-7 (1951)	148
Selected Govt Research Repts (London) (Powder Metallurgy) 9, 1-21 (1951)	38
Soc roy belg ing et ind Bull No 5, 225-30 (1952)	28
S African Ind Chemist 2, 212-16 (1948)	170
Stahl u Eisen 72, 1212-16 (1952)	183
Steel Processing 32, 669-676 (1946)	96
Tech moderne 38, 169-76, 223-8 (1946)	107
Trans Am Soc Mech Engrs 70, 401-8 (1948)	166
____ ____ Metals, Preprint No 42, 36 pp (1948)	225
____ Australian Inst Metals 3, 37-40 (1950)	24
____ ____ ____ 3, 67-70 (1950)	99
____ Electrochem Soc 91, 17 pp (1947)	92
____ ____ 91, 24 pp (1947)	81
____ Faraday Soc 43, 429-34 (1947)	98
____ ____ 45, 631-5 (1949)	178
____ ____ 46, 93-7 (1950)	161
____ ____ 47, 900-8 (1951)	45
____ Inst Chem Engrs (London) and Soc Chem Ind (London), Roads and Bldg Materials Group, Advance copy, Feb 4, 1947, 27-33	4
____ N Y Acad Sci 12, 245-56 (1950)	112
Welding J 27, 515s-20s (1948)	137
Vestnik Akad Nauk S S S R 1948, No 5, 28-31	128
Z Elektrochem 52, 72-5 (1948)	34
_ Metallunde 39, 17002 (1948)	25
_ ____ 40, 249-55 (1949)	3
_ ____ 40, 365-7 (1949)	228
_ Physik 124, 258-63 (1948)	209
_ ____ 124, 286-308 (1948)	215
Zavodskaya Lab 13, 71-7 (1947)	136
____ ____ 13, 635-7 (1947)	26
Zhur Fiz Khim 23, 115-23 (1949)	35
____ ____ 23, 1127 (1949)	40
____ Tech Fiz 17, 537-42 (1947)	150

PATENT			ABSTRACT
Fr	862,120	Feb 27, 1941	173
Ger	806,005	June 11, 1951	198
Ital	465,752	Sept 24, 1951	152
Japan	36	Jan 11, 1950	190
U S	22,887 (reissue)	June 3, 1947	66
- -	2,419,252	April 22, 1947	126
- -	2,420,886	May 20, 1947	184

PATENT			ABSTRACT
U S	2,421,863	June 10, 1947	63
U S	2,420,646	May 20, 1947	14
U S	2,433,311	Dec 23, 1947	238
U S	2,563,764	Aug 7, 1951	237
U S	2,574,318	Nov 6, 1951	122
U S.	2,619,458	Nov 25, 1952	186
U S	2,622,993	Dec 23, 1952	139

AUTHOR INDEX

The numerals following each entry are abstract numbers, and the letters succeeding the abstract numbers are indicative of book references

AUTHOR	ABSTRACT
Adam, Neil K	43A
Alexander, A E	43B
Antonoff, George	31
Aust, K T	111A
Baldock, G R	106, 109
Barrer, R N	1
Barwell, F T	113
Bastien, Paul	107
Beaujard, L	95
Beck, F H	102
Beck, Paul A	111A
Beck, Richard	63
Becker, H	13
Benard, J	217
Benedicks, Carl	32
Biren, J	227
Bisson, Edmond E	175, 176, 229
Bloom, Ralph, Jr	14
Bochvar, A A	207
Boudart, M	44
Bowden, F P	45, 114, 115, 115A, 116, 117, 118, 119, 120, 123
Bowen, R J	151
Bristow, J R	121
Brooks, Harvey	111A
Brummage, K G	165
Brunauer, Stephen	1, 7, 9, 10, 11
Burkhardt, Hans	122
Burns, R M	218
Burwell, J T	125
Burwell, J T , Jr	123, 124
Bychinsky, Wilfred A	126
Campbell, W E	166
Chalmers, B	111A, 127
Chaudron, Georges	21, 71, 108, 217
Clayton, D	219
Cook, Melvin A	46, 47
Cotton, P	49A
Coulson, C A	109
Courtel, R	167
Courtney-Pratt, J S	48
Dance, J B	220
Davey, William	168
Davies, C B	221
Deitz, Victor R	6
de Kadt, P J	170
Deryagin, B	169
de Senneville, C	107
Desch, C H	129
Deryagin, B V	76, 128
Dijck, Gaetan Van	28
Donelson, J G	77
Dravnieks, Andrew	78
D'yakonov, A	49
Emmett, Paul H	1, 2A, 7, 9, 10, 11
Engell, H J	79
Erbacher, Otto	3
Evans, U R	80, 81
Faust, Charles L	67A
Feng, I -Ming	171, 222
Finch, G I	130, 131, 132, 172
Fontana, M G	102
Forrester, P G	127

AUTHOR	ABSTRACT
Frey, K	156
Fricke, R	33, 34
Fujimoto, Nobumasa	54
Fullman, R L	111A
Gardam, G E	15
Galvin, Michael J	173
Geisler, Alfred H	111A
Gemant, Andrew	132A
Geniesse, J C	174
Glauberman, A E	35, 40
Godfrey, Douglas	175, 176, 177
Gorbunov, N S	223
Gottwald, F	16
Green, E	17
Gregg, S J	4, 9, 49A, 50, 50A
Gregory, J N	179, 180
Greenhill, E B	178
Grubitsch, H	82
Grumbach, A	68
Gulbransen, E A	83, 84, 85, 86, 89, 90, 92
Gurney, C	36
Hahn, Otto	5
Hanyen, Clyde K	139
Hargreaves, M E	134
Harkins, Wm D	9, 50B, 52
Hauffe, K	79
Haworth, Roy D , Jr	224, 225
Hayama, Fusao	226
Hedvall, J Arvid	110
Hencks, A	227
Heremans, F	105
Herring, Conyers	111A
Hess, James B	111A
Hickman, J W	83, 87, 88, 89, 90, 91A, 92
Hirst, W	181
Hogaboom, George B	64
Honjo, Goro	93
Hooker, Horace W	66
Huang, K	51
Hummel, Otto H	228
Huttig, G H	1
Itterbeek, A Van	61A, 105
Jacquet, Pierre A	69
Jandon, E	18
Jean, Marcel	69
Jenkins, C H M	219
Jensen-Hellmann, Gisela	3
Johnson, Robert L	182, 229
Jura, George	9, 52
Kainuma, Yoshiro	53
Kawasaki, Moto	70
Kerridge, M	181
Khachadurova, T M	20
Kimura, Osamu	37
Kindscher, E	135
Kislik, V A	136
Klemgard, Edwin N	14
Klemm, H	19
Kôhra, Kazutake	211
Kouwenhoven, W B	137
Krotov, I V	20
Krotova, N A	76
Kuhn, Martin	183
Kuwabara, Norikatsu	70
Lacombe, P	71, 94, 95, 217
Laffoon, Carthrae M , Jr	184
Lancaster, J K	181
Lane, T B	185
Larsen, R G	203
Lazarev, V P	223
Leadbeater, C J	38
Legrand, Charles	104, 208
Leise, Karl H	209
Levine, Erva C	138
Lewis, Winifred	53A
Loebenstein, Wm V	6, 7
Lustman, Benjamin	96
Lyadskiĭ, V B	230
Mackenzie, N	1
McBride, Byron V	186
McCullough, Robert W	139
McDonald, Hugh J	78
McFarlane, J S	140, 141
McMahon, H O	151
Macleod, D	1
Marcelin, M A	49A, 142, 187

AUTHOR	ABSTRACT
Mather, K B	22
Matsuura, Ryôhei	54, 57
Mellin, Auguste	3
Menter, J W	55, 188
Miller, Rudolph W	14
Miyagawa, Yukio	154, 155, 199
Miyazaki, Hiroshi	189
Mohler, J B	236
Moore, A C	45, 123
Moore, A J W	23, 24, 210
Morgan F	143
Morgan, O M	65
Morize, P	71
Mott, N F	97, 98
Mulcahy, M F R	99
Murray, S F	124
Muskat, M	143
Nagai, Yûzaburô	189
Nelson, Erva C	177
Newing, Marjorie J	180
Nonaka, Kôzô	211, 212
Norris, D J	220
Nozawa, Fusatoshi	190
Nurse, T J	100
Nowick, A S	111
Orr, C , Jr	8
Pack, Douglas H	47
Peterson, Marshall B	138, 182
Phelps, E F	127
Pomey, J	144
Potter, J H	137
Raether, Heinz	72, 213, 214, 215
Rabinowicz, E	231, 232, 233
Ramsauer, Rembert	145, 146, 147, 148, 191
Ratner, S B	149
Reed, D W	143
Rightmire, B G	234
Ronay, Bela	14
Ross, Sydney	9
Rowe, G	120
Saito, Seikichi	73, 74
Sakman, B W	234
Sakurai, Toshio	192
Samarin, A	49
Samoĭlovich, A G	39, 40
Sanders, J V	56
Sasaki, Tsunetaka	54, 57
Savage, Robert H	193, 194
Schiffers, H	235
Sears, G W	41
Sedusky, H J	236
Seeliger, Robert	25
Séjournet, Jacques	198
Seller, Helen	196
Shchedrov, V S	150
Shinohara, Shôzô	101
Shreĭner, L A	205
Shuttleworth, R	42
Simnad, Massoud T	58
Šimon, I	151
Smith, Cyril Stanley	111A
Smith, E A	197
Smith, G Pedro	133
Smolinanskiĭ, M	169
Soda, Norimune	153, 154, 155, 199
Spence, Harry	66
Spink, J A	59, 179
Spurr, R T	132
Stager, H	156
Stillman, Nathan	237
Stone M A	116
Strang, C O	125
Strauss, Jerome	200
Stroman, George	157
Sutherland, K L	43
Swiket, Max A	182, 229
Tabor, D	49A, 55, 56, 115A, 123, 140, 141, 158, 201, 202
Taboury, F J	216A
Tennenbaum, M M	26
Thielsch, Helmut	27, 157
Thorpe, R E	203
Thurber, E A	166
Tingle, E D	49A, 159, 202
Todt, F	103
Tolley, G	160
Trillat, Jean Jacques	75, 104
Tringle, E D	161
Udin, Harry	111A
Uhlig, Herbert H	60, 111A
Veĭler, S Ya	205

AUTHOR	ABSTRACT
Wachter, Aaron	237
Wagner, Carl	29
Waugh, Stanley P	238
Wenzel, Robert N	30
Weyl, W A	112
White, Locke, Jr	10
Whitehead, J R	162
Wiebe, R	163
Williams, A E	206
Wilson, R	164
Wolf, K L	148, 191
Wormwell, F	100
Wyllie, G	51
Wylie, R G	62
Wysong, W S	84, 85
Zettlemoyer, Albert C	11
Zhadaeva, O S	207
Zimens, Karl E	12
Young, J E	118, 119, 120

SUBJECT INDEX

The numerals following each entry are abstract numbers, and the letters succeeding the abstract numbers are indicative of book references

Acids
    boundary lubricating properties of, 168
Abrasion
    effect of surface roughness on, 157
    effect on metal hardness, 219
    wet and dry, resistance of metals to, 225
Absorption
    theory of, 49
Adhesion
    between surface films of lubricant, 162
    and friction, 118, 141
    effect of surface films on, 140
    lateral, between lubricant molecules, 201
    process in metallic pick-up, 221
    of surface coatings, 157
Adsorption of gases
    radioactive tracers in, 45, 201
    surface area determined by, 2, 4, 7, 8, 9, 11
    theory of, 43B, 46, 47, 50A, 50B, 60, 61A, 119, 201
Alchrome-6
    oxide films on, 92
Alchols, films of,
    effect on coefficient of friction, 56
    structure of, 56
Aliphatic esters, films of,
    structure of, 56
Alloy S-588
    oxide films on, 92
Aluminum
    friction of, 162, 234
    microhardness of, 207
    oxide films on, 86, 100

Aluminum alloys
    friction of, 122, 234
    oxide films on, 95, 100
Amontons's law, 162
Antifriction alloys
    composition of, 152
Area of contact
    between diamond surfaces, 119
    between sliding surfaces, 118
    control of, 127
    effect of stresses on, 140
    effect on coefficient of friction, 133
    temperature of, effect on lubrication failure, 185
Atmosphere
    effect on friction, 133, 222
    effect on metallic transfer, 222
    effect on wear of metals, 113, 222, 234
    effect on surface welding, 114, 229

Band theory of metals, 102
Bangham's equation, 47
Bearing alloys
    friction of, 158, 229
Bearing metals
    friction of, 134
Bearings
    self-lubricating, 206
Beilby layer
    absence of, 209
    effect on wear, 135
    examination of, 211, 215
    formation of, 117A, 211, 212
    theory of, 68A, 212, 215
Beryllium nickel
    friction of, 229
Blok's postulate, 185
Bond theory, 51
Brass
    friction of, 205
    microhardness of, 207
    oxide films on, 100
Bronze
    friction of, 121
    phosphor, friction of, 234
    wear of, 228
Brunauer-Emmett's adsorption theory, 61A
Brunauer-Emmett-Teller method
    determination of surfaces by, 1, 7, 9, 10, 11

Cadmium
    adsorption by, 45
    microhardness of, 207
    orientation of fatty acid films on, 55
Calcium stearate films
    lubricating properties of, 179
Caproic acid vapor
    effect on surface welding, 114
Carbon
    friction of, 119, 120
    pump seals, 206
    self-lubricating bearings of, 206
Cavitation
    wear by, 227
Chloride films
    boundary lubricating properties of, 117A
    effect on surface welding, 114
Chromates
    passivating action of, 58A
Chromium, oxide films on,
    electron-diffraction study of, 83
    friction of, 163
Chromium alloys
    oxide films on, 87
Chromium plates
    wear reduction by, 223
Cobalt
    oxide films on, 83
Contact, between metal surfaces
    intimacy of, 118, 131
    metal pick-up from, 203, 222
    resistance of, 203
    temperature of, 185, 219
Copper
    adsorption on, 45
    friction of, 151, 205, 231, 233
        effect of electrolytic polishing on, 162
        effect of molybdenum disulfide on, 115
        effect of oxide films on, 164
        effect of stearic acid on, 179, 181
    microhardness of, 207
    oxide films on, 83, 100
    recrystallization after polishing, 212
    single crystals, friction of, 133
Copper alloys
    oxide films on, 93
Copper-Copper interface
    free energy of, 41

Corrosion, electrochemical
effect on wear, 235
Corrosion, fretting
chemical action of, 234
prevention of, 237
Coulombic law, 145, 199
Coulombic force fileds
at surfaces, 112

Debye rings
on polished copper, 212
Debye-Scherrer rings
examination of, 217
Deformation (See also Plastic deformation)
effect of load on, 147, 162
of surface roughness, work required in, 146
Diamond, friction of
effect of surface films on, 114, 119, 120
Discaloy
friction of, 229
Dupré-Young equation, 76

Electrodeposited metals
wear of, 234
Electrolytic method
examination of metallic surfaces by, 68A
Electron diffraction
analysis of adsorption by, 45
examination of cold-worked surfaces by, 72, 215
examination of lubricant films by, 55, 59, 83, 86, 87, 88, 89, 90, 92, 93
165, 167, 188
examination of polishes surfaces by, 72, 75, 209, 211, 212, 214, 215
Electron microscope
examination of molybdenum disulfide films by, 53, 171
examination of polished surfaces by, 25, 72, 214
examination of surfaces by, 21
Electron transfer
near a metal surface, 51
Esters
boundary lubricating properties of, 56, 165, 168, 191
orientation of, 56, 165
Explosives
detonation by friction, 116

Fajan's ionic polarization rule
analysis of surface phenomena by, 112
Fatty acids
adsorption of, by metals, 48, 165
chemical reaction with metal surfaces, 55, 168, 202, 235
effect on metallic adhesion, 141
boundary lubricating properties of, 161, 165, 201, 202, 219
thickness of films, measurement of, 48

Film thickness
for effective boundary lubrication, 154
for prevention of surface welding, 138
Films (See also specific types of films)
adhesion of, electric theory of, 76
on metals, 49A, 50A, 50B, 82
phase changes in, 50
physical chemistry of, 50B
self diffusion and isotopic exchange in, 58A
structure of, 53A, 72
surface pressure of, 47
and surfaces, 53B
Float pycnometer method
surface energy determined by, 37
Friction
chemical reactions of, 129A
effect of surface films on, (See also Oxide films, effect on friction) 60, 115A, 117A, 118, 119, 120, 168, 222
effect of surface-active substances on, 205
effect of surface roughness on, 157, 160, 164
effect of velocity on, 127
energy balance in, 148
measurement of, 45, 162
at elevated temperatures, 118
reviews on, 128, 144, 163
German work, 159
studies, radioactive tracers used in, 123, 124, 125
theories of, 115A, 132A, 156A
adhesion, 118, 141, 151
molecular, 150
welding, 222
values, (See various materials)
Friction, boundary
analysis of, 153
effect of boundary lubrication on, 127
effect of temperature on, 121
Friction, coefficient of
effect of area of contact on, 133
effect of atmosphere on, 133, 221
effect of load on, 145, 148, 181, 199
effect of surface films on, 113
effect of surface conditions on, 113, 142A, 150
effect of temperature on, 154, 232
effect of velocity on, 203
values, (See various materials)
Friction, dry
characteristics of, 118, 127, 138, 140, 143, 144, 155, 158, 161, 205, 228
effect of temperature on, 151, 229
independent of surface finish, 127

Friction, static
    law of, 149
Frictional loss
    effect on wear, 147
Frictional oxidation
    occurrence of, 135
Frictional resistance
    energy considerations in, 146

Gases
    adsorption by solids (See Adsorption)
    decomposition of, at metal surfaces, 99
Gibbs' adsorption equation, 47
Glass, foam and plate
    lubricating properties of, 198, 199
Glauberman's theory of surface tension, 40
Gliding surfaces
    structure of, 130A
    wear by, 227
Gold, friction of
    effect of oxide films on, 164
Graphite
    friction of, 194
        effect of surface films on, 119, 120, 193
    lubricating properties of, 194, 197
    polishing of, 209
    surface states of, 109
Grit
    effect on the incidence of hot spots, 116
Hardness
    effect on wear between similar metals, 125
Harkins and Jura method, 9
Hastelloy alloys, oxide films on
    electron-diffraction study of, 89
Hot spots (See Surface temperature)
Hydrocarbons
    long-chain, boundary lubricating properties of, 188
    solid nonpolar, boundary lubricating properties of, 202
Hydrogen
    effect on wear, 133
Hysteresis
    of adsorption on solid surfaces, 62

Impact
    effect on wear, 224, 227
Inconel, cast
    friction and wear of, 229
    thermal expansion coefficient, 229
Inconel X
    friction and wear of, 229

Indium
    adhesion of, 140
    friction of, 141
Interfacial energies
    measurement of, 111A
Interfacial free energy
    measurement of, 41
Interferometric technique
    examination of films by, 48
Invar
    friction and wear of, 229
Ionic deformation
    role in surface chemistry, 112
Iron
    cast, friction of, 125, 219
       wear of, 203, 224, 226
    chromium-plated, wear of, 223
    electrolytical polishing of, 69
    friction of, 118
       coefficient of, 151
    oxide films on, 83, 86, 118
    perlitic, wear resistance of, 230
Iron alloys
    oxide films on, 87

Junctions (metallic), role of
    in adhesion and friction, 141

Laue spots
    formation of, during polishing, 217
Langmuir's theory, 61
Langmuir-Blodgett technique
    stearic acid deposited by, 199
Lauric acid
    lubricating properties of, 162
    orientation of, 55
Lead
    adhesion of, 140
    friction of, 141, 224
       coefficient of, 151
    microhardness of, 207
Lead-base bearing alloys
    friction of, 158
Load
    effect on coefficient of friction, 145
    effect on deformation, 145
Lubrication, boundary-friction
    properties of, 183
Lubricant films
    molecular adsorption of, 204

Lubricant, solid (See also Lubrication, boundary)
    application of, 184
    composition of, 186, 190
Lubrication
    reduction in shear strength of surface by, 146
    reviews on, 156A, 163, 170, 174, 195A
Lubrication, boundary
    effect of atmosphere on, 166, 189
    effect of surface conditions on, 113
    effect of temperature on, 41, 117A, 121, 127, 131, 140, 168, 219
    effectiveness, 117A, 121, 135, 154, 180, 187, 188, 201, 202, 203, 229
    extreme pressure, 170
    failure of, 115A, 185
    theories of, 191, 196, 201

Magnesium, oxide films on
    formation of, 86
Machine parts
    rubbing surfaces of, 197, 238
Metal sulfonate
    wear-resisting properties of, 221
Metallic pick-up
    at points of actual contact, 222
    effect of load on, 181
    effect of lubrication on, 201, 232
    effect of surface films on, 222
    effect of temperature on, 232
    measurement of, 203
    radioactive detection of, 124, 232, 233
Metallic curfaces (See Surfaces, metallic)
Microhardness
    effect of polishing on, 207
Molecular theory of friction, 150
Molybdenum disulfide (Molybdenite)
    bonding of, 53A, 139, 175, 176
    coefficient of sliding friction of, 171
    lubricating properties of, 115, 117A, 171, 173, 175, 177, 186
Monel
    friction and wear of, 229
Monolayers of lubricants
    effectiveness, 178, 181, 192, 199

Nichrome V
    friction and wear of, 229
Nickel
    beryllium, friction of, 229
    coefficient of static friction of, 151
    L, friction and wear of, 229
    oxide films on, analysis of, 87, 90
Nimonic 80
    friction and wear of, 229
    thermal expansion coefficient of, 229

Nitride films in presence of lubricants
    wear-resisting properties of, 221
Nitrogen-oxygen mixture
    effect on wear, 133
Noble metals
    oxide films on, measurement of, 103
Nonmetallic solids
    friction of, 120

Oblique-section technique
    surface-roughness measurements by, 19, 23, 220
Octacosanoic acid
    lubricating properties of, 162
Oil films
    formation of, effect of molecular shape on, 156A
    thickness, measurement of, 77
Oleic acid
    boundary lubricating properties of, 121
    effect on wear, 221
Olive oil
    effect on wear, 221
Ordering
    mechanism of, 146
Oxide films
    dissociation pressures of, 96
    effect on adhesion, 140
    effect on friction and wear, 113, 114, 117, 118, 119, 161, 164, 202, 221
    effect on surface welding, 114, 132, 229
    formation of, effect of temperature on, 71
        mechanism of, 80
        rate of, 88
        theory of, 53A, 78, 81, 91A, 98
    in presence of lubricants, effect on wear, 221
    isolation of, examination of surfaces by, 94, 95, 100
    kinetic and structural theories of, 86
    on aluminum, 94, 100
    on aluminum alloys, 86, 88, 100
    on brass, 100
    on chromium, 83
    on cobalt, 83, 91A
    on copper, 83, 100
    on copper alloys, 93
    on Hastelloy, 88, 89
    on Hypernik, 88
    on iron, 83, 86, 91A, 118
    on Inconel, 88
    on Kovar, 88
    on magnesium, 86
    on mechanically polished metals, 213
    on metals, 83, 96, 101, 167

on metals and alloys, 79, 87, 91A
on mild steel, 88
on molybdenum, 85, 86, 90, 91
on molybdenum alloys, 90
on nickel, 83
on nickel Z, 88
on nickel alloys, 90
on Nichrome, 88
on noble metals, 103
on platinum, 118
on Refractaloy, 88
on stainless steel, 86,100
on steel, 100, 220
on stellite, 88
on titanium, 100
on tungsten, 84, 86, 90, 91A
on tungsten alloys, 90
on uranium, 118
on zinc, 100
passivation of metals by, 102
reaction with extreme-pressure additives, 132
removal of, 63, 66
surface conditions, studied by (See Oxide films, isolation of)
thickness, measurement of, 20

Paneth's equation, 12
Paraffins
lubricating properties of, 165
Pick-up (See Metallic pick-up)
Plastic deformation (See also Deformation)
at high spot interfaces, 222
effect of surface-active substances on, 205
Plastic flow, (See Surface flow)
Platinum
friction of, 118
effect of oxide films on, 118, 164
effect of stearic acid films on, 179
orientation of fatty acid and soap films on, 55
wear of, effect of silicone films on, 180
Polanyi's adsorption theory, 61A
Polished surfaces
examination of by electrolytic method, 68A
recrystallization after, 212
Polishing
formation of Beilby films in, 135
Polishing, electrolytic
effect on microhardness, 207
effect on surface properties, 21, 67A, 69, 71, 72, 95
formation of Beilby layer, 75, 135
formation of Laue spots, 217
removal of oxides, 213
mechanism of, 28, 73, 74
theory of, 214

Polishing, mechanical
    effect on surface properties
        distortion of crystalline layer, 214
        formation of Beilby layer, 216A
        formation of Debye-Scherrer rings, 217
        presence of oxides, 213
    effect on microhardness, 207
    theories of, 210, 214
Polytetrafluoroethylene (Teflon)
    boundary lubricating properties, 117A
Pressure
    effect on thermal resistance, 137
    effect on wear, 224
Pump seals, (See Carbon)

Radioactive tracers, use of
    in detection of chemical reactions, 45
    in detection of pickup, 124, 233
    in friction studies, 123, 125
Recrystallization
    of polished metallic surfaces, 212
Refractalloy 26
    friction of, 229
Resistance, thermal
    of steel to steel, 137
Rolling, dry and wet
    wear by, 227
Roughness (See Surface roughness)

Scuffing
    effect on surface properties, 219
Seizure of metal parts
    occurrance, 118
    prevention of, 66
    review on, 144
Shear strength
    effect of lubrication of, 146
    effect on friction, 127
Silicones
    boundary lubricating properties of, 180
Silver
    friction of, 162
        effect of oxide films on, 164
    orientation of fatty acid films on, 55
    wear of, effect of silicone films on, 180
Slider curvatures
    effect on friction, 199
    effect on metallic pickup, 232

Soap films
    boundary lubricating properties, 168
    disorientation of, 55
    formation of, 45, 165, 168, 187, 201, 202, 229, 235
    lubricating properties of, 168, 178
    removal of, 219
    structure of, 55, 57, 59
Solids
    chemistry of, 110
    surfaces, forces in, 36
Stearic acid films
    adsorption of, 45
    boundary lubricating properties of, 168, 182
    monolayers of, 169, 178, 179, 181, 199
    multilayers of, 59, 199
    orientation of, 55
    stabilization of, 54, 57
    transition temperatures of, 154
Steel
    alloys, friction of, 234
        wear of, 227
    boundary-lubricated by stearic acid, 182
    carburized, friction of, 125
    friction of, 121, 125, 136, 138, 141, 162, 166, 182, 205, 219, 229, 233
    hard, adhesion of, 140
        friction of, 121
        wear of, 224
    isolation of oxide films from, 100, 182
    mild, friction of, 231, 234
        adhesion of, 140
        isolation of oxide films from, 100
    orientation of fatty acid films on, 55
    surface roughness, measurement of, 25
    surface tension of, 32
    thermal resistance of, 137
    wear of, 227
Steel, chromium-molybdenum
    abrasion of, 220
Steel, chromium-plated
    friction and wear of, 125, 223
Steel, stainless
    friction of, effect of calcium stearate films on, 179
        effect of stearic acid films on, 179
        effect of surface preparation on, 113
    oxide films on, formation of, 86
        removal of, 100
        structure, 92
    surface structure of, 208
Stick-slip motion
    analysis of, 143, 155
    measurement of frictional properties of bearing alloys by, 158
    measurement of mechanical transition temperature of molecular layers by, 199

Sulfide films
    boundary lubricating properties of, 117A, 138
    effect on surface welding, 114
Sulfurized lubricant
    properties of, 196
Surface, absolute
    determination of, 3
Surface area
    determined by analysis of surface films, 104
    determined by emanation method, 5
    determined by gas adsorption, 1, 2, 4, 6, 7, 8, 11, 30
    determined by "point B" method, 10
    determined by surface exchange, 12
    determined, comparison between methods, 160
Surface damage
    effect of boundary lubrication on, 202
    effect of surface films on, 114, 117A, 201
    mechanism of, 23
    radioactive tracers used in studies of, 232
Surface energy
    determination of, 33,36, 37, 43
Surface exchange
    specific surface area determined by, 12
Surface flow
    effect of surface-active substances on, 205
Surface roughness
    analyzed by isolated oxide films, 94
    detection of, 14
    effect of load on, 145
    effect of plastic deformation on, 222
    effect on friction, 157, 160, 164
    effect on metallic surface properties, 157
    effect on thermal resistance of steel, 137
    electrochemical study of, 18
    measurement of, 15, 16, 17, 19, 20, 21, 22, 24, 25, 26, 28, 29, 30, 160
Surface states
    theories of, 106, 107, 108, 109, 111
Surface structure
    of metals, studied by isolation of oxide films, 95
    of metals, studied by taper-sectioning technique, 108
    of stainless steel, 208
Surface temperature, between sliding surfaces
    and Beilby layer formation, 117A
    measurement of, 116
Surface tension
    of metals, 32, 33, 34, 35, 39, 40
    of solids, 31, 36, 42, 43A

Surfaces, metallic
adsorption on, radioactive tracers used, 45
atomistic theory of, 111A
autoradiographic study of, 231
bound states of, 106
cleaning of, 64, 65
examination of, 13, 27
heterogeneity of, 44, 58A
load-carrying capacity of, 238
phenomena of, 111
physiochemical properties, 23, 43A
properties of, 24, 53A, 218
reactions of, 160
state of, 107

Taper-Sections technique (See Oblique-Section method.)
Temperature
effect on kinetic boundary friction, 121
effect on thermal resistance of steel, 137
effect on wear, 224
transition of friction, effect of film thickness on, 154, 155
Tin
coefficient of static friction of, 151
friction of, 234
microhardness of, 207
Tin-base bearing alloys
friction of, 158
Titanium
isolation of oxide films from, 100
Tribometric method
for measuring adsorption on a solid, 169
Tritolyl phosphate
wear-reducing properties of, 219, 221
Tungsten
oxide films on, 84, 86, 90
Tungsten alloys
oxide films on, 90

Uranium
friction of, 118
oxide films on, 118

van der Waals adsorption, 61, 117A
Vapors
unitary thermodynamic theory of adsorption of, 52
Velocity
effect on friction, 127
effect on wear, 224
effect on the coefficient of friction, 121

Water vapor
    effect on friction, 119
    effect on surface welding, 114
Wear (See also wear under specific types of materials)
    between dissimilar metals, effect of chemical composition on, 125
    between similar metals, effect of hardness on, 125
    chemical reactions of, 129A
    effect of atmosphere on, 133
    effect of Beilby film on, 135
    effect of boundary lubrication on, 168
    effect of frictional loss on, 147
    effect of lubricant on, 147
    effect of moisture on, 224
    effect of oxidation on, 221
    effect of pressure of water vapor on, 119
    effect of speed, pressure, impact, moisture and heat on, 224
    effect of surface films on, 60, 222
    effect of surface reactions on, 160
    effect of surface roughness on, 133, 157, 221
    effect of wet and dry rolling on, 227
    electrochemical reactions in, 235
    measurement of, 236
    mechanism of, 227, 228
    of uni- and multimolecular layers, 199
    of rolling-contact bearings, 229
    reduced by tritolyl phosphate, 185
    reviews on, 144, 163
        German work, 160
    theory of, 222
Welding
    and friction, 222
    effect of surface films on, 114, 132, 138, 229
    after breakdown of film, 168
    of soft metal films to steel shaft, 158
Worthite
    oxide films on, 92

X-ray reflection
    examination of surface conditions by, 208, 217

Zinc
    adsorption by, 45
    friction of
        effect of oxide films on, 164
        coefficient of, 151
    orientation of fatty acid films on, 55
    oxide films isolated from, 100