THE MATERIALS ANALYSIS PARTICLE PROBE (MAPP) DIAGNOSTIC SYSTEM IN NSTX

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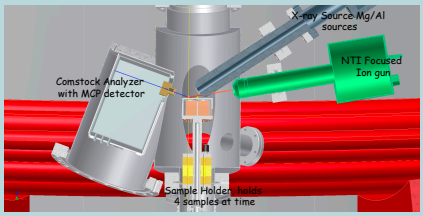
Abstract

- MAPP is the first in-vacuo surface analysis diagnostic system directly attached to a tokomak, capable of shot-to-shot chemical surface analysis of plasma facing surfaces (PFS) and identification of chemical interactions responsible for deuterium retention.
- MAPP also allows the exposure of variety of material compositions (solid Li, liquid Li, W etc) samples to a variety of NSTX plasma configurations.
- X-ray photoelectron spectroscopy (XPS) and direct recoil spectroscopy (DRS) can show the relative chemical functionalities of low-energy D2 interactions with thermal lithium in ATJ graphite matrix as well as Li thin-films on porous Mo used in the LLD.
- MAPP will enable the correlation of plasma facing component (PFC) surface chemistry with plasma conditions and point the way to improved plasma performance.
- MAPP direct attachment to NSTX presented numerous engineering challenges to remote control all motion and analysis systems.

MAPP Surface Analysis Chamber



MAPP Surface Characterization

X-Ray photoelectron spectroscopy (XPS) with Al and Mg Ka sources

- 40 mm working distance at the magic 56 deg angle from sample normal
- Can show unique chemical functionalities such as "Li-O-D" seen in ATJ graphite, to identity D_2 chemical interactions in lithiated graphite surfaces

Low energy ion scattering spectroscopy (LEISS) and direct recoil spectroscopy (DRS)

- Forward scattering angle $\Theta_s = 30^o$
- Shows elemental concentration (even hydrogen) on first few atomic monolayers

Thermal desorption spectroscopy (TDS)

- Residual gas analyzer (RGA) with individual sample heating up to 800 deg C
- Quantify desorbed deuterium for retention studies

Sample holder

- Houses up to four different samples that can be analyzed between plasma discharges
- Has both remote rotary and linear motion for quick switching between samples

MAPP Engineering Constraints

Space Constraints

- MAPP analysis chamber lies in between TF coils on NTSX vessel, compact design and detailed mockups and measurements were used.

High Ambient Magnetic Field

- MAPP lies in an ambient magnetic field of 8 Gauss
- Analyzer chamber will experience pulsed 6,000 Gauss magnetic fields
- Operating the electron analyser in 8-10 gauss DC magnetic field (anticipated on NSTX) had no effect on spectrum.

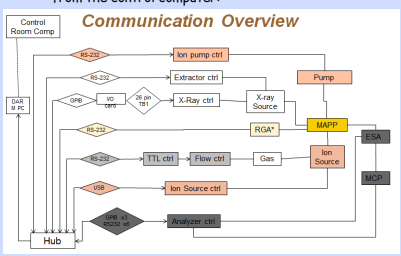
NSTX Interlocks/ Vessel Pressure

- Controlled shutdown of all analysis equipment with 24 volt signal ± 10 seconds before and after shots
- NSTX monitoring and control of vacuum valves and remote control systems.

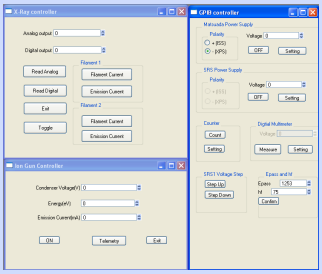
MAPP Engineering

MAPP Communications System

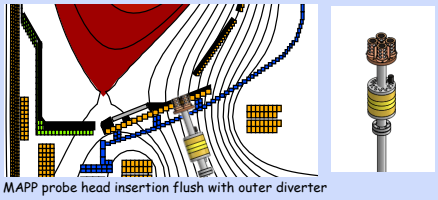
- Below is a flow chart which outlines the communication system that is being used to control all MAPP components from the control computer:



- Protocols that are used to interface with MAPP equipment are GPIB, RS-232, and USB.
- A graphical user interface (GUI) has been developed using IGOR Pro, for control of all systems and data acquisition.



MAPP Sample Holder

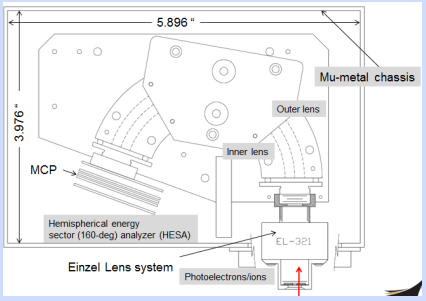


MAPP probe head insertion flush with outer diverter

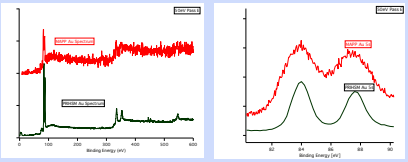
Probe head contains individual heaters for sample TDS measurements along with rotary motion for alignment of all samples for XPS/ISS characterization.

Hemispherical sector analyzer system

- The hemispherical section is biased with bias volts and only photo electrons in an energy bandwidth of (300-1300) eV (for XPS) or ions with an energy bandwidth of (10-1500) eV (for ISS/DRS) are transmitted to a microchannel plate (MCP).
- The energy spectrum is obtained by plotting the MCP counts vs. bias voltage



MAPP XPS Calibration



XPS Spectrum of MAPP vs. PRIHSM (in-situ Surface analysis facility at Purdue) VG Scienta R30000 analyzer

- MAPP Comstock Analyzer configuration uses a 75,50,25eV pass energy and a 3 mm aperture.

Deuterium-Lithium Surface Chemistry Laboratory

ATJ graphite surface chemistry

with ~2μm lithium deposition and D^+:

Oxygen:

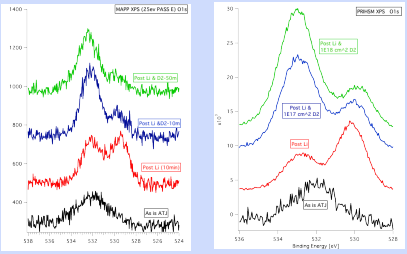
What happens?

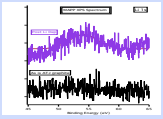
Li and O interactions are manifest at 530.1 eV in the XPS spectrum.

Li, O, and D interactions, on a graphite substrate, are manifest at 533.0 eV.

Carbon:

Li, D, and C interactions are manifest at 291.4 eV.





XPS can give qualitative data to the concentration and chemical functionalities lithium has on the surface

MAPP can detect Lithium presence on Surface!!

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Installation Timeline Pending NSTX Repair/ Schedule

Dec-Jan (??)

- Installation of the MAPP rack and wiring
- Vacuum prep and installation of MAPP analysis chamber to TIV
- MAPP characterization installation and pumping down of analysis chamber
- Integration of NSTX safety interlock to MAPP controls

Jan(??)-MAPP calibration at PPPL

- Remote control interface for control room interface with fiber optic communication system.
- Recalibration of remote systems and data acquisition systems (XPS spectrum)
- Integration of probe head and probe rotary and linear actuation

Impact of MAPP

MAPP will, for the first time, enable prompt and sophisticated surface analysis of materials exposed on an operating tokamak

- Exposure and surface characterization of candidate plasma facing materials (PFM) to tokomak plasma environment
- Study the chemical interactions and D retention liquid and solid metals have as plasma facing surfaces
- Engineering milestone for application of surface analysis techniques in such harsh environments
- Technical insight into future applications of PMI diagnostics

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