Oak Ridge National Laboratory
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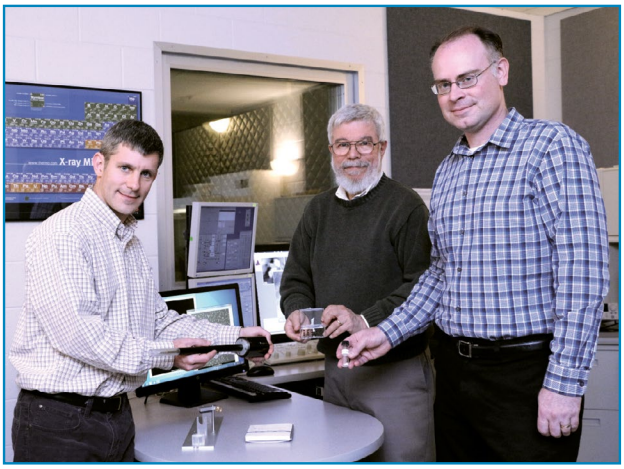
ORNL, industry partnership establishes enhanced microscopy for vehicle emission catalyst development



Protochips CEO David Nackashi (left), ORNL's Larry Allard, and Protochips CTO John Damiano show the gas-cell holder and heater devices.

One of the country's first aberration-corrected electron microscopes, housed at ORNL, was recently upgraded as microscopy components maker Protochips tested a fourth generation catalyst specimen holder and control system for *in situ* gas-reaction research at elevated temperatures and pressures. The new gas-cell technology makes this one of the world's most powerful and unique microscopes for characterization of catalyst materials at the single-atom level under simulated real-world conditions.

Larry Allard, ORNL's lead microscopist for catalyst materials characterization with the Sustainable Transportation Program (STP) Propulsion Materials (PM) research group, uses the microscope in cutting-edge materials research that is crucial to enabling fuel-efficient, clean, and reliable vehicle technologies. ORNL's PM researchers resolve powertrain-related materials challenges today that impact future development of advanced engines, hybrid and electric drive systems, and vehicle exhaust systems components.

"Using Protochips' unique Aduro™ microfabricated heater devices, we can study catalyst materials for cleaner vehicle exhaust emissions, rapidly raising and lowering the temperature of the sample while watching how it reacts in certain environments," Larry said.

Using electrons instead of light, the microscope with the new gas-cell is doing more than just taking pictures. It is turning the instrument into a laboratory. "The systems we provide as accessories to transmission and scanning electron microscopes let the researcher recreate in real-time, or *in situ*, reaction conditions that allow imaging at high resolution," said David Nackashi, CEO and co-founder of Protochips.

ORNL's research with this new equipment is providing materials discoveries related to atom mobility and reactivity on catalyst oxide support surfaces, which will play a key role in enabling the development of both lower precious metal content catalysts and self-regenerating catalyst systems.

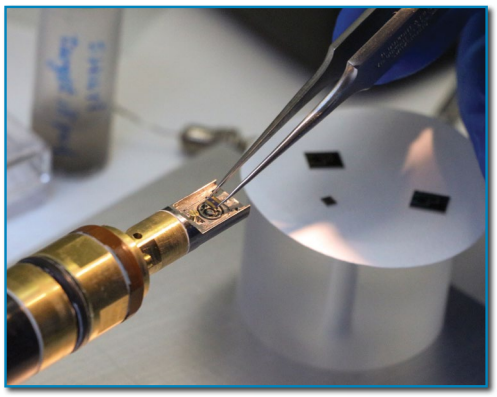
The Protochips relationship through ORNL's applied materials user program began in 2006 with a Department of Energy (DOE) Small Business Innovation Research (SBIR) Phase I award to the Raleigh, NC-based vendor. Through Work for Others contracts and a research collaboration, ORNL and Protochips are developing and deploying new high-tech characterization tools that are accelerating the scientific understanding of catalytic materials.

"The High Temperature Materials Laboratory (HTML), the Propulsion Materials program, as well as DOE's SBIR program, have played a key role in enabling Protochips' growth from three to 30 employees and contractors over the course of our relationship," said Allen Haynes, ORNL's PM program manager.

After the SBIR ended in 2008, ORNL and Protochips continued to collaborate on the development of new *in situ* capabilities for characterization of catalysts and other nanophase materials, with Protochips providing ORNL with prototype equipment.

Protochips' gas-reaction system – first established and refined through testing at ORNL – is aimed to be commercially introduced in the near future as the company continues evaluation by international electron microscope manufacturers.

Additional Resources continued on page 2



A researcher loads the Protochips Aduro™ heater device with a catalyst material into the gas-cell holder.

continued from page 1

Additional resources:

"Evolution of gold structure during thermal treatment of Au/FeOx catalysts revealed by aberration-corrected electron microscopy." L.F. Allard, A. Borisevich, W. Deng, R. Si, M. Flytzani-Stephanopoulos and S.H. Overbury; Journal of Electron Microscopy 58, pp 199-212, 2009.

"Characterization of alumina-supported Pt and Pt–Pd NO oxidation catalysts with advanced electron microscopy." O.K. Ezekoye, A.R. Drews, H.-W. Jen, R.J. Kudla, R.W. McCabe, M. Sharma, J.Y. Howe, L.F. Allard, G.W. Graham and X.Q. Pan; J. Catalysis 280(1), pp 125-136, May 2011.

ORNL Propulsion Materials R&D is sponsored by the DOE Vehicle Technologies Office (VTO).

Driver behavior study to influence safety

ORNL researchers are working with the Department of Transportation's (DOT) Federal Highway Administration (FHWA) Exploratory Advanced Research Program to investigate links between driver behavior and safety as part of the Transportation Research Board's (TRB) Second Strategic Highway Research Program. The lab's project team is assisting with a Naturalistic Driving Study (NDS) that will examine about 3,000 vehicles outfitted with video cameras that will capture valuable information, which could influence the safety of America's roadways.

Using sensor technology installed in each vehicle, data streams are collected from forward-looking radar, the accelerator, a global positioning system (GPS), and a passive alcohol sensor. The bulk of this massive data set – about four petabytes collected so far – comes from video data from four cameras focused on the driver's face, steering wheel and pedals, and the driver's front and rear views. Researchers expect to capture an estimated one million hours of recorded drive time over the course of the two-year study.

"We'll be able to provide an unprecedented look into what a driver was doing, or not doing, leading up to a crash or near-crash, as well as their actions during routine driving," said Tom Karnowski, principal investigator with ORNL's Imaging, Signals, and Machine Learning Group.

He added that the data gleaned from the NDS study will be used to improve roadway and roadside design, the development of on-board safety systems, and law enforcement and driver's education.

The ORNL team is working to characterize the cameras used in the study, which will improve the accuracy and effectiveness of automated data extraction algorithms. In later phases of the project, the team will also be developing procedures for measuring and comparing the effectiveness of automated video data extraction algorithms. Traditionally, the extraction, or labeling, of items of interest from video data has been a brute force process, requiring tedious frame-by-frame review.

"Automating this coding through computer vision can make these data sets accessible to a wide range of researchers, improve labeling accuracy and speed, and reduce costs," Tom said.

ORNL researchers perform calibration measurements on the front camera installed in a Toyota Prius.

While the primary mission in crash prevention is safety and preserving human life, crashes also represent a large energy waste, a particular concern of DOE's Energy Efficiency and Renewable Energy Office and their Clean Cities initiative. Vehicle idle time in traffic congestion is responsible for the loss of 2.8 billion gallons of fuel annually – or nearly 3% of total fuel use.

ORNL's NDS project team comprises researchers from the Electric and Electronics Systems Research Division, Computational Sciences & Engineering Division, and Nuclear Security & Isotope Technology Division. The collaboration involves FHWA, TRB, and Virginia Tech Transportation Institute.

ORNL-mentored FIRST® LEGO® student teams earn awards

Congratulations to the FIRST LEGO League student teams, mentored by Claus Daniel, STP deputy director, and transportation analysis researcher Ingrid Busch, who participated in league competitions last fall in Tennessee. On the state level, Claus' Lab R.A.T.S. (Robots Are Technology in Service) placed second in "Programming." At the local competition in Knoxville, Lab R.A.T.S. had the third highest robot performance score, but also the highest cumulative score and won the first-place Core Values Award for Inspiration. Ingrid's Golden Mean team took first place for "Strategy and Innovation in Robot Design" at the local level. Teams used LEGO-framed miniature robots to perform a series of functions on a table to solve posed natural disaster-type challenges and presented an original research and project idea to a team of judges.

ORNL's Claus Daniel mentors students Stina Daniel and Derek Ott.

Golden Mean team is mentored by Ingrid Busch with ORNL.

Transportation seminars highlight success, opportunities

In November, Burak Ozpineci, program manager of the Power Electronics and Electric Machinery (PEEM) research group, gave a talk titled, "Advanced Power Electronics for Electrified Transportation" as part of STP's Transportation Science Seminar Series, an effort to promote cross-cutting capabilities of transportation R&D within ORNL.

ORNL's Burak Ozpineci presented the history and future of electric vehicles.

ORNL's James Li and Chattanooga-based traffic experts John Van Winkle and Stephen Meyer presented, "Big Data Informatics: Intelligent Transportation Systems with the Chattanooga Wireless Mesh Network," detailing ORNL's work with industry. This seminar took place at ORNL on January 10.

WBIR highlighted the talk in a brief newscast and online at http://www.wbir.com/story/news/2014/01/10/chattanooga-ornl-team-up-for-traffic-study/4420955, and The Oak Ridger published an article at http://www.oakridger.com/article/20140114/NEWS/140119948.

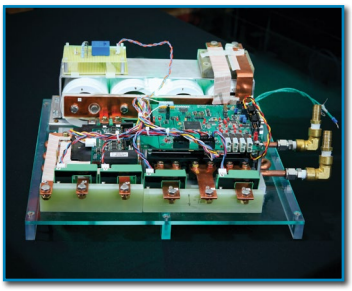
Claus Daniel will present,
"Electrification of Transportation:
Where Does the Battery Stand?"
at 10 a.m. Friday, March 7 at ORNL in the
JICS Auditorium (Building 5100, Room 128).

New inverter, licensed to Arcimoto, a boost for HEVs

Less expensive, lighter, and more efficient inverters could put hybrid electric vehicles (HEV) on the highway to improved viability. While batteries receive a lot of attention, Gui-Jia Su, inventor from the PEEM research group, noted that inverters play an equally important role in powering HEVs.

ORNL licensed the inverter technology to US-based all-electric prototype manufacturer Arcimoto. This partnership was the focus of an article titled, "A Promising New Electric Car Is on the Horizon" that appeared in Innovation Magazine Online: http://www.innovation-america.org/promising-new-electric-car-horizon.

The patent-pending inverter is more compact, reduces battery losses, improves operating conditions and reliability, and can be operated in high-temperature conditions. The inverter also significantly reduces undesirable motor torque ripples.



Inverters, which convert direct current into alternating current, play an equally important role as batteries in powering HEVs.

In the news

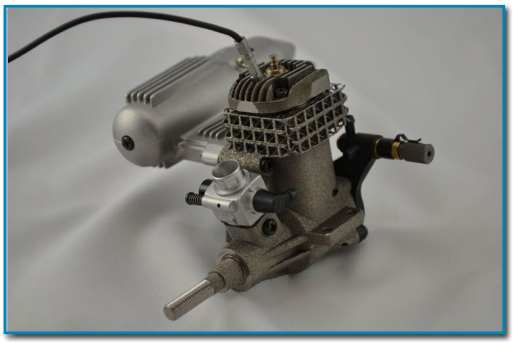
- An ORNL project led by researcher Mike Kass on miniature engines research, which could be implemented in military surveillance systems, was profiled on world energy news source The Daily Fusion at http://dailyfusion.net/2013/11/ornl-uses-titanium-to-make-tiny-uav-engines-hugely-efficient-25105.

- A cover story featuring ORNL's Robert Wagner appeared in Automobil Industrie's Chinese publication. Robert discussed how ORNL is exploring advanced combustion concepts and mentioned ORNL's Titan supercomputing research support. The article (in Chinese) can be found at http://www.vogel.com.cn/magazinelist.html?id=5_19_33_34.

- ORNL researcher Jun Qu's work was featured in an article titled, "Molten Salts Could Improve Fuel Economy," on Inside Science News Service, whose content is syndicated to subscribers at FoxNews.com, NBCNews.com, Live Science, Scientific America, and others. Read the full text at http://www.insidescience.org/content/molten-salts-could-improve-fuel-economy/1492. His research was also highlighted on Green Car Congress online in an article titled, "Oak Ridge-GM prototype low-viscosity ionic liquid-additized engine oil delivers 2% fuel economy improvement over 5W-30", which can be accessed at http://www.greencarcongress.com/2013/12/20131230-qu.html.

- Esther Parish and Virginia Dale with ORNL's Environmental Sciences Division were interviewed about bioenergy sustainability for an upcoming biofuels episode of PBS's series, This American Land.

- The Winter 2014 issue of Fuels Fix included an article about the addition of ORNL's new C-MAX to the lab's fleet. Fuels Fix is published by the East Tennessee Clean Fuels Coalition in collaboration with DOE Clean Cities. See page 7:



ORNL researchers used additive manufacturing capabilities to print the engine head out of titanium and to install special sensor ports.

Employee Excellence

Mike Kass was invited to serve on the advisory committee of the University of California-Riverside College of Engineering Center for Environmental Research and Technology (CE-CERT) to guide the research program of their materials and fuels compatibility projects. The State of California has recognized the importance of the DOE fuels compatibility studies being performed at ORNL and has initiated a similar program at the CE-CERT facility to examine material interactions with biofuels.

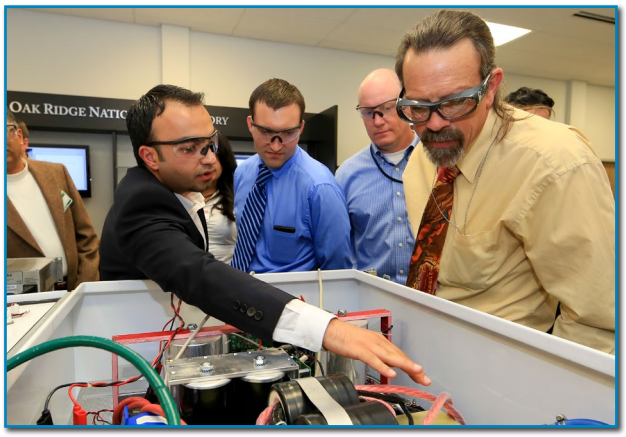
- Robert Wagner earned the 2014 SAE International Leadership Citation in recognition of his "outstanding accomplishments which have led to the success of the Society of Automotive Engineer's global initiatives."

- James Li was invited to be an oversight panel member for a Transit Cooperative Research Synthesis Study SA-34 on Open Data and Open Government for Transit Agencies.

- Claus Daniel has been invited to talk at the 2014 US Frontiers of Engineering Symposium in September in Irvine, California organized by the National Academy of Engineering.

Visits & Events

- Researchers from ORNL's National Transportation Research Center (NTRC) hosted Florida Congressman Daniel Webster, providing facility tours that included the Vehicle Systems Integration (VSI) lab.
- Members of the DOE-VTO Advanced Combustion Engine team visited NTRC in October to review the DOE's Advanced.
- Combustion Engines R&D Program activities at ORNL. Researchers led the group through detailed tours of the Fuels, Engines, and Emissions Research Center (FEERC) and the VSI lab, as well as presentations of STP, the fuels and lubricant technologies program, and research supported by the Bioenergy Technologies Office.
- Roy Primus from General Electric used funding from a GE lifetime achievement award to visit the NTRC for two weeks to work with ORNL on new analysis methods for understanding opportunities of high efficiency engines.
- Project partners including Clemson International Center for Automotive Research, Evatran, Cisco, Toyota, and General Motors attended and participated.
- Brian Peaslee, Chief Engineer-Propulsion Systems, and Andy Pinkos, Technical Lead Engineer-Propulsion Systems from Magna E-Car Systems, visited the PEEM lab to discuss wide bandgap devices and electric traction motors.
- Allison Transmission visited the NTRC to discuss involvement in the upcoming Environmental Protection Agency (EPA) Greenhouse Gas Phase 2 test procedure development and support of SAE standard J2711 rewrite. ORNL researchers gave presentations and led tours of the FEERC labs, PEEM lab, Transportation Research and Visualization Laboratory (TRAVL), and VSI lab.
- PEEM researchers hosted Anjan Bose from Washington State University, representatives from Ford Motor Company, and visitors from General Motors/United States Council for Automotive Research.
- Visitors from TOYOTA North American Research Center, Hitachi, and Kyoto University met with ORNL researchers to discuss cathode materials for lithium-ion batteries and toured the Battery Manufacturing Facility (BMF). Other visitors to the BMF included Peter Faguy, manager of Applied Battery Research in the DOE Vehicle Technologies Office; Joe Hagerman and George Hernandez, program managers in the DOE Building Technologies Office, and a group from the Society of Environmental Journalists.
- General Motors' (GM) Greg Smith, John Czubay, Sean Gleason, and Nitin Patel visited the HTML and NTRC research facilities to discuss materials science and materials engineering issues associated with GM's power electronic devices and electric motors for hybrid- and all-electric vehicles.



ORNL's Omer Onar is describing the grid-side unit of the wireless power transfer system to Lee Slezak and David Anderson from DOE-VTO and Jason Conley from the National Energy Technology Laboratory (NETL) who visited the NTRC for a wireless power transfer project review and demonstration.

Industry visitors including representatives from Growth Energy, POET, the Renewable Fuels Association, and Daimler toured the NTRC facilities.

ORNL's Norberto Domingo describes prototype variable compression engine technology and corresponding efficiency opportunities to DOE visitors (from left) Ken Howden, Gurpreet Singh, Steve Gougen, and Leo Breton (not pictured).

ORNL R&D referenced in Senate hearing on biofuels

Steve Chalk, DOE Deputy Assistant Secretary for Renewable Power, cited ORNL transportation-related research during a December 11 US Senate hearing titled, "Oversight Hearing on Domestic Renewable Fuels". He described the Billion Ton Study as a solid and credible foundation for the long range potential of biofuels. In the same hearing, a Growth Energy representative referred to ORNL-compiled data on ethanol intermediate blends. View the archived Webcast at http://www.epw.senate.gov/public/index.cfm?FuseAction=Hearings.Hearing&Hearing_id=c30fd6c6-c92b-013d-741d-ebbeefd81e87.

Battery materials work yields positive results

Recent work by ORNL and Plextronics on conductivity enhancing materials for lithium-ion battery electrodes has shown improved high-rate performance in lithium-based cathode materials. At ORNL's Battery Manufacturing R&D Facility, researchers are testing and assembling the Plexcore® materials (supplied by Plextronics), which could be used in energy storage applications from power tools to electric vehicles to boost lithium-ion battery power density, energy density, and capacity retention.

ORNL to advance hydrogen infrastructure

ORNL's Zhenhong Lin received funding to provide analytical support for US hydrogen infrastructure project H2USA, a new public-private partnership launched by DOE to support more transportation energy options for US consumers including fuel cell electric vehicles (FCEV). This project will use ORNL's system analysis capabilities to generate insights on spatial deployment and business models of hydrogen infrastructure and FCEVs.

SAMPE Journal features crashworthiness test machine

The Jan/Feb issue of SAMPE Journal (Society for the Advancement of Material and Process Engineering) featured the Testing Machine for Automotive Crashworthiness at ORNL on the cover, including photos that illustrate composites versus metals research in terms of crashworthiness. The project by ORNL's Mike Starbuck and Dan Adams from the University of Utah aims to develop an understanding of the crash behavior of composites in future automotive applications performed in conjunction with the Automotive Composites Consortium.

Do you have news or information you would like to share?

Please submit to Kim Askey,
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The Sustainable Transportation Update newsletter aims to cover news and technical highlights associated with transportation and transportation-related research activities and projects. This publication is produced and distributed by the Oak Ridge National Laboratory's Sustainable Transportation Program Office.

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