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OSTC VISIONS

The University of Iowa

Inside this issue:

MODELING AND CHARACTERIZING THE HETEROGENEOUS NATURE OF THE TROPOSPHERE

In 2005, Professor Mark Young celebrates 15 years at The University of Iowa in the Department of Chemistry. As an undergraduate at Princeton University, Dr. Young majored in chemistry before moving on to do graduate work at the University of California at Berkeley. He then held a post-doctoral position at Colorado State University, where he studied molecular dynamics and photochemistry. A key member of the Optical Science and Technology Center (OSTC), Professor Young's research focuses on heterogeneous atmospheric chemistry and real-time environmental mass spectrometry.

The study of heterogeneous atmospheric chemistry involves examining how small particulates in the earth's atmosphere react and how their properties change depending on atmospheric conditions. "We look at laboratory systems that mimic the atmosphere," Professor Young says. "Basically, we're trying to replicate the atmosphere in a big metal can." The "big can" is a large-volume atmospheric reaction chamber which can monitor gas-particle interactions at pressure, temperature and relative humidity conditions found in the troposphere. With his collaborators, Professor Paul Kleiber of physics, Professor Greg Carmichael of chemical and biochemical engineering, and Professor Vicki Grassian of chemistry, Dr. Young is one year into a new project to study how the optical properties of particles are affected by certain chemical interactions in the atmosphere. Incoming solar radiation can interact with particles—for example, soot or dust in the atmosphere—and if the radiation is absorbed, there is a warming effect, while if the radiation is scattered, cooling occurs. These interactions are important to understanding the effect of atmospheric pollutants on global warming. This area of research is critical, Professor Young notes, because the optical and chemical properties of these particles are closely related, but their effect on each other is not yet fully understood. An offshoot of this project is a reexamination of the Mie Theory, which is the fundamental theory that underlies many models about how light and particles interact. Young is testing this widely used theory and asking "what if this model isn't correct?"

Mr. Jason Vanlerberghe stands next to a single particle mass spectrometer. The aerodynamic lens inlet and laser light scattering region are just behind him.

A second major project in Professor Young's laboratory characterizes the chemical composition of particles in real time using mass spectrometry. The study of particulate matter is complicated because the particles are so tiny, just one micron, or

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X-RAY PHOTOELECTRON SPECTROMETER

The University of Iowa Central Microscopy Research Facility is pleased to announce that the new x-ray photoelectron spectrometer (XPS) is operational and available to investigators. "We're enormously excited about the XPS," says the facility's director, Dr. Kenneth Moore. "It's a unique opportunity to have it available to both our physical and biomedical science communities."

The spectroscopy system, also described as an electron spectrometer for chemical analysis (ESCA), was purchased with funds from a successful National Science Foundation grant awarded to Professor Vicki Grassian as the principal investigator as well as Professor Sarah Larsen and Professor Ed Gillan; all three researchers are from the Department of Chemistry and are members of the Optical Science and Technology Center (OSTC). The XPS uses a state-of-the-art scanned and focused x-ray beam to characterize surface properties of particles and thin films, thereby obtaining quantitative elemental information as well as information about the chemical state of these elements and their local bonding environments.

The Kratos (UK) Axis Ultra DLD XPS system arrived on campus four months ago, and researchers are quickly discovering its capabilities. Chemistry gradu-

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RECENT FUNDING

David R. Andersen-$100,000 from the National Science Foundation, "Harnessing the Spin-Stabilized Motion of a Multi-walled Carbon Nanotube for Memory Cell Operation."

Vicki H. Grassian-$80,000 from the American Chemical Society-Petroleum Research Fund, "In-Situ Atomic Force Microscopy Studies of Surface Reactions Under Ambient Conditions."

Vicki H. Grassian-$600,000 from the National Science Foundation, "Chemical Reactions of Environmental and Atmospheric Relevance on Carbonate Surfaces."

Vicki H. Grassian-$399,906 from the National Institute of Occupational Health and Safety, "Assessment Methods for Nanoparticles in the Work Place."

Congratulations to the following members on their recent appointments:

Mark Arnold—Edwin B. Green Chair in Laser Chemistry

Edward Gillan– Chair of the Solid State and Materials Chemistry subdivision of the American Chemical Society Division of Inorganic Chemistry

FROM THE DIRECTOR

Director of the Optical Science & Technology Center—Mark Arnold

As an organization like the Optical Science and Technology Center (OSTC) makes plans for the future, it is sometimes beneficial to look briefly at the past. This fall marks the beginning of the eleventh year for the OSTC. Our center started with a founding group of twelve inspired scientists in physics, chemistry, and electrical engineering under the leadership of Professor Paul Kleiber. Professor Kleiber envisioned the creation of an interdisciplinary research environment to facilitate collaborations between researchers from different disciplines. In those early days, few on campus recognized the term "OSTC" and fewer had an accurate understanding of the research being pursued by the OSTC membership. One of the principal objectives of the early OSTC leadership was to establish a strong and vibrant science program that would demand recognition on campus and that would be attractive to newly hired faculty and inspiring to young graduate students with research interests in the optical sciences and engineering.

Clearly, Professor Kleiber's vision has been realized over the past ten years by the hard work and dedication of all current and past members of the OSTC. Today, we enjoy recognition on campus as a successful interdisciplinary research center composed of many complementary groups of research excellence. Our strong and continued growth over the years has served us well and provides a strong foundation for future advances.

The future gives us an opportunity to expand further our sphere of influence. Possibilities include helping to establish other interdisciplinary research centers on campus and participating in the advancement of optical sciences and technology on the national and international stages. Indeed, many of our OSTC faculty colleagues are recognized nationally and internationally for their scientific ingenuity, expertise, and cumulative accomplishments. Now, we must work to achieve this same level of recognition as a center. Exciting advancements are brewing that will significantly and positively impact the OSTC and The University of Iowa. A prime example is the recent formation of two different companies, both with the overriding objective of catalyzing the transfer of technology and intellectual property from OSTC research laboratories to the private sector.

In my view, the most important feature of a successful interdisciplinary research center is communication between the members. All OSTC faculty, students, and professional scientists must communicate on a frequent basis in order to identify overlapping research interests and to devise strategies for meaningful collaborations. Inter-group communication will be especially important as we aspire to achieve greater national and international recognition as a center of excellence. For this reason, I propose the creation of the OSTC Seminar Series. The idea is to provide a forum for the open exchange of research ideas under the structure of a seminar series. Professor Mark Young, whose research program is featured in this issue of *Visions*, has kindly agreed to deliver the first OSTC seminar this coming October. Other OSTC faculty will be asked to participate in the upcoming months. I strongly encourage everyone to participate as we push the OSTC to the next level.

TROPOSPHERE CHARACTERIZATION...CONTINUED

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10^{-6} meter, and are difficult to collect in sufficient quantity for bulk analysis. Dr. Young's solution to this problem is to collect particles directly from the atmosphere into a mass spectrometer. "Then we blow them apart with a laser," Professor Young says, "and examine the sample on a single particle basis." This process allows for a dynamic look at the evolution of the particle and is a way to profile particles taken directly from the atmosphere. This process could be used for identifying airborne allergens or toxins, thereby characterizing closed environments, such as confinement facilities in the agricultural workplace. "This is the most applied work I've ever done," Professor Young notes, "We're able to get more information with greater rapidity and sensitivity to show what particles are present, their size, and their chemical composition."

X-RAY PHOTOELECTRON SPECTROMETER...CONTINUED

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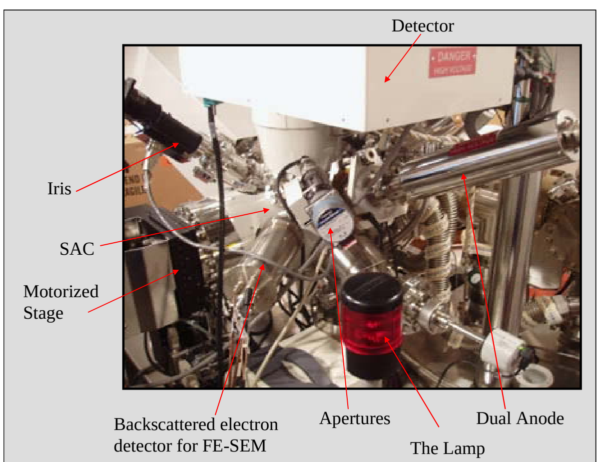
ate student Mr. Jonas Baltrusaitis uses this instrument for his research. In addition, he is responsible for teaching investigators how to use the system and he is responsible for all instrument maintenance. His training involved an introductory course by the Kratos technicians who installed the system, and also instructions from technicians in research centers at the Pennsylvania State University and Duke University who provided details for advanced applications and analysis. "We're just starting to work with other researchers," Mr. Baltrusaitis notes, "and we want to spread the word about what the XPS can do."

Iowa's XPS is a uniquely customized instrument with many capabilities. It features high energy resolution and charge neutralization for both conductive and insulating samples; multi-point spectroscopy via an incorporated electrostatic deflection system; and the ability to obtain fast parallel chemical images. The instrument operates under ultra high vacuum (UHV) conditions; that is, base pressure is maintained below 1×10^{-9} torr allowing analysis of clean samples. Equipped with an option for sample stage heating or cooling, the system offers a high degree of automation for sample throughput. A delayed line detector (DLD)



Detailed diagram showing major spectrometer components of the Axis Ultra DLD XPS.

allows for enhanced small spot performance and quantitative imaging capability. In addition, angle-resolved x-ray photoelectron spectroscopy (ARXPS) can be performed in order to elucidate the surface structure of more complex samples such as biomaterials or even liquid surfaces. With the help of an ion gun, the in-depth distribution of the elemental composition of thin films can be determined. Additional accessories allow an AXIS ultra electron spectrometer to be used for ultraviolet photoelectron spectroscopy (UPS) of solids, and high performance Auger

Mr. Jonas Baltrusaitis shown with the XPS.

electron spectroscopy (AES) to determine elemental composition of the outermost few atomic layers of materials. A state-of-the-art field emission gun (FEG) combined with a secondary electron detector (SED) can be used to obtain scanning electron microscopy (SEM) images and Auger electron spectroscopy (AES) maps with 1000 Angstrom resolution. In addition, there is a custom reaction chamber for *in situ* specimen reactions.

These features enable the system to be useful in examining any solid material where surface chemistry is important, such as investigations of adhesion, catalysis, interface formation, surface cleanliness, corrosion/oxidation, surface segregation, diffusion, stoichiometry and thickness of thin films, molecular orientation, self assembled monolayer formation, analysis of discolored surfaces, reverse engineering, surface modification and process monitoring. "The applications are so broad," Mr. Baltrusaitis notes, "it's really impossible to briefly summarize all the applications because the system can do so many different things."

Anyone interested in using this instrument should contact Mr. Baltrusaitis at jonas-baltrusaitis@uiowa.edu.

PUBLICATIONS

For a Full Listing: www.uiowa.edu

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Johnson, ER, **Grassian, VH**, "Environmental Catalysis of the Earth's Atmosphere: Heterogeneous Reactions on Mineral Dust Aerosol," Environmental Catalysis, Ed. Vicki H. Grassian, CRC Publishing, Boca Raton, FL, (2005).

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Founded in 1994, The Optical Science and Technology Center consists of faculty members from the University Departments of Chemistry, Chemical and Biochemical Engineering, Electrical and Computer Engineering, Physics and Astronomy, Biological Sciences, and Environmental and Civil Engineering. Among the faculty are distinguished scientists who have developed international reputations for innovative research on the frontiers of optical science and engineering. Current general research areas include: nanoscience, photopolymerization, environmental sciences, biomedical devices, and semiconductor materials.

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The next issue of *Visions* will focus on Professor Alec Scranton and his interests in photopolymerization and the Center for Fundamentals and Applications of Photopolymerization.

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OSTC SYMPOSIUM

On February 18, 2005 the Optical Science and Technology Center (OSTC) presented a symposium on "Optics, Lasers, and Nanoscale Materials in Environmental Science." New technologies using lasers and other detection devices are becoming important in understanding the properties of materials on the nanometer scale; applications in this area are particularly appropriate for the study of environmental science. The symposium, which was attended by 140 researchers from The University of Iowa and surrounding colleges, featured a morning session including presentations by OSTC members and comments from Ms. Beth Freeman of Senator Tom Harkin's office, followed by an afternoon poster session, and a tour of the Environmental Protection Agency's ASPECT aircraft.

To begin, Professor Bill Eichinger from Civil and Environmental Engineering discussed "LIDAR Sensing of the Atmosphere." LIDAR is an acronym for Light Detection and Ranging, where a strong pulsed laser light is sent into the atmosphere and the back scattered light is collected and analyzed. Absorption of selected frequencies of light can provide chemical information while the time between sending and receiving the pulse provides distance or range information. This analytical technique provides valuable information related to atmospheric pollutants, clouds, contaminants, etc. Broadly applied, this technology can result in an increased understanding of pollution sources and distribution; for example, Dr. Eichinger's research focuses on the detection and dispersal of hog farm emissions. LIDAR can also be used by law enforcement to track aircraft and drug processing labs, and by national security agencies to detect biological and chemical agents in the atmosphere.

In the next presentation, entitled "Novel Infrared Optoelectronic and Photonic Semiconductor Devices," Professor John Prineas from Physics described how the Molecular Beam Epitaxy facility allows the bandstructure engineering of semiconductor optoelectronic devices, such as LED's and detectors, on the atomic level. Professor Prineas's group has been creating devices useful in the sensing of blood glucose levels,

Conference participants tour the ASPECT Aircraft.

but the devices have applications for environmental sensing as well. In addition, Professor Prineas noted the ability to 'fingerprint' selected molecules with infrared spectroscopy, thereby allowing highly sensitive detection of specific molecules.

Professor Vicki Grassian, from the Department of Chemistry, began her presentation with an overview of environmental particles and then discussed how relatively ordinary materials become extraordinary when made on the nanoscale, so that even a material's fundamental properties can change at that scale. Professor Grassian went on to point out that nanoparticles play a crucial role in atmospheric chemistry; for example, atmospheric nanoparticles are important precursors to larger particles, these nanoparticles may play a role in the deleterious effects of air pollution on humans, and nanoparticles may provide novel chemical pathways in the chemistry of the atmosphere.

A highlight of the morning session was a presentation by Dr. Mark Thomas of the Environmental Protection Agency about the "EPA ASPECT Program for Airborne Chemical Sensing." Dr. Thomas described the Airborne Spectral Photometric Environmental Collection Technology (ASPECT), which is an aircraft deployed instrumentation system capable of real-time detection and collection of analytical information. The instrumentation onboard the aircraft includes three primary sensors: an infrared line scanner for imaging, a high speed infrared spectrometer for identifying and quantifying plumes, and a gamma-ray spectrometer for radiological detection.

One of Dr. Thomas's collaborators spoke next. Professor Gary Small of Chemistry gave a presentation entitled "Passive Infrared Measurements for Automated Environmental Monitoring." In this presentation, Professor Small demonstrated the ability to process information obtained in real-time from the ASPECT aircraft to map selected chemicals during natural and man-made disasters, such as emergency chemical spills. This type of real-time chemical information can by used by first responder units to more efficiently and safely deal with such events.

Following Professor Small's presentation, attendees had lunch, followed by a poster session and tours of the ASPECT aircraft at the Iowa City Airport. When viewing the aircraft, one of the program participants, Professor John Prineas, noted that because the ASPECT system could scan such broad areas, it was "a really practical way of tracking large chemical spills and emissions that affect the environment."

Overall, the symposium was a huge success and provided a great opportunity for OSTC researchers to share information about their work, to discover new avenues for collaboration, and to invite researchers from outside the university to see the interesting research under way at the OSTC.