NATIONAL SCIENCE FOUNDATION
TOKYO REGIONAL OFFICE

January 8, 2010

This report appeared in the September 2009 issue of the American Ceramic Society's Bulletin and is presented here as a Special Report with their permission. Pennsylvania State University's Center for Dielectric Studies laid the groundwork for future collaborations when it organized a trip to meet with Japanese students and businesses. This activity was supported by NSF's Industry & University Cooperative Research Program (I/UCRC) in the Engineering Directorate (ENG,) and the Office of International Science and Engineering (OISE).

Special Scientific Report #10-01

Students and Faculty Inspired by Japan Dielectrics Conference

Asking the right questions and defining the challenges are two of the most crucial steps governing the long-term success of continued research in dielectric materials. To begin to take these steps, veteran scientists know how important it is to consult with other experts in the field who may have a different background and, hence, perspective. With this lesson in mind, a group of faculty and students departed in mid-May 2009 from Pennsylvania State University to meet with some Japanese counterparts to look for opportunities to share information and lay the groundwork for future collaborations.

Japan has long been at the forefront of research involving electronic materials and devices, and research concerning electronic materials is a cornerstone of ceramics research at Penn State. The school's Center for Dielectric Studies (http://www.mri.psu.edu/centers/CDS/), one of the National Science Foundation-sponsored Industry/University Cooperative Research Centers, provides a forum for electroceramics research. Since its inception, the CDS has encouraged collaboration among scientists and engineers at companies and universities within Japan and the United States.

Thus, it was only fitting to hold one of the biennial CDS meetings in Japan. And, although

taking a large group overseas can generate logistical complications, the participants knew that the benefit to the member companies and the research community as a whole would greatly outweigh the complexities of holding the meeting in Japan. Strictly speaking, the U.S. and Japanese gathering officially was a joint spring meeting of the CDS and the new Center for Piezoelectric Materials and Devices (also headquartered at Penn State), held in Narita, Japan, May 19–20. Three Penn State faculty members, Clive Randall, Susan Trolier-McKinstry and Elizabeth Dickey, made the trip along with Fatih Dogan of Missouri University of Science and Technology. In addition, seven Penn State students were able to attend thanks to generous travel grants provided by NSF and Bayer Materials Science. The meeting featured technical presentations on the synthesis, processing and properties of dielectric materials.

The conference also generated many points of discussion for defining the needs of industry and viable courses of research programs. The meeting was preceded by an inaugural seminar on tantalum and its relevance to the electrolytic capacitor industry. The Cabot Corporation's Tomoo Izumi organized the seminar that brought together educators (the U.S. professors plus Japanese professors, including Toru H. Okabe, University of Tokyo; Hiroki Habazaki, Hokkaido University; and Sachiko Ono, Kogakuin University) and students with suppliers of tantalum anodes and producers of electrolytic capacitors. The seminar was a good jumping-off point for participants to present and debate emerging research related to electrolytic capacitors.

Discussions about future avenues of research for improving electrolytic capacitors continued during the CDS meeting during presentations by Penn State students Jennifer Ray Sloppy and Angela Kramer, who discussed the kinetics of tantalum oxide anodization and curvature effects on leakage current in electrolytic capacitors. Izumi also provided a sweeping 30-year overview of the use of tantalum powders for capacitor applications. Focusing on materials for piezoelectrics, Randall discussed single-crystal degradation in the PMN–PT system and how it is an example of why understanding the science of crystal chemistry is vital for defining methods for improving reliability. Trolier-McKinstry described exciting new opportunities in thin-film piezoelectrics and dielectrics, and Penn State student Russell Maier presented results crucial to defining and understanding the reliability of PZT-based actuators.

The CDS approach

The philosophy of CDS is based on the need for three types of goal-oriented research

programs: evolutionary, revolutionary and basic science. Indeed, work related to each of these goals surfaced during the presentations. Evolutionary research seeks to improve upon current materials and processing to enhance device properties and reduce cost. Along this line, Samsung's Sung-Bum Sohn and Penn State student Roni Levi presented recent findings related to barium titanate processing. Related to this, Dogan offered information concerning the methodology and effects of binder burnout in ceramic tapes.

Much of the evolution of dielectric technology depends on exploring the properties of dielectric materials in hostile conditions. As shown by Penn State student Ichiro Fuji, dielectric and piezoelectric materials exhibit nonlinear behavior at high fields. Fellow student Dennis Shay gave a talk on the importance of engineering high-energy-density linear dielectric materials for high-temperature applications. Moving from the evolutionary to the revolutionary, Randall also gave a presentation of his university's research using thin-glass-dielectric technology for achieving exceptionally high energy densities.

Basic science – the search for a better understanding of the fundamental factors that control properties or limit a device – is the third major research philosophy of the CDS. Much of current basic science is focused on characterizing the defect chemistry of metal oxides. It was appropriate, then, that local phenomena and defect chemistry were major points of discussion during the CDS meeting.

Group photo of CDS delegations and TDK employee participants during a company tour

Randall, again, made a key presentation that centered on his insights into defects and compositional developments in metal oxide ferroelectric materials. Satoko Ueda, of the TDK Corp., beautifully demonstrated the capabilities of atomic site chemical determination in defective perovskites. Dickey highlighted the work by Penn State student Xin Li in the fundamental modeling of defects in dielectric materials. Another student, Malay Samantary, demonstrated local microscale impedance measurements of commercial multilayer ceramic capacitors, and discussed the relationships between conduction mechanisms and electrode geometry. The enthusiasm was so high that participants wasted no time during the meeting, as even coffee breaks became a forum for discussions among Japanese engineers and the CDS students and faculty regarding the limitations of current dielectric technologies and strategies for overcoming them.

Reflecting on the visionaries

Participants garnered an appreciation for the importance of collaboration between U.S. and Japan, and of the good that scientists can offer the world, during a portion of the meeting set aside as a memorial tribute to the life and scientific work of the late Robert E. Newnham. Newnham, a professor at Penn State, had an impact on dielectric science – exceeded only by his impact on the scientists themselves – which was not limited by national boundaries. Those in attendance spoke of the need to continue to honor visionaries, such as Newnham, who lay the foundation for entire fields of science by studying the history of their research endeavors. Even after the adjournment of the CDS meeting, the discussions and collaboration continued, beginning with a tour of the TDK factory and its R&D facilities in Narita, where the students and faculty were received with generosity and openness. For the first time in their lives, the students had the opportunity to observe work that was connected to their own research being implemented on the industrial scale by a world leader in the electronics industry.

For graduate students accustomed to toiling away at some small aspect of a greater vision, watching the production and research efforts at TDK made them realize the value of their daily research activities. In addition, the opportunity to witness the manufacturing of powerful rare-earth magnets provided an unforgettable lesson on the importance of studying the processing and properties of metal oxides.

Another highlight of the trip was a visit to Tokyo Institute of Technology. Penn State and TIT are world leaders in the study of dielectric materials. Students from the two schools shared and compared the various courses of research undertaken at each university. Connections

made at this meeting between graduate students mark the beginning of collaborations for many years into the future. The scientific discoveries and applications of ferroelectric materials during the past 50 years were based on a fundamental understanding of physics, chemistry and crystallography and put into action by visionary scientists. The globalization of scientific research has increased dramatically in the past few decades, and the partnership among CDS, Japanese companies, and Japanese universities is at the vanguard of America–Asia collaborations. Continued success in science and technology likely will be precipitated by such joint, international efforts.

The participants in these U.S.–Japan exchanges hope to continue the rich and productive tradition of such research. They know that the trip laid the foundation for future research collaborations that will have a profound effect on the development and application of dielectric materials.