Probing the Structure and Dynamic Behaviors of Nanostructured Materials by in situ TEM

Pacific Northwest NATIONAL LABORATORY

Proudly Operated by **Battelle** *Since 1965*

Frontiers in Chemical Imaging Seminar Series

Presented by

Xiaoqing Pan, Ph.D.

Department of Materials Science and Engineering

University of Michigan

Abstract

As advances in aberration-corrected transmission electron microscopy (TEM) have enabled the determination of the three-dimensional structure of nanostructures and defects with the sub-angstrom resolution, the recent development of in situ holders and environmental cells for TEM allows us to study the dynamic behaviors of materials under applied fields and environments while the atomic structure is imaged directly. In this talk I will show our atomic resolution TEM studies of precious-metal-doped perovskites promoted by researchers in Japan as 'intelligent' three-way catalysts (TWCs) for automotive exhaust treatment, using a novel gas-cell specimen holder within an aberration-corrected scanning transmission electron microscope. We found that the precious metals do not cycle between free surfaces and the bulk of the perovskite hosts due to limited ionic diffusion. Our observations show that nanometer-scale metal particles tend to precipitate throughout the bulk of the perovskite upon reduction, and most of the metal that participates in the reversible process of metal precipitation/dissolution remain entirely within the perovskite matrix, where it is unavailable for gas-phase catalysis. I will also show that the atomic scale polarization map in ferroelectrics can be determined using aberration-corrected TEM images owing to the large atomic displacements responsible for the dipole moment. This study reveals how interfaces in complex multidomain geometries lead to the formation of polarization vortices with electric flux closure domains. Using aberration-corrected transmission electron microscopy (TEM) in combination with a customized in situ scanning probing holder the kinetics and dynamics of ferroelectric switching is followed at millisecond temporal and sub-angstrom spatial resolution in an epitaxial bilayer of an antiferromagnetic ferroelectric ($BiFeO_3$) on a ferromagnetic electrode ($La_{0.7}Sr_{0.3}MnO_3$). We observe localized nucleation events at the electrode interface, domain wall pinning on point defects, and the formation of metastable ferroelectric states localized to the ferroelectric and ferromagnetic interface. These studies show how defects and interfaces impede full ferroelectric switching of a thin film. Using the similar techniques the dynamics of ferroelectric switching in a $PbZr_{0.2}Ti_{0.8}O_3$ (PZT) film, which is a key material for nonvolatile ferroelectric memories, was also studied. It was found that 180° polarization switching initially forms domain walls along unstable planes due to the inhomogenous electric field from the small switching electrode. After removal of the external field, they tend to relax to low energy orientations. In sufficiently small domains this process results in complete backswitching. These findings suggest that even thermodynamically favored domain orientations are still subject to retention loss, which must be mitigated by overcoming a critical domain size.

Bio

Xiaoqing Pan is the Richard F. and Eleanor A. Towner Professor of Engineering at the University of Michigan – Ann Arbor. He received B.S. (1982) and M.S. (1985) degrees in Physics from Nanjing University, China, and Ph.D. degree (1991) in Physics from the University of Saarland, Germany. After a postdoctoral research fellow at the Max-Planck Institut für Metallforschung in Stuttgart, he joined the faculty of the University of Michigan – Ann Arbor as an Associate Professor of Materials Science and Engineering in 1996. He was promoted to Professor of Materials Science and Engineering with tenure in 2004. Pan is Director (2009 – present) of the Electron Microbeam Analysis Laboratory at the University of Michigan. He also served as the Director (Adjunct) of the Multifunctional Materials and Nano-device Division of the Ningbo Institute of Materials Technologies and Engineering, Chinese Academy of Science. He was the Chief Scientist of the CAS International Innovative Team (for Oversea Scientists) on Multifunctional Oxide Materials and Applications (2008-2011). Pan received the U.S. National Science Foundation's CAREER Award and the Chinese Natural Science Foundation's Outstanding Young Investigator Award. He was a named Cheung-Kong Distinguished Professor (visiting position at Nanjing University, 2008 - 2010), Chinese Ministry of Education. Pan was selected as a National Distinguished Professor (China 1000 Talent Program), as adjunct Professor at Nanjing University in 2009. He was selected as an oversea member of the Scientific Review Board, Chinese Academy of Science, 2005-2010. Pan is a Fellow of the American Ceramic Society.

Friday

November 16, 2012

10:00 am

EMSL/1077

More Info:
http://www.mse.engin.umich.edu/people/faculty/pan

Host: Nigel Browning – 375-7569

POC: Lacy Elsner – 371-6483