

Fall 2017 Joint Colloquium

Materials Department & Materials Research Laboratory

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Materials Science
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Friday, October 6th, 2017
11:00 am, Elings 1601

***In-situ* Microscopy with Atomic Resolution at Atmospheric Pressure**

Understanding the atomic structures of catalysts under realistic conditions with atomic precision is crucial to design better materials for challenging transformations. For example, under reducing conditions, certain reducible supports migrate onto supported metallic particles and create strong metal-support states that drastically change the reactivity of the systems. The details of this process are still unclear and preclude its thorough exploitation. In the past decade, most of atomic-scale transmission electron microscopy (TEM) studies involving gas-solid interactions were conducted in an environmental TEM, where the gas pressure is typically limited to less than 1/100 of atmosphere. Recently, it has become possible to overcome this limitation through a MEMS-based, electron-transparent closed cell with a heating stage.

In this talk, I will present our recent results using this device (the Protochips Atmosphere™ system) in selected catalyst systems. In a palladium/titania (Pd/TiO₂) catalyst, we directly observed the formation of the oxide overlayers on the supported Pd particles with atomic resolution under atmospheric pressure and high temperature. It shows that an amorphous reduced titania layer is formed at low temperatures, and that crystallization of the layer into either mono- or bilayer structures is dictated by the reaction environment. This transition occurs in combination with a dramatic reshaping of the metallic surface facets. *In-situ* TEM observations of a modular Pd-ceria core-shell nanostructured catalyst (Pd@CeO₂) showed that an unexpected structural transformation occurs upon heating at high temperatures. The system reaches to a stable state with the mixture of nanoparticles with two different sizes, which accounts for the exceptional catalytic properties that have been reported. Using the similar techniques, we also studied the core-shell platinum-metal (Pt-M) nanoparticles which show a catalytic performance in the oxygen reduction reaction (ORR) superior to that of pure Pt nanoparticles. To understand the formation mechanism of the Pt shell, we studied thermally activated core-shell formation in Pt₃Co nanoparticles via *in-situ* electron microscopy with the gas cell. The disordered Pt₃Co nanoparticle was found to transform into an ordered intermetallic structure after annealing at high temperature (725 °C) in 760 Torr O₂, followed by layer-by-layer Pt shell growth on (100) surfaces at low temperature (300 °C). The apparent 'anti-oxidation' phenomenon promoted by the ordered Pt₃Co phase is favorable to the ORR catalyst, which operates in an oxidizing environment.

Bio

Xiaoqing Pan is a Professor and Henry Samueli Endowed Chair in Engineering, in Department of

Chemical Engineering & Materials Science and Department of Physics & Astronomy at UC Irvine. He is also the inaugural Director of the Irvine Materials Research Institute (IMRI). Before moving to UC Irvine, Pan was the Richard F. and Eleanor A. Towner Professor of Engineering in Department of Materials Science and Engineering, and also Director of Electron Microbeam Analysis Laboratory at the University of Michigan, Ann Arbor. Pan's research interests center on understanding the atomic-scale structure-property relationships of advanced functional materials, including oxide electronics, ferroelectrics and multiferroics, and catalysts. He is recognized internationally for his work in electron microscopy, that has led to the discovery of new properties and novel functionalities in these technologically important materials. Pan has received awards including the National Science Foundation's CAREER Award and the Chinese NSF's Outstanding Young Investigator Award. Pan is a Fellow of the American Ceramic Society in 2011, a Fellow of the American Physical Society in 2013, and a Fellow of the Microscopy Society of America in 2014. Pan has published over 300 scientific papers and given more than 200 invited talks or keynote presentations at national/international conferences.

<http://imri.uci.edu/>

Hosted by Susanne Stemmer.