

Transmission electron microscope technique reveals atomic movements useful for next-generation devices

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Life in the nano lane is fast and just got faster in terms of knowledge of fundamental mechanisms working at the nanoscale—where processes are driven by a dance of particles such as atoms and ions one-billionth of a meter in size.

Advancing nanoscale understanding, a team of Chinese researchers has developed a visualization technique based on in situ transmission electron microscopy (TEM) that offers novel and powerful functionality. It directly correlates the atomic-scale structure with physical and chemical properties.

The researchers explain how their finding is important to the design and fabrication of the next-generation of technological devices this week in the journal *Applied Physics Letters*. This work has potential applications that range from smart windows based on electrochromic technology that change tint when an electrical field is applied to a window surface, to altering its opacity in response to voltage, to novel devices for managing energy, information and the environment.

Researcher Xuedong Bai, Ph.D., of Beijing's National Laboratory for Condensed Matter Physics and Institute of Physics, Chinese Academy of Sciences, and the Collaborative Innovation Center of Quantum Matter, leads a team that also collaborates with International Center for Quantum Materials, School of Physics, Peking University.

"At present, the atomic mechanism of new devices for energy, information and environmental applications is an important issue," said Bai. "The real-time imaging of atomic processes in physical and chemical phenomena is the task of the in situ TEM technique. One goal of our research is to understand the basic principles of the available devices from atomic scale, another one is to explore the revolutionary devices based on the in situ TEM imaging of the atomic processes."

In the Nobel prize-winning TEM technology, an electron beam—instead of a light beam used in traditional microscopes—is transmitted through a metal specimen under study. Due to the smaller wavelengths of electrons, TEM technology offers investigators much higher resolution so they can see more detail than is possible with a light microscope.

Bai emphasizes that the relationship between structure and property is a fundamental interest in materials science. However, one constraint to investigating this relationship is that the structure characterization and the property measurements are usually carried out separately, by conventional methods, especially for the nanoscale materials. Their novel move involved combining these steps.

"For the past 15 years, our work has been focused on the construction and applications of in situ [transmission electron microscopy](#) (TEM) technique, so the properties at nanoscale under various physical stimuli, including electric and optical, have been studied inside TEM," Bai said.

In particular, the team focused on one of the most widely used electrochemical materials, tungsten oxide, and a critical phase transition of its production. Using their streamlined TEM technique inside an electrochemical cell, their microscopic, dynamic observations revealed real-time detailed mechanisms involved in the formation and evolution of electrochemical tungsten oxide nanowires that have many applications in industry.

One of the most interesting aspects of their investigation was to probe the ion electromigration processes and their induced dynamic structural transformation. They found these are closely related with the electrochemical performance, and gained insight into the broad potential for in situ TEM imaging investigations.

"Novel properties and important science concerns can be revealed by in situ TEM imaging, for example, the electrically-driven redox process, the occupation site of lithium atoms in the operation of lithium ion batteries, and the mass transfer in the electromechanical reaction cell, can all benefit from in situ TEM imaging," Bai said.

For their next step, the researchers are extending the in situ TEM atomic scale imaging technique to combine it with ultrafast optical spectroscopy. With this extension, high-resolution imaging in both space and time will be possible.

More information: In-situ TEM imaging of formation and evolution of Li_xWO_3 during lithiation of WO_3 nanowires, Kuo Qi, Xiaomin Li, Qianming Huang, Jiake Wei, AA Zhi Xu, Wenlong Wang, Xuedong Bai and Enge Wang, *Applied Physics Letters*, June 7, 2016. [DOI: 10.1063/1.4950968](https://doi.org/10.1063/1.4950968)

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