# High-Resolution Imaging and Spectroscopy at High Pressure: A Novel Liquid Cell for the TEM

Mihaela Tanase,[1,2] Renu Sharma,[1] Glenn Holland,[1] Vladimir Aksyuk,[1] J. Alexander Liddle[1]
[1]*Center for Nanoscale Science and Technology, National Institute of Standards and Technology, 100 Bureau Drive, Gaithersburg, MD 20899*
*liddle@nist.gov*

[2]*Maryland Nanocenter, University of Maryland, College Park, MD 20742*

The transmission electron microscope (TEM), with its capabilities for atomic-scale imaging and analysis, has provided deep insight into many important problems in materials science. However, the same strong electron-matter interactions that make the TEM such a powerful tool also limit its fields of application. In particular, many important processes that take place in liquids and high-pressure gases (e.g. electrochemistry and catalysis) are currently beyond its reach. The key to resolving this dilemma is to develop systems that minimize electron interactions with everything but the material of interest, but that also enable the creation of environments that match *operando* conditions.

We have developed an integrated fabrication scheme to produce a novel, microfabricated SiN membrane-based, high-pressure cell that provides a large viewing area, whilst maintaining a uniform liquid or gas layer thickness of ≈ 100 nm. The cell design is optimized to satisfy both the mechanical constraints imposed by the pressure differential between the contents and the microscope vacuum and the electron-scattering criteria necessary to enable both lattice-resolution imaging and quantitative electron energy-loss spectroscopy to be performed. We have also developed a modular holder for the TEM that permits a microfluidic and electrochemical interface to be made with the liquid cell.

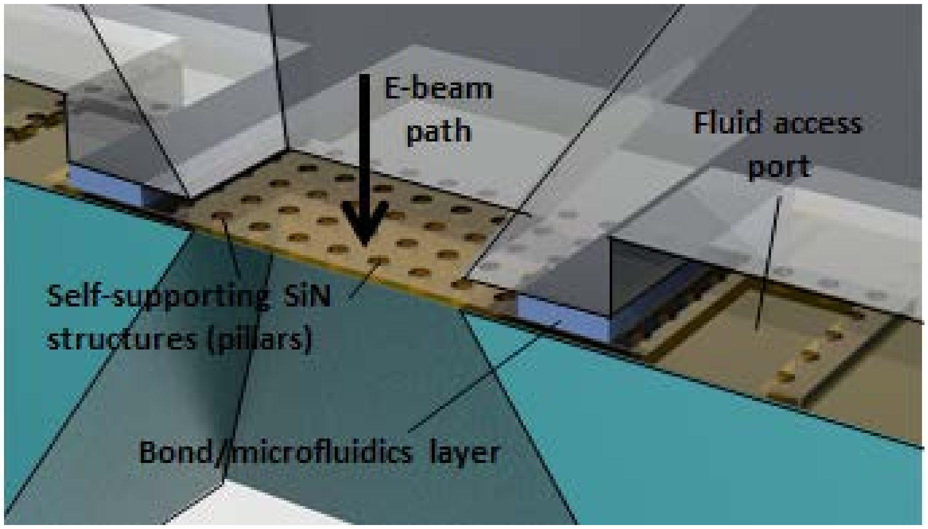


Figure 1. Schematic of microfabricated high-pressure cell.

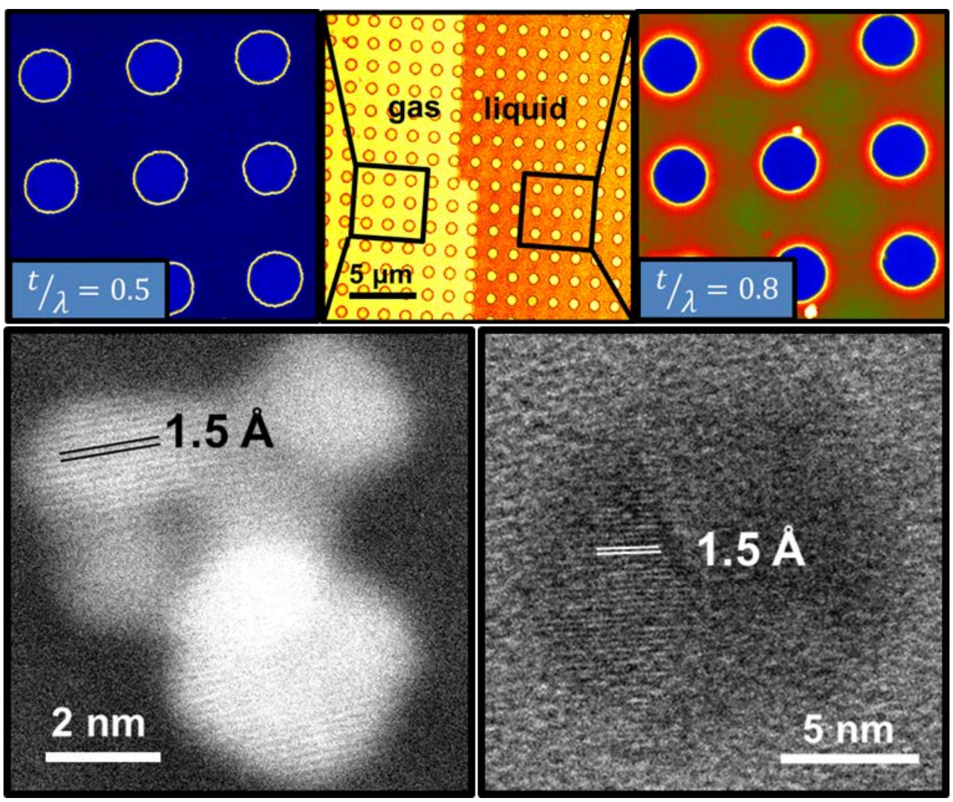


Figure 2. Electron energy-loss thickness maps for a gas-filled region of the cell (top left) and a liquid-filled region (top right) showing the uniformity of the cell thickness. Lattice images of Ag nanoparticles in liquid obtained in STEM (bottom left) and TEM (bottom right) modes.