Analysis of Defects and Interfaces with Single Atom Sensitivity through Aberration-Corrected Scanning Transmission Electron Microscopy

S. J. Pennycook[1], M. F. Chisholm[1], A. R. Lupini[1], A. Borisevich[1], M. Vareal[1], Y. Peng[1], K Van Benthem[1] and N. Shibata[1,2]

[1]Condensed Matter Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6030, USA
[2]School of Engineering, university of Tokyo, Tokyo 113-8656, Japan

The ability to correct the major aberrations of the electron microscope is bringing enormous improvements not only tin resolution but also in sensitivity. We have recently achieved a resolution of 0.06 nm in a Z-contrast image using a VG Microscopes 300 kV scanning transmission electron microscope (STEM) equipped with a Nion aberration corrector. The small beam size allows oxygen columns to be imaged within perovskite materials, and individual high atomic number dopant or impurity atoms to be imaged on and within specific columns of a crystal. In addition, a simultaneous, aberration corrected, conventional phase contrast image is available which shows oxygen columns with high contrast. Local electronic structure can be studied with electron energy loss spectroscopy, and single *atom* spectroscopy has been recently been achieved.

Applications will be presented on the study of defects and interfaces in perovskite-based oxide materials, structural ceramics, nanomaterils and catalysts, showing how single atom sensitivity and the ability to image dislocation core structures leads to new insights into structure-property relations and has solved some longstanding problems.

A previously unanticipated advantage of aberration correction is the reduced depth of focus. It is now possible to perform optical sectioning in the STEM simply be changing the focus of the beam. Single Hf atoms have been imaged in 3D in a Si/Si02/Jf02 gate dielectric structure; they are not attached to the Si implying good passivation may be possible. In future generations of aberration-corrected STEM, 3D atomic resolution imaging may become routine.