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Probing Atoms With an Electron Nanoprobe : The Frontier of Nanotechnology

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The scanning transmission electron microscope is now capable of forming electron probes of atomic dimensions. Through the technique of Z-contrast microscopy, direct images of nanostructures can be formed at atomic resolution. Furthermore, the probe can be stopped on individual atomic columns selected from the image, and analysis performed by electron energy loss spectroscopy. Our current resolution is 1.3 Å, and information transfer has been demonstrated to 0.78 Å, the world record.

Recent applications of these techniques have revealed the double helix arrangement of iodine atoms inside single wall carbon nanotubes. Complementary first-principles theoretical calculations have revealed the doping mechanism. The same combination of imaging, spectroscopy and theory has revealed the microscopic origins of the electrical barriers at $SrTiO_3$ grain boundaries. In superconductors, the same mechanisms are responsible for the poor critical currents across grain boundaries. The unique properties of nanosized metal or semiconductor clusters depend on their exposed facets, their morphology and surface termination. Recently we have shown how the Z-contrast image can be used to determine the surface reconstruction and also to reconstruct the three-dimensional shape of nanocrystals. With a highly dispersed Pt catalyst on gamma-alumina it is possible to image single atoms and small dimers and trimers. Theory can again provide the link from atomic structure to properties.

Over the next two years, we aim to reduce the microscope probe size to 0.5 Å by the correction of lens aberrations. This will result in unprecedented improvements not only in resolution, but also in image contrast and signal to noise ratio. Single atom sensitivity is predicted for both imaging and spectroscopy.