Imaging of Nanoscale Form and Function:
Atom Mapping and Correlated Functional Imaging of Semiconductor Nanowires

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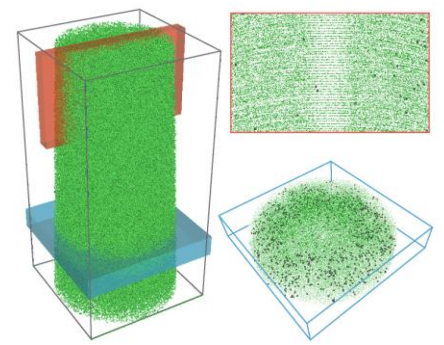
Nanowires are nanoscale in two dimensions and microscale in a third dimension, providing a wealth of opportunities to exploit novel nanoscale electronic, optical, magnetic, and thermal properties in devices with well-defined microscale electrical contacts. An attendant challenge is the establishment of quantitative structure-property relationships that enable rational engineering of new and/or superior function. In semiconductors, the dopant concentration determines the carrier concentration, so correlated studies of dopant distribution and local conductivity are important when intentional or unintentional inhomogeneities are present. In materials that undergo phase-changes near room temperature, such as vanadium oxide (VO_2), the crystal structure influences the conductivity, so local mapping of phase domains is important to understanding and controlling switching behaviors. Doping in VO_2 can also be used to control the phase transition temperature. The talk will describe the functional imaging of nanowires, that is, the correlation of local structure and electronic properties with the characteristics of devices by integrating scanning probe techniques with electrical transport measurements. We have used atom probe tomography to map the distribution of dopant atoms in Si and Ge nanowires [1,2], and we have used scanning photocurrent microscopy to correlate non-uniform dopant distributions with device characteristics [2,3]. We find that surface doping can play a useful role in the fabrication of improved nanowire transistors [4]. In VO_2 nanowires, we have used temperature-dependent Raman spectroscopy to map structural domains in devices under test, revealing the key role of the Mott insulator M_2 phase in the metal-insulator transition of clamped devices. We also find that charge injection can induce an electronic phase transition even in the absence of a structural phase transformation, i.e., we observe metallic monoclinic phases. These findings are potentially relevant to the development of the Mott field-effect transistor.

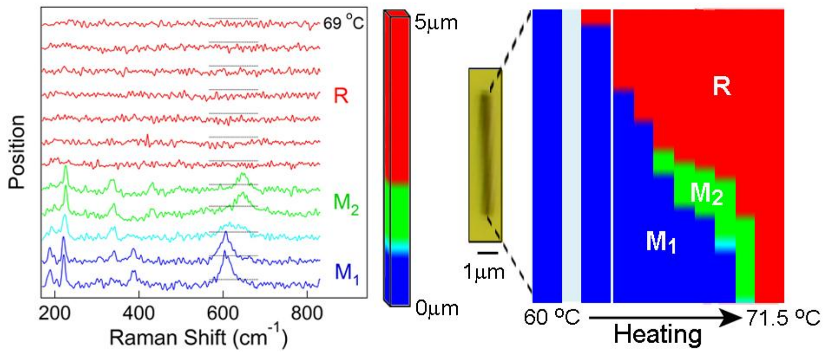
References

[1] Perea, Hemesath, *et al, Nature Nanotech*. **4**, 315 (2009).
[2] Allen *et al*, *Adv. Mater*., **21**, 3067 (2009).
[3] Zhang *et al, Nano Lett.,* **9**, 4527 (2009).
[4] Allen *et al, Nano Lett.* **9**, 1903 (2009).

Figures



3-D distribution of P atoms in Ge NW by atom probe tomography [1].



Raman domain mapping of phase transition in single VO2 nanobeam [3].