Electronic Effects of Defects in One-Dimensional Channels

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As electronic devices squeeze down to the one-dimensional limit, unusual device physics can result, even at room temperature. The effects can be probed by traditional transport measurements, but direct imaging of the electronic consequences is preferable. The development of electronic imaging modes in scanning probe microscopy provide new ways of investigating these effects. The combination with traditional transport measurements is a powerful tool for understand the electronic scattering of point defects in low dimensional devices. Here, we develop such combined methods using a model system of single-walled carbon nanotubes (SWNTs).

For instance, Kelvin Probe Force Microscopy (KPFM) directly maps the electrostatic potentials in an active device, and SWNTs provide an excellent test of the technique’s resolution. By applying KPFM to pristine SWNTs, we can directly measure potential gradients and fit them to a mean-free-path model of surface scattering (Fig. 1) [1].

A single scattering site in an otherwise pristine SWNT can dominate two-terminal device characteristics and even provide the amplification to observe single electron events at room temperature [2]. By investigating the same SWNT before and after defect incorporation, we have developed a deterministic and direct method of studying the electronic consequences of such sites.

For example, using Scanning Gate Microscopy (SGM) we have studied the gate sensitivity added by a defect site and its overall contribution to two-terminal transconductance (Fig. 2) [3,4]. Using KPFM, the potential drop across a defect can be directly resolved (Fig. 3) [5]. The contributions of defects can be fit by Frenkel-Poole trapping models, and this has led to a better understanding of SWNTs’ capabilities for single-molecule sensing [5,6].


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