Diameter-dependent electronic transport properties of Au-catalyst/Ge-nanowire Schottky diodes

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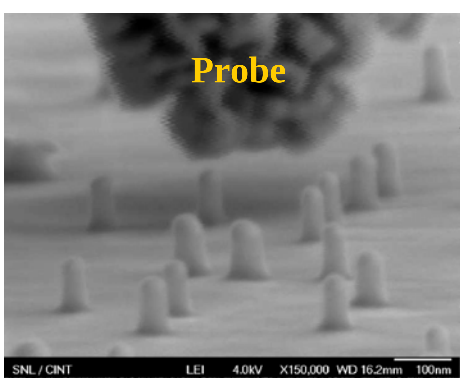
Semiconductor nanowires show promise as active elements in electronic, optoelectronic and sensing devices. Often, metal-catalyzed chemical vapor deposition is used to grow the nanowires, with Au the most frequent catalyst metal. Typically, a small hemispherical Au particle remains attached on the tip of the nanowires after the growth is ceased. To date, the electrical nature of the Au-catalyst/nanowire junction remains largely unknown. Yet, there are several scientific and technological reasons to explore the electronic transport characteristics of such contacts. For example, catalyst/nanowire junctions offer a unique opportunity to examine how nanoscale dimensions affect contact properties; and rectifying contacts to free-standing, vertically oriented nanowires could prove useful in a number of applications such as Schottky detectors and mixers.

Here, we use a microprobe retrofitted inside of a scanning electron microscope to examine the charge injection at Au-catalyst/Ge-nanowire interfaces and subsequent transport in the Ge nanowire. Our measurements indicate that this interface is rectifying with a large Schottky barrier. Remarkably, the current density increases with decreasing nanowire diameter, in contrast to common expectations. By modeling the nanowire electrostatics, we show that this arises because the current is dominated by electron-hole recombination in the depletion region, a contribution which is usually negligible in bulk junctions, but is strongly enhanced in nanowires due to the increased importance of surface recombination. Combining the modeling results with the experimental data, we find that the recombination time decreases as the nanowire diameter is decreased; a simple theory including bulk and surface recombination explains this result.



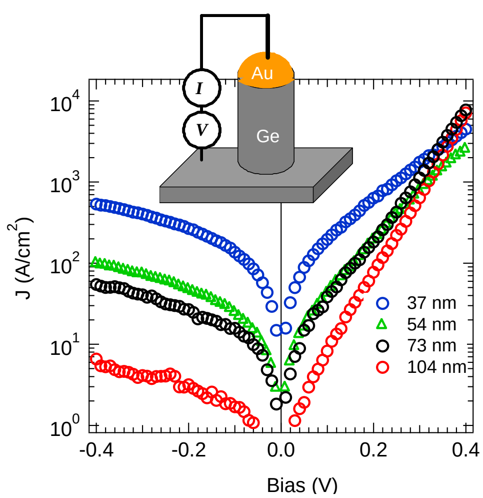


Fig. 1(a) A Au/W probe above a Ge nanowire with Au catalyst cap (b) four I-V curves showing increasing conductance and ideality factor (decreasing slope) as the nanowire diameter decreases.

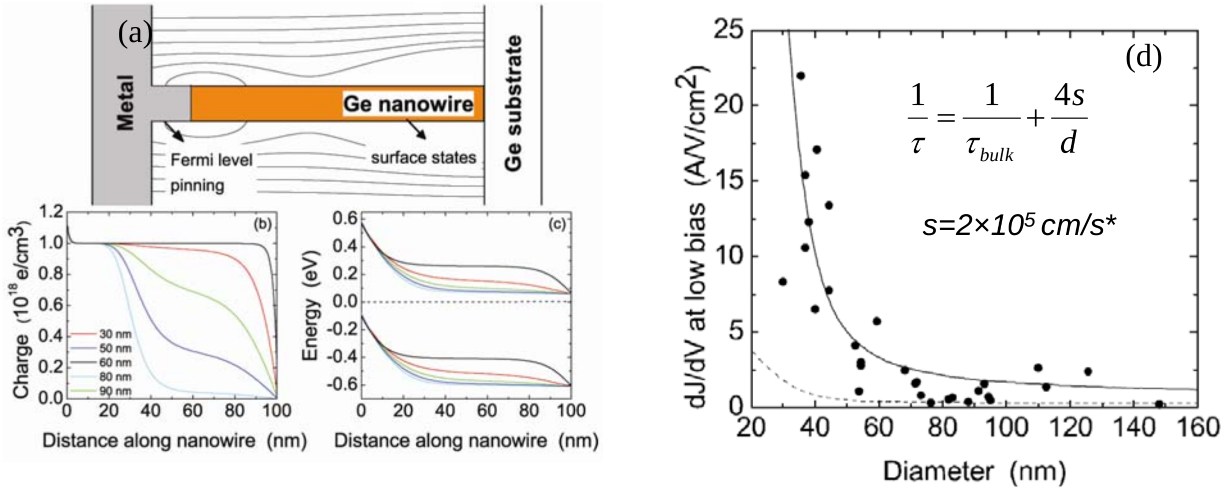


Fig. 2(a) calculated electric field and (b) self-consistent charge (c) and band-bending for nanowires of different diameters; (d) Small-bias conductance density of the Au nanoparticle/ Ge-nanowire interface as a function of the nanowire diameter. The dashed (solid) line is calculated with a diameter-independent (-dependent) recombination time.