

Devices and Interconnects at the Scaling Limits

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As electronic components scale towards nano-dimensions, quantum physics, atomic chemistry and many-body effects start to contribute crucially to their conductance. Using simple models as well as more elaborate electronic structure methods, I will discuss operational limits of such components. For wire sizes smaller than typical mean-free paths, the conductance deviates from Ohm's law due to a quantization of the conductance through each mode. The number of contributing modes, however, does not scale with metallic valency, as one may expect. To understand the origin of this non-intuitive behavior, we need to describe the mechanism of current conduction in terms of the orientation and energetics of its frontier chemical orbitals. By combining chemical intuition with transport physics, we will develop a 'bottom-up' description of current through such small systems. We will see how the current in nanoscale components can be controlled through bandstructure engineering of the channel and its contacts. In particular, the notable advantages of all-graphene devices, as well as the fundamental limits of gated molecular FETs will be discussed. Another crucial determinant of device performance is the nature of its potential profile, which includes the nature of the voltage drop and the gateability of an ultimately scaled channel. The potential profile along a metallic wire depends on the degree of screening, which in turn depends on the wire thickness as well as interwire capacitance. Decreasing the dielectric constant of the interwire dielectric decreases the interconnect delay, but increases the interwire charge tunneling through image-induced barrier lowering. Finally, for ultrascale devices many-body Coulomb Blockade effects start to dominate, that can suppress its zero-bias conductance, but also create interesting new applications involving the characterization of defects in the channel.