

Transport Characterization in Nanowires Using an Electrical Nanoprobe

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Electrical transport in semiconductor nanowires is commonly measured in a field effect transistor configuration, with lithographically defined source, drain and in some cases, top gate electrodes. This approach is labor intensive, requires high-end fabrication equipment, exposes the nanowires to extensive processing chemistry and places practical limitations on minimum nanowire length. Here we describe an alternative, simple method for characterizing electrical transport in nanowires directly on the growth substrate, without any need for post growth processing. Our technique is based on contacting nanowires using a nano-manipulator probe retrofitted inside of a scanning electron microscope. Using this approach, we characterize electrical transport in GaN nanowires grown by catalyst-free selective epitaxy, as well as InAs and Ge nanowires grown by a Au-catalyzed vapor solid liquid technique. We find that in situations where contacts are not limiting carrier injection (GaN and InAs nanowires), electrical transport transitions from Ohmic conduction at low bias to space-charge-limited conduction at higher bias. Using this transition and a theory of space-charge-limited transport which accounts for the high aspect ratio nanowires, we extract the mobility and the free carrier concentration. For Ge nanowires, we find that the Au catalyst forms a Schottky contact resulting in rectifying current-voltage characteristics, which are strongly dependent on the nanowire diameter. This dependence arises due to an increase in depletion width at decreased nanowire diameter and carrier recombination at the nanowire surface.