Conduction mechanisms in Undoped and Doped ZnO Nanowires

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Due to the wide bandgap and large exciton binding energy, ZnO is recognized as a promising material as transparent electrode, sensor, UV photodetector and emitter. It exhibits *n*-type semiconducting behavior originating from native defects, mainly of Zn interstitials or oxygen vacancies. Nanowires with diameters ranging from 20 to 50 nanometers are synthesized via pulsed laser assisted chemical vapor deposition. The as-grown nanowires are configured into field effect transistor (FET) devices through fabrication processes and measured in a 4-K helium cryostat. The conductivity of ZnO FET as a function of temperature shows Arrhenius behavior. For T > 50 K, thermally activated conduction can be expressed as $\sigma \sim \exp(-E_a/kT)$, where E_a is the activation energy attributed to the shallow donor levels below the conduction band edge. For T < 50 K, 3D Mott's variable range hopping model governs the transport, with conductivity expressed as $\sigma \sim \exp(-AT^{-1/4})$. It has been found that doping impurities not only enhances the electrical conductivity, but also could achieve higher optical transparency in the visible light range, rendering promising applications in flat panel display and photovoltaic devices. Furthermore, the quasi-one-dimensional (Q1D) structure of nanowires provides an ideal paradigm for fundamental research. We present the temperature and magnetic field dependent conductance of In doped ZnO (ZnO:In) nanowires. At low temperatures (< 20 K), the conductivity is found to follow a power law dependence of $T^{-1/2}$. In addition, the ZnO:In nanowires reveal negative magnetoresistance behavior, with resistance change proportional to B^2. The experimental results are modeled with weak localization theory in the Q1D regime.