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Conduction Mechanisms in Zinc Oxide Nanowires

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Due to the wide bandgap and large exciton binding energy, ZnO is recognized as a versatile material with promising applications in transparent electronics, sensors, UV photodetectors and emitters. It naturally exhibits *n*-type semiconducting behavior originating from native defects, mainly consisting of Zn interstitials or oxygen vacancies. Nanowires with diameters ranging from 20 to 100 nanometers have been synthesized via pulsed laser assisted chemical vapor deposition. The as-grown nanowires are configured into field effect transistor (FET) devices and measured in a 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 $\sigma \sim \exp(-E_a/k_B T)$, where E_a is the activation energy attributed to the shallow donor levels below the conduction band edge. For $T < 50$ K, 3D Mott variable range hopping governs charge transport, with conductivity expressed as $\sigma \sim \exp(-AT^{-1/4})$. Furthermore, it has been recently observed that heavily-doped ZnO nanowires behave as a quasi-1D disordered system. The doped nanowires are measured at low temperatures in magnetic fields with directions both perpendicular and parallel to the wire axes. At low temperatures ($T < 20$ K), the conductivity follows a power law dependence of $T^{-1/2}$. Negative magnetoresistance is characterized, with conductivity change proportional to B^2 . The quadratic slope of the $\Delta\sigma - B^2$ curves for the magnetic field perpendicular to the wire axis is found to be about twice as large as for that in the parallel case. These experimental results are modeled with weak localization theory in the quasi-1D regime.