Exchange-Induced Electron Transports in Heavily Phosphorus-Doped Si Nanowires

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Heavily phosphorus-doped silicon nanowires (Si NWs) show intriguing transport phenomena at low temperature. The Si NWs were synthesized by using vapor-liquid-solid (VLS) mechanism with silane (SiH_4) and Au catalyst in a low pressure chemical vapor deposition (CVD) system. We measured the resistivity of Si NW using four Pt electrodes equally distributed on the NWs with an inter-gap distance of 700 nm. As we decrease the temperature, the resistivity of the Si NWs initially decreases like metals, and starts to increase logarithmically below a resistivity minimum temperature (T_{min}), which is accompanied by (i) a zero-bias dip in the differential conductance and (ii) anisotropic negative magnetoresistance (MR) depending on the angle between the applied magnetic field and current flow. These results are presumably associated with the impurity band conduction and electron scattering by the localized spins at phosphorus donor states. The analysis on the MR reveals that the localized spins are coupled antiferromagnetically at low temperature via the exchange interaction mediated by the conduction electrons in the impurity band.