HOPPING CONDUCTION IN POLYDIACETYLENE SINGLE CRYSTALS


Introduction

Polydiacetylene (PDA) is a unique, essentially one dimensional, fully conjugated polymer, which can be polymerized without disruption of the crystallinity of its monomer. PDA crystals with the highest mobility are expected to be both non doped (or lightly doped) and demonstrate some transport features characteristic of quasi-1D systems. Therefore the better understanding of the dominant transport mechanism in PDA single crystals, especially at low temperatures, remains a question of particular interest.

Experimental

PDA-PTS (poly[2,4-hexadiyne-1,6-diol-bis-(p-toluenesulfonate)]) single crystals are synthesized in Wegner’s group. The details of synthesis are described elsewhere. The transport measurements are performed in the two-probe geometry in vacuum, 10⁻⁵ Torr with a Keithley SCS4200 semiconductor characterization system and carried out under magnetic fields up to 20 Tesla at the National High Magnetic Field Laboratory (NHMFL) in Tallahassee, Florida.

Results and Discussion

The charge transport in PDA quasi-1D single crystals (PDA-PTS) has been studied as a function of temperature, electric and magnetic fields. In the Ohmic regime the temperature dependence of the resistivity, \( \rho(T) \), is characteristic of variable range hopping (VRH) conduction with \( \rho(T) = \rho_0 \exp \left( \frac{T_0}{T} \right)^p \), with \( p \approx 0.65–0.70 \) at \( T<50K \). The charge transport in PDA quasi-1D single crystals (PDA-PTS) has been studied as a function of temperature, electric and magnetic fields. In the Ohmic regime the temperature dependence of the resistivity, \( \rho(T) \), is characteristic of variable range hopping (VRH) conduction with \( \rho(T) = \rho_0 \exp \left( \frac{T_0}{T} \right)^p \), with \( p \approx 0.65–0.70 \) at \( T<50K \).

Figure 1 Magnetoresistance in ln\[\rho(H,T)/\rho(0,T)\] vs. \( H^{-1/2} \) for the PDA sample at different temperatures.

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The charge transport in PDA quasi-1D single crystals (PDA-PTS) has been studied as a function of temperature, electric and magnetic fields. In the Ohmic regime the temperature dependence of the resistivity, \( \rho(T) \), is characteristic of variable range hopping (VRH) conduction with \( \rho(T) = \rho_0 \exp \left( \frac{T_0}{T} \right)^p \), with \( p \approx 0.65–0.70 \) at \( T<50K \). The PDA thin film didn’t show any magnetic field dependence of the resistance. However, longitudinal magnetoresistance (MR) is found to be negative in magnetic fields up to 16 T. The theory of negative MR in the VRH conduction regime predicts the following for disordered semiconductors near the metal-insulator transition; \( \ln\left[\rho(H,T)/\rho(0,T)\right] \sim \left( e^2 aH/\hbar c \right)^{1/2} \ln\left[\rho(T)/\rho(0)\right] \), where \( v \) is the critical index. Taking into account \( v \approx 1 \) and the variation of the resistivity without magnetic field \( \ln\left[\rho(T)/\rho(0)\right] \sim T^{-0.5} \), one may expect \( \ln\left[\rho(H,T)/\rho(0,T)\right] \sim H^{0.5} \) in strong magnetic fields. As can be seen from the Fig.1 our data are in qualitative agreement with this model for VRH transport. Therefore, temperature dependencies of the resistivity in both Ohmic and non-Ohmic regimes and the low temperature MR (partially) altogether demonstrate that quasi-1D VRH with the influence of electron-electron interactions is the most appropriate low temperature transport mechanism in quasi-1D PDA single crystals.

Conclusions

Magnetoresistance of PDA at \( T<4.2 \) K is negative and depends as \( \sim H^{0.5} \). The results demonstrate that at low temperature the charge transport is mainly supported due to quasi-1D VRH with the influence of Coulomb interactions.

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References