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Magnetotransport in the amorphous carbon films prepared from succinic anhydride

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Abstract

In this paper, we report the low-temperature electrical conductivity of amorphous carbon films prepared from an organic precursor succinic anhydride at different pyrolysis temperatures (700–980 °C). The films prepared at low temperatures show activation behavior. The films prepared at 900 °C and above show metal-like behavior, with positive temperature coefficient and a resistivity hump below about 25 K in the *R–T* behavior. The metal-like behavior at low temperatures was suppressed by the application of a magnetic field. The magnetoconductance in the metal-like films at low and high field limits were analyzed in terms of weak localization and electron–electron interaction models. Negligible magnetoconductance was observed at higher temperatures.
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1. Introduction

The two allotropes of carbon, diamond and graphite, are found with either complete sp^3 or sp^2 bond configuration. Between these two, disordered carbons spread in a wide range having arbitrary sp^2/sp^3 bond concentration. Diamond-like carbon, tetrahedral carbon and glassy carbon are the few non-graphitic disordered carbons having various sp^2/sp^3 ratios. Disordered carbons show a variety of electronic structures owing to the sp^2 clustering features and the absence of perfect graphitic structure. The degree of clustering of sp^2 carbons is significant in determining the electronic properties of the disordered carbon systems. Amorphous carbon is one such form of disordered structure having clustering features. The studies on the electrical properties are interesting in these

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carbons as the degree of disorder changes the mode of conduction. The carbon, polymer and doped semiconductors are interesting materials that undergo metal–insulator (M–I) transitions. Studying the behavior of electrical conductivity in these disordered systems has been an active area of research for many years. Various theories were proposed to understand the phenomena as the transition is approached from the metallic side to the insulating side. The Mott [1] prediction for variable-range hopping conductivity and the Efros–Shklovskii [2] prediction for VRH in the coulomb gap have appeared in the literature long ago and were applicable for the samples in the insulating regime. Castner [3] has summarized some interesting predictions that describe the cross over from Mott to Efros–Shklovskii VRH conductivity. The crossover from Mott to Efros–Shklovskii VRH conductivity was observed in n-Cd Se crystal [4] indium oxide film [5] at low temperatures. The transition from metallic to an insulator state is associated with the carrier localization at the Fermi level. In some cases, the localization is induced by disorder. The extent of disorder can be tuned by varying the preparation temperature, application of a magnetic field, pressure or impurity concentration. Such systems show interesting features like weak localization [6] and electron–electron (e–e) interaction [7]. Strongly doped semiconductors or heavily doped conducting polymers are good candidates for the study of M–I transition caused by disorder-induced localization. Application of pressure, magnetic field or impurity conduction can tune the position of the mobility edge with respect to the Fermi energy. The application of a magnetic field in particular is of interest in carbon compounds especially in graphite [8] pyrocarbons [9] and conducting polymers [10].

2. Experiment

The carbon films were prepared using a high-temperature pyrolysis method. The organic precursor succinic anhydride ($C_4H_4O_3$) was taken at one end-closed quartz tube and placed at the low-temperature zone of the furnace. The tube was initially evacuated to rotary vacuum level and purged with argon gas. The films were deposited at different temperatures on smoothened quartz substrate from 700 to 980 °C at 50 °C step. The substrate was placed at the high-temperature zone of the furnace. The deposited carbon films were black, shiny and reflecting in nature. The films were annealed for 2–3 h after pyrolysis to release the stresses. This improved the quality and compactness of the film. The electrical contacts were made with conducting silver epoxy paste and the van-der-Pauw technique is applied for conductivity measurements. The low-temperature magnetoconductivity measurements were done using a superconducting magnetic liquid helium cryostat.

3. Results

The XRD pattern of the films prepared at different pyrolysis temperatures showed amorphous character. Fig. 1 shows the XRD pattern of the precursor and one such carbon film prepared at 980 °C. A broad hump at $2\theta = 22.2°$ was observed, which is the characteristic of an

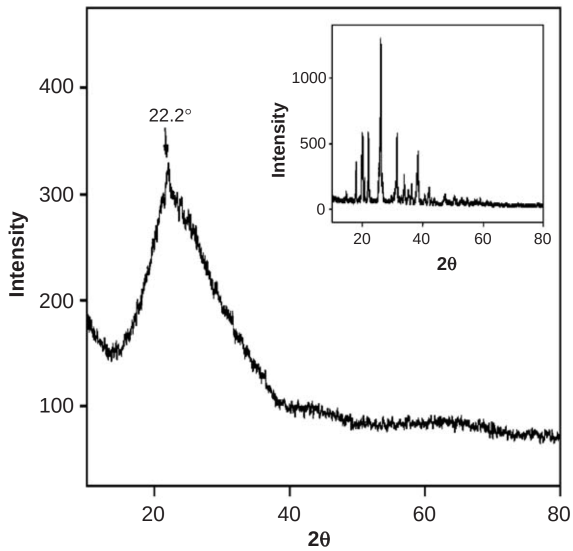

Fig. 1. X-ray diffraction of the carbon film g deposited on quartz substrate (inset shown is the XRD pattern of the precursor).

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