Characterization of Planar-type Structures in Graphite Flakes

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1. Introduction

In this paper we present the temperature dependent transport characterization for micron scale graphite flakes, through which the properties at low temperature have been discussed. Highly oriented pyrolytic graphite (HOPG) is a periodical stack of two dimensional (2-D) graphene sheets along the ***c***-axis. The interlayers of graphite are loosely bonded each other with weak Van der waals forces. We describe a technique for preparing micronscale graphite sheets out of bulk graphite, method of electrical ohmic contacts and fabrication of planar-type structures in graphite sheet using focused ion beam (FIB). We also report the temperature dependence transport characteristics for several sizes of planar-type structures patterned in graphite flakes. We have observed semiconducting behavior and a small drop in resistance during the temperature down to 30 K. This paper will further describe the current (I) – voltage (V) characteristics for those planar structures.

The electronic properties of micron scale graphite and graphene have been attracted much attention nowadays from the point of view of basic research and applications. The charge carriers in graphene are predicted to have zero effective mass and the transport properties are expected to be governed by the relativistic Dirac equation. The discovery of carbon nano tubes, which are rolled up graphene sheets, has brought renewed interest in this material. Bulk graphite has been studied for decades, but there has been no work done on thin mesoscopic samples. HOPG is a suitable starting material for getting graphene, not only because of its availability in large quantity and in large size pieces, but also because of its unique structure. It is polycrystalline with highly oriented graphene sheets, the typical domain size in HOPG is 1 to 10 µm in the basal plane and greater than 0.1 µm perpendicular to basal plane.

2. Sample Preparation

We have used Si/SiO_2 substrates which were cleaned by using acetone. Then the substrates were put in ultrasonic bath for 15min. The graphite flakes used in this study are extracted from HOPG.
We have used the method of repeated peeling off the surface layers of HOPG using 3M scotch tape and transferred to Si/SiO_2 substrate in order to obtain micron scale graphite flakes. The silver paint has been used for making electrodes and focused ion beam (FIB) has been used to fabricate planar-type structures on the sample.

3. Experimental results

The close cycle refrigerator system has been used for resistance-temperature (R-T) measurements and current-voltage characteristics at low temperature. We have fabricated 10x10 μm^2 6x5 μm^2, 6x2 μm^2 and 1x1 μm^2 sizes of planar-type of graphite structures using FIB. The in-plane resistance shows a gradual increase into high resistance value of Mega ohm at 30 K. This exhibits semiconducting behavior and a small drop in resistance at 49 K for the 10x10 μm^2 planar structure as shown in Fig. 2.

The other planar structures of 6x5 μm^2, 6x2 μm^2, and 1x1 μm^2 also show small drops in resistance at 54 K, 69 K, and 102 K respectively. This result reveals that the temperature values where the resistance drops are varying depend on the in-plane areas. This behavior may be due to the offset of weak localization of graphite at low temperature. Also we have performed Current-Voltage characteristics for these planar-type graphite structures. Figure 3 represents I-V characteristics for 10x10 μm^2 structure measured at 300 K and 30 K. It shows exact ohmic behaviour at 300 K and diode-like characteristics at 30 K. Due to weak interlayer interaction forces (Van der waals forces) between neighboring layers of graphite flake, the high electric resistances may be generated by adjacent domains.

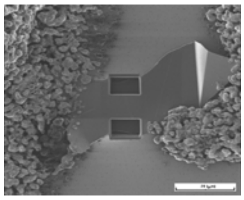

Fig. 1 FIB image for the 10x10 μm^2 planar-type structure.

4. Summary

In summary, we consolidate our results of temperature dependent transport characteristics, the sample preparation technique, fabrication details of planar-type structures in graphite flake. The in-plane resistance measurement results exhibit semiconducting behavior for these planar-type structures. Also we have discussed I-V characteristics for these planar-type structures and found ohmic behavior at 300 K & diode-like characteristics at 30 K.

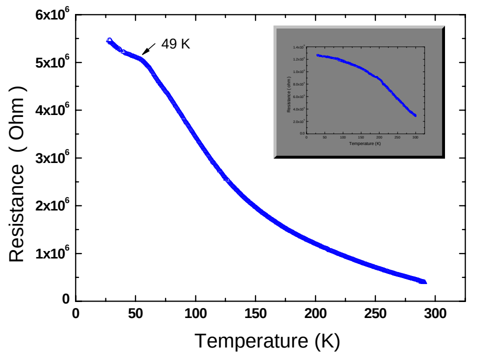

Fig. 2 R-T characteristics of 10x10 μm^2 planar-type structure. Inset shows no drop in resistance for graphite flake without planar structure.

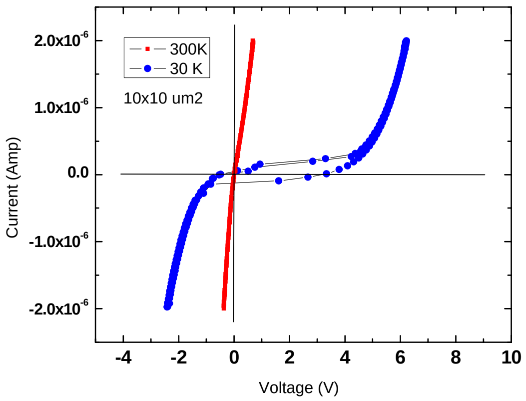

Fig. 3 I-V characteristics for the 10x10 μm^2 planar type structure.

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