Micro fabrication of planar-type structures on graphite layer using Focused Ion Beam and Transport characterization

V. Gunasekaran,* S. J. Kim#
Nano Materials & System Lab, Dept of Mechanical Engineering
Jeju National University, Jeju 690-756 Republic of Korea
*Email: *guna@cheju.ac.kr, # kimsangj@cheju.ac.kr*

We have demonstrated the fabrication of planar-type structures on thin graphite layer using focused ion beam (FIB) 3-D etching technique and their electrical transport characteristics results. In this study, we used the mechanical exfoliation technique to obtain thin graphite crystallites. Figure 1 shows the SEM image of exfoliated graphite layer on Si/SiO_2 substrates. We have fabricated several in-plane areas of planar-type structures on thin graphite layers (thickness ~ 500 nm) using focused ion beam. Those in-plane area sizes were 10 μm x 10 μm, 6 μm x 5 μm and 6 μm x 2 μm. These in-plane areas were etched by the tilting the sample stage by 30º anticlockwise with respect to ion beam and milling along *ab*-plane. The *c*-axis stack with height of several nanometers were fabricated (Fig.2) by rotating the sample stage by an angle of 180º and then tilted by 60º anticlockwise with respect to ion beam and milled along the *c*-axis[1]. The electrical transport characteristics were performed for both *ab*-plane and *c*-axis stack structures using four-probe contact measurement by closed-cycle refrigerator system.

Resistance *(R)*-temperature *(T)* characteristics of bare graphite flakes reveal its typical metallic behavior which is shown as inset in Fig.1. However the fabricated planar-type structures (inset in Fig.3) of all the different sizes show semiconducting behavior. Most noticeably, we find a nonlinear curve-like behavior in current *(I)* - voltage *(V)* curves at 20 K and an ohmic behavior at 300 K. An asymmetricity in I-V curves is also observed (Fig.3). We notice that the least size of planar-size structure provides more resistance to charge carriers. The fabricated *c*-axis stack also shows semiconducting behavior with high raise in resistance at 20 K (top right inset in Fig.2). However, the *c*-axis stack exhibits a symmetric non-linear I-V characteristics (Fig.4). The *c*-axis stacks behave as a high barrier to charge carrier tunnelling. This is because of the high resistance generated by weakly bonded adjacent layers in the stack[2]. The observation of this transition from linear to non-linear behavior along *ab*-plane and *c*-axis stack of graphite sheets will open a route to new generation graphite based non-linear electronics devices.

[1] S. J. Kim, and T. Yamashita, J. Appl. Phys. **91**, 8495 (2002).

[2] B.T. Kelly, *Physics of graphite* (Applied Science: London, 1981), pp 267-361.

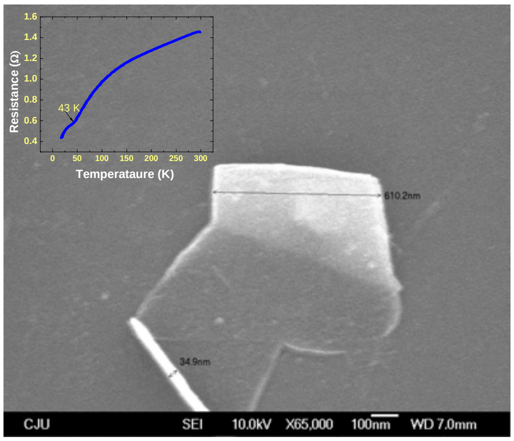

Fig 1: SEM image of graphite crystallite obtained from mechanical exfoliation technique (image scale bar 100 nm.) Inset shows the perfect metallic behavior of bare graphite flake.

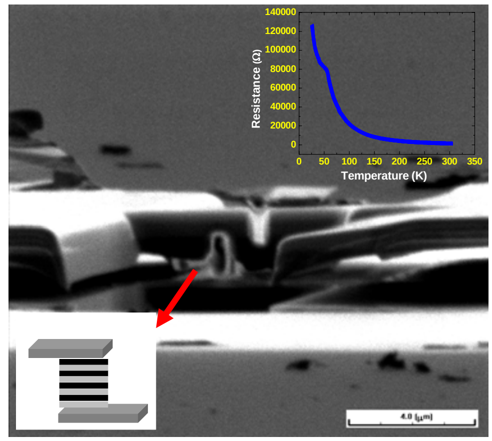

Fig 2: The FIB image of *c*-axis stack fabricated on graphite layer. The size was W = 2 μm, L= 1 μm, H = 200 nm. Inset(left bottom) shows the schematic diagram of stack along the *c*-axis. Inset (top right) shows the semiconducting behavior of *c*-axis stack.

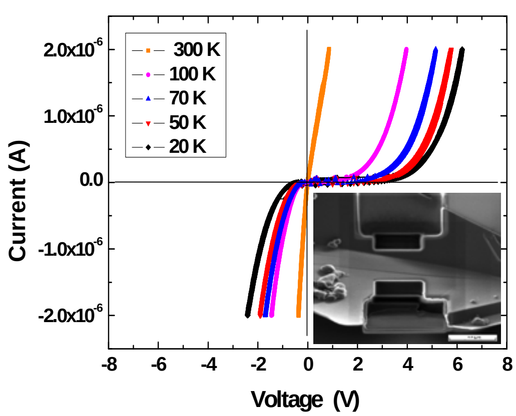

Fig 3: I-V characteristics of the 6 μm x5 μm planar-type structure. Inset shows the FIB image of 6 μm x5μm planar-type structure fabricated on a graphite layer (image scale bar 6 μm).

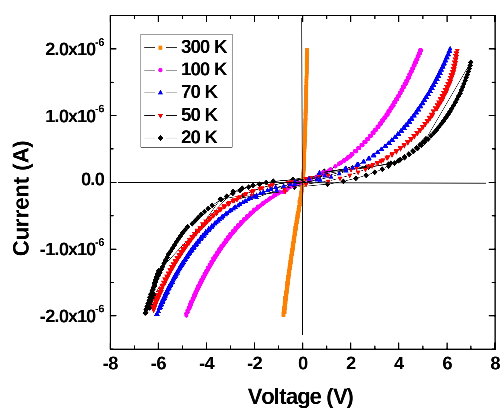

Fig 4: I-V characteristics of *c*-axis stack which shows symmetric non-linear behavior.