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Synthesis and chemical doping of millimeter-size homogeneous epitaxial graphene on SiC

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Graphene is a supreme material with many extraordinary physical, chemical, thermal and optical properties. The extensive theoretical and experimental studies of graphene in the past two decades have demonstrated its future application in metrology, electronics, optics and energy-harvesting devices. For example, the ultrahigh mobility and transparency of monolayer graphene make it a strong candidate for transparent conducting electrodes in solar cell.

While the legendary exfoliation technique that produced the first graphene in the world still supplies the highest quality graphene flakes, the two popular methods to obtain large-scale monolayer graphene are chemical vapor deposition (CVD) on metal foils and epitaxial growth on SiC. At NIST, we grow epitaxial graphene (EG) on SiC(0001) substrates using a FTG (face-to-graphite) technique at 1200°C ~ 2000°C with 101 –kPa Ar background. Large-area and homogeneous monolayer graphene is obtained on the Si-face of the SiC substrate and characterized by Raman microscopy, AFM, contrast-enhanced microscope, and magneto-resistance measurement. The transparent SiC substrate allows quick screening for desired EG through the contrast-enhanced technique.

We also developed a polymer-free process for high-quality quantum Hall effect devices by protecting graphene with a thin precious metal layer during the fabrication. The etchant to remove the precious metal layer initiates a chemical doping process which reduces the inherent high electron-doping level in EG. The doping level can be reversed by annealing in vacuum at moderate temperatures. One of our high-quality, large-scale (5 mm x 5 mm) octagonal EG devices has demonstrated the possibility of using EG for the next generation of resistance standard. Nowadays, devices used for quantum Hall effect (QHE) resistance standards are GaAs heterostructures operated below 1.6 K with current ~50 μA in intermediate to high magnetic fields. We observed robust $\nu = 2$ QHE plateaux in the EG device at 9 T magnetic field for temperatures up to 5 K and 3.4 K, respectively, for the two perpendicular orientations of current. Over the magnetic field range 7 T – 9 T, zero longitudinal resistivity ρ_{xx} was measured at an uncertainty of 150 μΩ for temperature 2.7 K and source-drain current 70 μA.

Keywords: epitaxial graphene, SiC, quantum Hall effect, polymer-free, chemical doping