Low temperature transport on surface conducting diamond

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Abstract: Magneto-transport measurements were performed on surface conducting hydrogen-terminated diamond (100) hall bars at temperatures between 0.1-5 K in magnetic fields up to 8T.

1 Introduction: Diamond with a band gap of 5.47 eV is an insulating material when undoped. However, when the diamond surface is terminated with hydrogen and then exposed to air or synthetic surface adsorbates, a p-type surface conductivity is observed [1]. Changes in the electronic properties of the diamond surface as a result of this p-type surface conductivity are well understood [2,3], and transport measurements on surface conducting diamond have been performed at room temperature and liquid nitrogen temperatures [4,5]. However, little attention has been paid to the transport properties of the p-type carriers in diamond at liquid helium temperatures and in high magnetic fields.

2 Experiment: Two samples were used in this study: an electronic grade sample (E1) with low impurity content and surface roughness ~0.1 nm and one standard grade sample (SG1) with a higher level of impurities and larger surface roughness ~1.0 nm. Hall Bars were fabricated on these samples using standard photolithography techniques. In the inset of Fig. 1 the blue region of the Hall Bar represents the h-terminated conducting region and the region outside of the Hall Bar is insulating oxygen-terminated diamond. After fabrication magneto-transport measurements were performed using a dilution refrigerator at temperatures between 0.1-5.0 K in magnetic fields up to 8 T.

3 Results: Figure 1 shows the sheet conductivity as a function of temperature between room temperature and 0.1K. Both samples show only weak temperature dependence with the electronic grade sample having a higher room temperature sheet conductivity. Carrier activation energies have been determined from Fig. 1 to be 0.43 meV and 0.14 meV for SG1 and E1 respectively in the linear region.

Longitudinal resistivity $\rho_{xx}$, and Hall resistivity $\rho_{xy}$ was measured as a function of magnetic field perpendicular to the sample, for temperatures between 0.3 K and 5.0 K for both samples. Fig. 2 shows the data for E1 at 3.9 K. From a linear fit to the Hall resistivity as a function of magnetic field the hole concentration is found to be $\sim 10^{13}$ cm$^{-2}$, very close to that obtained at room temperature indicating no carrier freeze out. The mobility of 78 cm$^2$V$^{-1}$s$^{-1}$ has slightly decreased from the room temperature value of 105 cm$^2$V$^{-1}$s$^{-1}$; this follows the change in sheet conductivity which decreases with temperature. This low carrier mobility at cryogenic temperature is attributed to scattering from adsorbate anions.

Fig. 1. Main: Sheet conductivity as a function of temperature. Inset: Image of a Hall Bar fabricated on IIa (100) diamond.
Surface conductivity on diamond deals with a 2D system with carriers and scatterers confined to two adjacent planes separated by only a few nanometers [2]. With such a small separation between the charge sheets, scattering from anions in the adsorbed water layer is expected to be the dominant scattering mechanism.

Magneto-resistance as a function of magnetic field in Fig. 2 exhibits weak localization similar to that observed for highly disordered Si:P δ-doped two-dimensional electron systems [6].

Further magneto-transport measurements are required between 4K and mK at constant temperature to fully understand the hole-hole interaction in this highly disordered system and to obtain the weak localization correction to the Drude conductivity.

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