Superconductivity in Two-dimensional Crystals

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Since the first isolation of graphene in 2004 several theoretical [1] and experimental [2,3] works have addressed the problems of superconductivity and the superconducting proximity effect in it. Here we describe our experiments in this field that include studies of both the proximity effect in single and few-layer graphene flakes as well as the superconducting transition in few unit cell chalcogenide flakes. Graphene structures with superconducting Al electrodes have been realised by micromechanical cleavage techniques on Si/SiO_2 substrates. Devices show good normal state transport characteristics, efficient back-gating of the longitudinal resistivity, and low contact resistances. Proximity-induced critical currents are being investigated in devices with junction lengths in the range 250-750nm, and characterised as a function of temperature, back gate voltage (carrier type – electron/hole) and magnetic field.

In addition this work has been extended to investigations of two-dimensional superconducting crystals of $NbSe_2$ produced using the same techniques used for graphene except with normal Au electrodes. While very thin $NbSe_2$ flakes do not appear to conduct, slightly thicker flakes are superconducting with a T_c that is only slightly depressed from the bulk value (7.2K). The resistive transition shows a rather sharp high temperature transition to about 50% of the normal state resistance followed by a much broader tail-like transition to zero resistance at very low temperatures, and exhibits a dependence on back-gate voltage, albeit a relatively weak one. The behaviour of several flakes has been characterized as a function of temperature and applied field. The sharp high temperature transition could be indicative of the formation of superconducting order in inhomogeneous ‘puddles’ while the low temperature tail is reminiscent of a Berezinskii–Kosterlitz–Thouless (BKT) transition due to the binding/unbinding of vortex-antivortex pairs. Our results will be analysed in terms of available theories for these phenomena.

References

[1] M. V. Feigel'man *et al*., Solid State Communications **149**, 1101 (2009).
[2] H. B. Heersche *et al*., Nature **446**, 56 (2007).
[3] A. Kanda *et al*., Physica C **470**, 1477 (2010).