Title: Superconductivity in Two-Dimensional Crystals

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Abstract

Since the first isolation of graphene in 2004 interest in superconductivity and the superconducting proximity effect in monolayer or few-layer crystals has grown rapidly [1]. Here we describe investigations of the superconducting transition in few molecular layer dichalcogenide flakes. Our lithographically-defined 4-terminal devices have been realised by micromechanical cleavage from a 2H-$NbSe_2$ single crystal onto Si/SiO_2 substrates followed by the deposition of Cr/Au contacts (c.f., the atomic force microscope image in Figure 1). Atomic force microscopy and Raman spectroscopy have been used to characterise the quality and number of molecular layers present in our flakes [2]. While very thin $NbSe_2$ flakes do not appear to conduct, slightly thicker flakes are superconducting with an onset T_c that is only slightly depressed from the bulk value (7.2K). Figure 2 plots the 4-point resistance of one of our devices from 0-300K. The resistance typically shows a small, sharp high temperature transition followed by one or more broader transitions which end in a wide tail to zero resistance at low temperatures (c.f., inset of Fig. 2). The temperature of the highest transition drops slowly as the flake thickness decreases in agreement with earlier works [3,4]. Estimates of the 300K resistivity for our flakes are several times higher than that found in bulk single crystals, and we speculate that these multiple resistive transitions are related to disorder in the layer stacking rather than lateral inhomogeneity as was proposed by Frindt [3]. The behaviour of several flakes has been characterised as a function of temperature, applied field and back-gate voltage. We find that the resistance and transition temperatures depend weakly on the gate voltage, with both conductivity and T_c *decreasing* as the electron concentration is *increased*. The application of a small perpendicular magnetic field rapidly suppresses the highest temperature T_c and for H>0.2T the transition broadens into a single featureless curve. Our results will be analysed in terms of available theories for these phenomena.

References:

[1] Novoselov K. S., et al., PNAS 102, (2005), 10451.

[2] Dattatray J. Late, et al., Advanced Functional Materials 22, (2012), 1894-1905.

[3] Frindt, R. F., Physical Review Letters 28, (1972), 299.

[4] Neal E. Staley, et al., Physical Review B 80, (2009), 184505.

Figure 1:

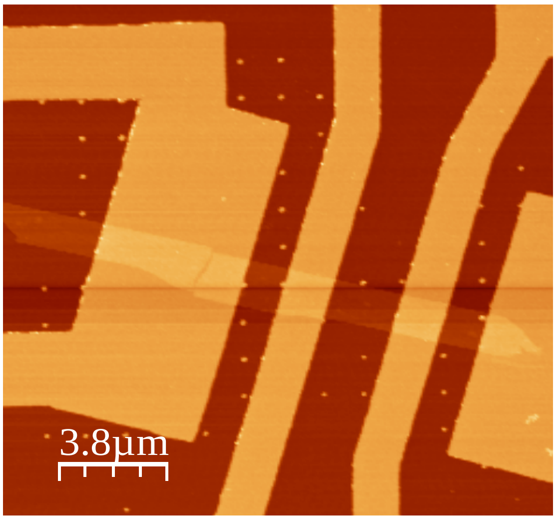

Figure 2: