Weak anti-localisation in p-type surface conducting (100) hydrogen-terminated diamond: Proof of a 2DHS

M. T. Edmonds[1], L. H. Willems van Beveren[2], O. Klochan[3], J. Cervenka[2], S. Prawer[2], L. Ley[1,4], A. R. Hamilton[3] and C. I. Pakes[1]

[1] *Department of Physics, La Trobe University, Victoria, Australia*
[2] *School of Physics, The University of Melbourne, Victoria, Australia*
[3] *School of Physics, University of New South Wales, Sydney, New South Wales, Australia*
[4] *Institut für Technische Physik, Universität Erlangen, Erlangen,Germany*

Hydrogen-terminating an insulating diamond and exposing it to air results in electrons being transferred out of the diamond valence band into the adsorbed water layer so that holes accumulate near the diamond surface and give rise to *p*-type surface conductivity. This doping mechanism is known as surface transfer doping and allows doping of diamond without introducing impurities into the diamond lattice [1]. Whether this *p*-type surface conductivity is confined to a two-dimensional hole system (2DHS) has yet to be conclusively proved experimentally, in part because the highest mobility of the holes accumulated at the diamond surface is less than μ~500 $cm^2V^{-1}s^{-1}$.

We have fabricated high quality (100) hydrogen-terminated diamond hall bars, and performed low temperature magneto-transport measurements on the *p*-type surface conducting state. We observe clear weak localization and weak anti-localization effects, which are in excellent agreement with the Hikami-Larkin-Nagaoka model of two-dimensional localization [2]. The extracted phase coherence length obeys a power-law dependence with temperature of $l_\phi \sim T^{-0.45}$ in agreement with the theoretical prediction by Altshuler et al. for 2D systems [3]. This data provides direct evidence for the formation of a two-dimensional hole system at the hydrogen-terminated diamond surface.

The observation of weak anti-localization is a result of the strong spin-orbit interaction present at the diamond surface due to a lack of inversion symmetry that is predicted by DFT calculations. From calculation of the in-plane carrier effective mass the phase and spin coherence times were determined. The presence of spin-orbit interaction at the hydrogen-terminated diamond surface is also discussed, along with the implication for quantum information processors [4] and magnetometers [5] that utilise NV centres located near the hydrogen-terminated diamond surface.

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