Supplementary Material

Engineering the Spin-Orbit Interaction in Surface Conducting Diamond with a Solid-State Gate Dielectric

Kaijian Xing, [1] Alexander Tsai, [2] Daniel L. Creedon, [2] Steve A. Yanni, [1] Jeffrey C. McCallum, [2] Lothar Ley, [3] Dong-Chen Qi, *, [1, 4, 5] Christopher I. Pakes *, [1]

* Corresponding author: Dong-Chen Qi, Christopher I. Pakes

[1] Department of Chemistry and Physics, La Trobe Institute for Molecular Science, La Trobe University, Melbourne, Victoria 3086, Australia

[2] School of Physics, The University of Melbourne, Melbourne, Victoria 3010, Australia

[3] Institute for Condensed Matter Physics, Universität Erlangen, Staudt-Str. 1, 91058 Erlangen, Germany

[4] Centre for Materials Science, Queensland University of Technology, Brisbane, Queensland 4001, Australia

[5] School of Chemistry and Physics, Queensland University of Technology, Brisbane, Queensland 4001, Australia

1. Determination of an initial value of K_{HH}

An initial value of K_{HH} was determined following the approach of Goh *et.al.*,[1] using the fact that the HHI produces a ~ln(T) correction to the Hall coefficient, ΔR_H. This term is evaluated from the change in Hall coefficient at different temperatures,

$$\Delta R_H = \frac{R_H - R_H(8K)}{R_H(8K)} \quad , \tag{S1}$$

under the assumption that at 8 K the Hall resistance approaches its Drude limit. Figure S1 shows a plot ΔR_H vs. ln(T) for each gate bias. The slope of ΔR_H vs. ln(T) in each case provides guidance as to the value of K_{HH}:

$$K_{HH} = -\frac{Slope \cdot \sigma_{xx}(8K)}{2G_0}, \tag{S2}$$

where σ_{xx} is the longitudinal conductivity and $G_0 = e^2/\pi h$. From eqn. S2 an initial value for K_{HH} is attained, however, further fitting of K_{HH} is required to ensure that the HHI correction is appropriate as described in the manuscript.

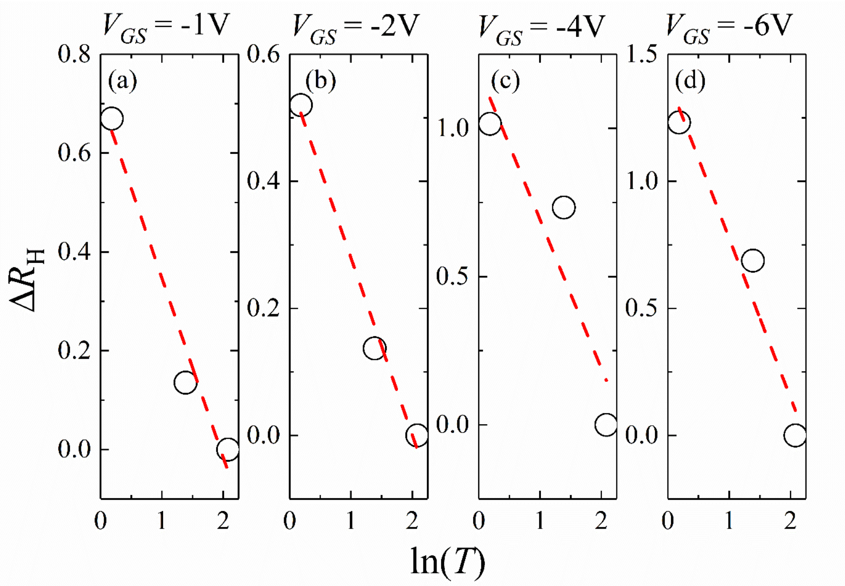

Figure S1: ΔR_H plotted as a function of temperature for different gate biases, illustrating a logarithmic dependence on temperature. The slopes are the initial K_{HH} at different gate bias.

2. Hall resistance, R_{xy}, before and after removal of the HHI correction

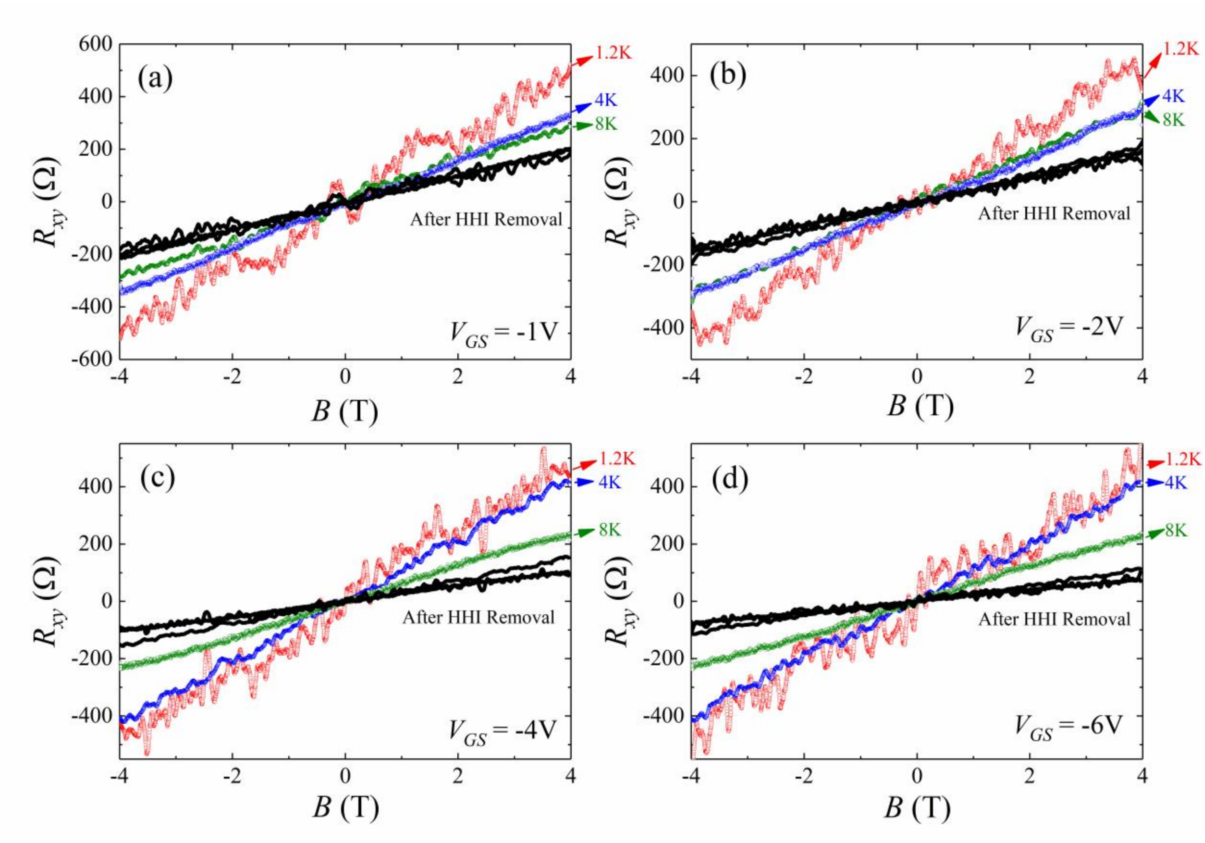

Figure S2. Hall resistance measured as a function of applied magnetic field and temperature in the range 1.2 K to 8 K. Data for gate biases of -1 V, -2 V, -4 V and -6 V are shown in (a), (b), (c), and (d) respectively. Each of the temperature dependent $R_{xy}(B)$ traces collapse onto a single slope, as illustrated by the black lines, after removal of the HHI correction to the Drude conductivity.

3. Dependence of B_{SO} and L_{SO} on hole carrier density

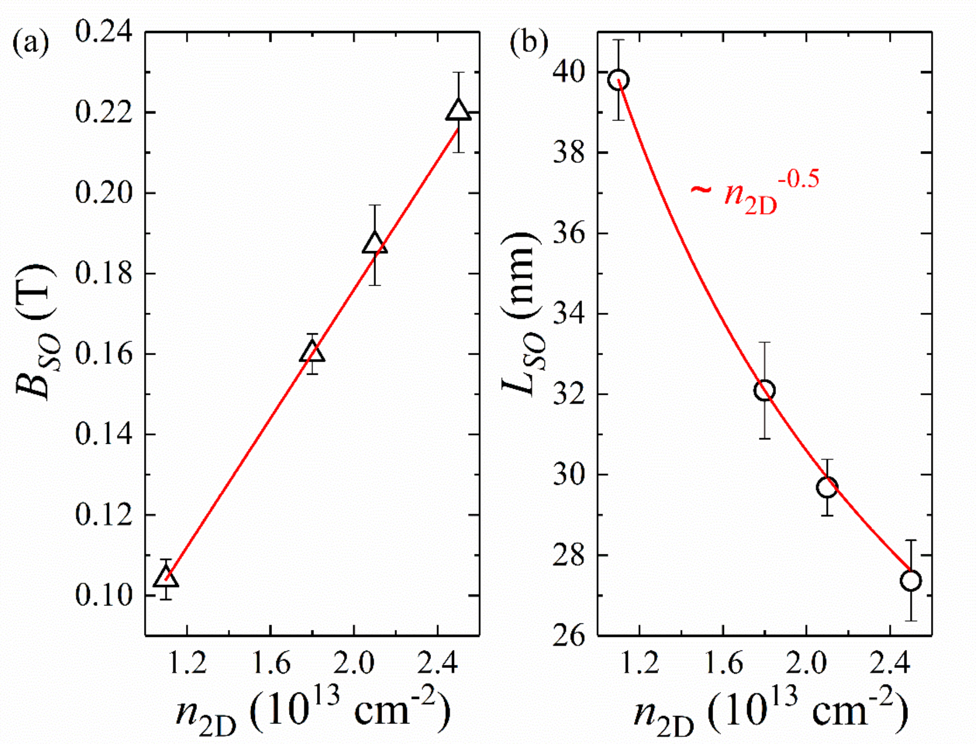

Figure S3: The spin coherence field B_{SO} (a) and spin coherence length L_{SO} (b) plotted as a function of hole density.

4. Summary of the key parameters

	V_{GS} (V)			
	- 1.0	- 2.0	- 4.0	- 6.0
K_{HH}	0.10 ± 0.01	0.21 ± 0.01	0.55 ± 0.01	0.81 ± 0.01
l (nm)	0.80 ± 0.02	1.01 ± 0.02	1.32 ± 0.01	1.40 ± 0.02
D (m^{2}s^{-1})	1.87×10^{-4}	2.73×10^{-4}	4.31×10^{-4}	4.96×10^{-4}
τ_{SO} (ps)	11.0	3.7	2.0	1.5
B_{ϕ} (T)	0.14±0.02	0.19±0.02	0.15±0.01	0.16±0.01
L_{ϕ} (nm)	34.3 ± 0.1	29.4 ± 0.1	33.14 ± 0.05	32.09 ± 0.05

Table S1: Key parameters evaluated from fitting of the experimental data: hole-hole interaction strength (K_{HH}); hole mean free path (l); diffusive constant (D); and spin relaxation time (τ_{SO}). The diffusive constant is given by $D = l^2 / 2\left(\sigma_D m^* / n_{2D} e^2\right)$, where the mean free path, $l = \left[\left(2\pi\right)^{0.5} \hbar\sigma_D\right] / \left[e^2\left(n_{2D}\right)^{0.5}\right]$, σ_D is the Drude conductivity and m^* is the in-plane hole effective mass. The phase coherence length is given by $L_\phi = \left[\hbar / \left(4eB_\phi\right)\right]^{0.5}$.

Reference

[1] K.E.J. Goh, M.Y. Simmons, A.R. Hamilton, *Phys. Rev. B - Condens. Matter Mater. Phys.* **2008**, 77, 235410.