Quantum Transport in Nanostructures at the Interface of $LaAlO_3/SrTiO_3$

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Introduction

The 2D electron liquid (2DEL) forming at the interface of $LaAlO_3$ (LAO) and TiO_2-terminated $SrTiO_3$ (STO) expresses signatures of superconductivity, magnetism, and strong spin-orbit coupling. Conducting AFM (c-AFM) lithography[1] is used to write nanostructures at the interface with nanoscale precision to study these properties and their interactions in quasi-one-dimensional (q-1D) geometries.

Experimental

We wrote various low-dimensional (~10-50 nm line width) conducting nanostructures at the LAO/STO interface using c-AFM and studied magnetotransport at low temperatures in SCM-1 of the DC Field facility.

Results and Discussion

Figure 1a-b shows the out-of-plane and in-plane Hall magnetoresistance of a multi-terminal nanostructure (**Figure 1c**). Current is sourced through channels that are either parallel or perpendicular to the in-plane magnetic field (Figure 1c). The out-of-plane Hall magnetoresistance for both channels shows a crossover from carriers with density n=2.5x10^{13} for B<5 T to n=3.5x10^{13} for B>5 T. The in-plane Hall magnetoresistance shows a sudden increase near this transition as the field is raised above $B\approx$5 T. This may indicate that the intrinsic in-plane magnetism has different strengths for the two carriers. In a similar device, we see a large *nonlocal* resistance R_{nl}>1.5 kΩ (**Figure 1d**). Current is sourced between two local leads, and the nonlocal voltage is measured by two other leads that are separated from the current-carrying channel by 6.5 µm. The nonlocal voltages are suppressed in the presence of Cooper pair formation, when the magnetic field is below the superconducting critical field (Figure 1d). The long, 6.5 µm channel means it is unlikely that the nonlocal signal arises from spin diffusion. Similar experiments at fields below 9 T (Ref. 2) also suggest long coherence lengths in these nanostructures.

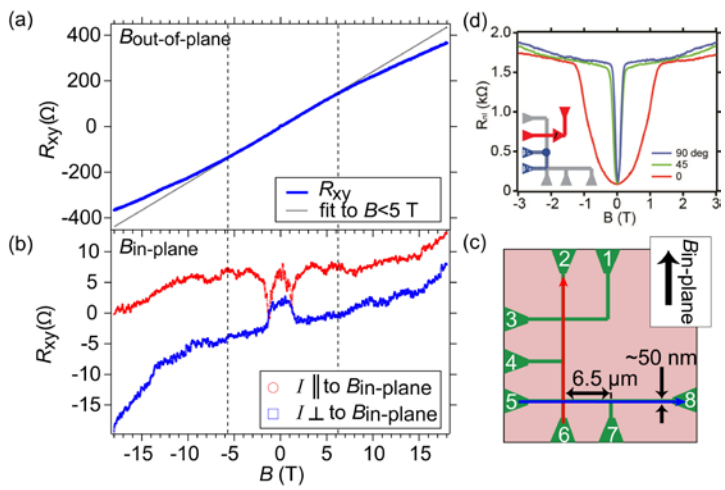

Figure 1: (a) Out-of-plane and (b) in-plane Hall magnetoresistance for current-carrying channels parallel to and perpendicular to the in-plane magnetic field. (c) Schematic of the nanostructure from (a-b). For the parallel (perpendicular) channel, current is sourced between leads 6/2 (8/5), while Hall voltage is measured between 8/5 (6/2). (d) Nonlocal resistance observed when sourcing current between 3/1 and measuring voltage between 5/4, 6.5 µm away. The signal vanishes in the presence of Cooper pairs (B<B_{c2}).

Conclusions

We observed a crossover at high magnetic fields between two different carrier bands in LAO/STO nanostructures. The in-plane high magnetic field suggests that the intrinsic in-plane magnetism may be attributed to one type of carrier. In addition, we observe nonlocal resistances that vanish in the superconducting state, suggestive of long-range spin-coherent transport.

Acknowledgements

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References

[1] Cen, C., *et al*., Nature Materials, **7**, 298-302 (2008).
[2] Cheng, G., *et al*., unpublished.