Doping of Py/Ag/Py lateral spin valves with non-magnetic impurities

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Abstract

Pure spin currents are the spintronic phenomena that describe the transfer of spin information without the accompanying transfer of charge. They can be achieved in nanoscale devices known as lateral spin valves (LSVs) through the injection, diffusion and detection of spins within a lateral array of nanowires. There has been substantial disagreement over the origin of a reduction in spin diffusion at low temperatures[1]; one leading theory is that it is caused by an increase in Kondo scattering at low temperatures due to the presence of magnetic impurities[2]. However, not all findings corroborate this theory[3]. In this study, Permalloy (Py)/ Silver (Ag) LSVs were intentionally doped with non magnetic impurities (Vanadium(V) and Platinum(Pt)) in order to test whether the downturn is spin diffusion at low temperatures can be recreated with non-magnetic impurities which would not contribute to Kondo scattering. It was found that after doping with V and Pt, no Kondo upturn was present in the ρ Ag; However, the often seen downturn in the spin diffusion length of the Ag (ℓ_{sf}) was observed for both sets of doped devices.

Sample Fabrication

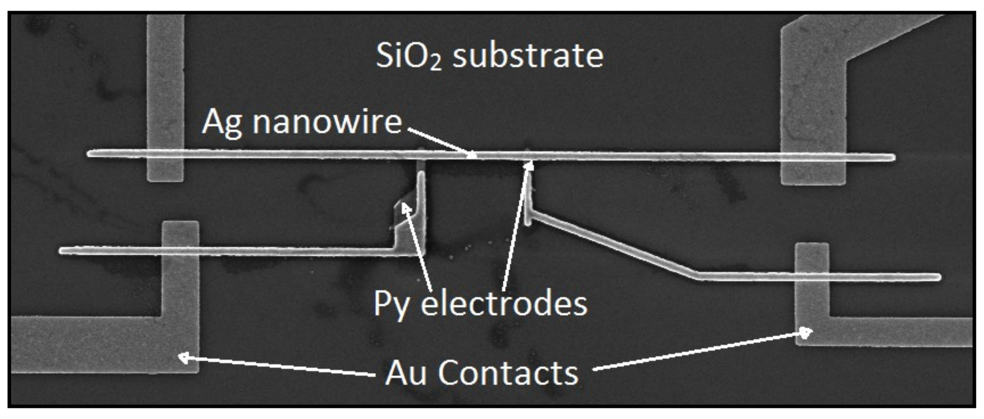
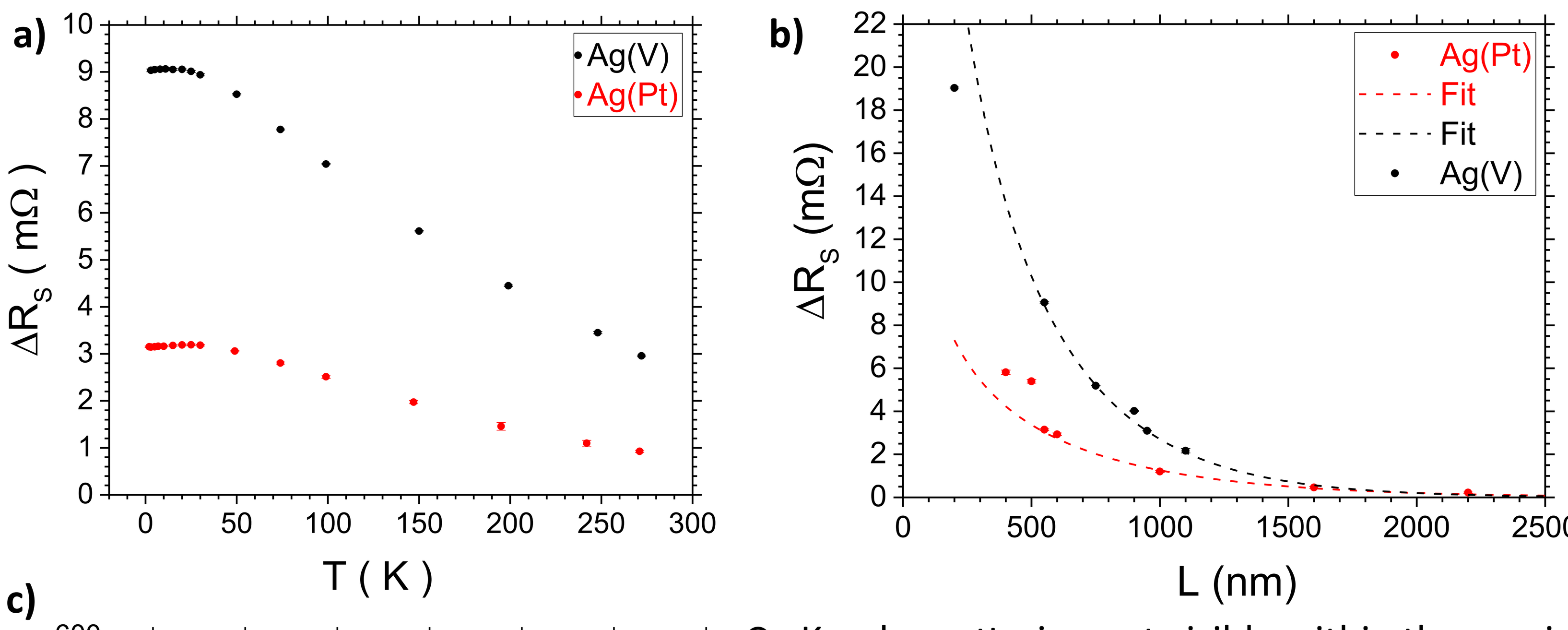
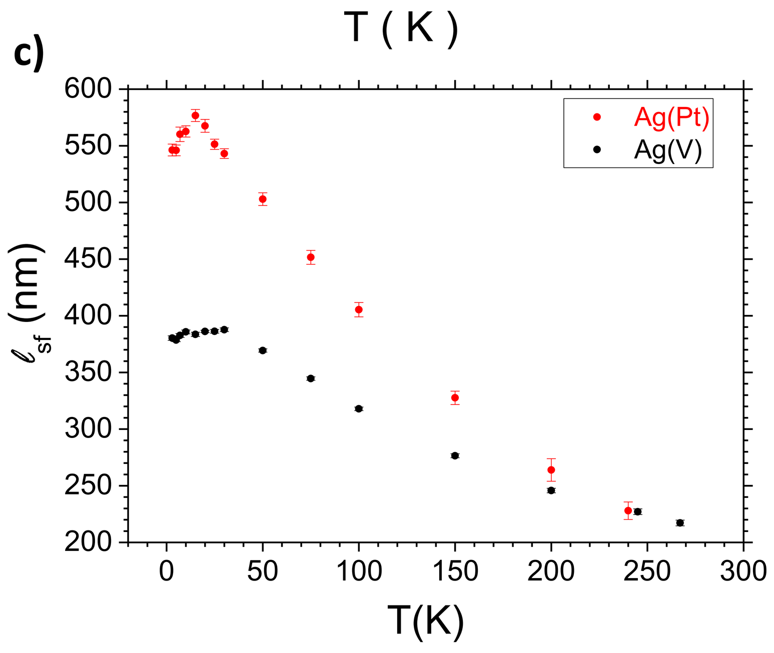


Fig.1 - An SEM image of an LSV demonstrating the structure required to produce pure spin currents.

- LSVs produced using a shadow deposition technique under a single UHV (≈ 1 x 10^{-9} mBar).
- Combination of thermal and e-beam evaporation onto a bilayer of resists (MMA and PMMA).
- Doping was achieved by growing a 0.5 Å thick layer of the desired metal, halfway up the 1000 Å thick Ag channel.

Analysis and Conclusions





- Kondo scattering not visible within the precision of the local measurements indicating little to no magnetic impurities.
- ΔR_S was larger for the V doped devices. However, ℓ_{sf} was longer for the Pt doped devices which may be explained by the lower ρ.
- A downturn in ℓ_{sf} was observed for both devices and is more significant for the Pt doped Ag. Suggests downturn is not linked to Kondo scattering.

Fig.4 - **a)** Comparison of ΔR_s for the two different doped samples. **b)** ΔR_s instead plotted as a function of separation (L) between the two ferromagnetic electrodes, the dashed lines are fits to a 1D diffusion equation. **c)** ℓ_{sf} of the two sets of devices which is derived from the fits in b).

Future Work

The two sets of devices were measured on using different elements of equipment, therefore the quantative nature of the results is not necessarily dependable. However this should not affect the qualitative results. The experiment should be repeated on the same piece of equipment for a more fair test. Additionally a reference device of clean Ag should be grown for comparison.

Acknowledgements

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Measurements

Local Measurements

- A current was applied across the central nanowire, whilst the voltage across the two ferromagnetic electrodes (see **Fig.1**) was measured.
- An upturn in ρ at low temperatures would be an indication of Kondo scattering due to magnetic impurities. ρ was also used to derive ℓ_{sf} in combination with the spin Transport measurements.

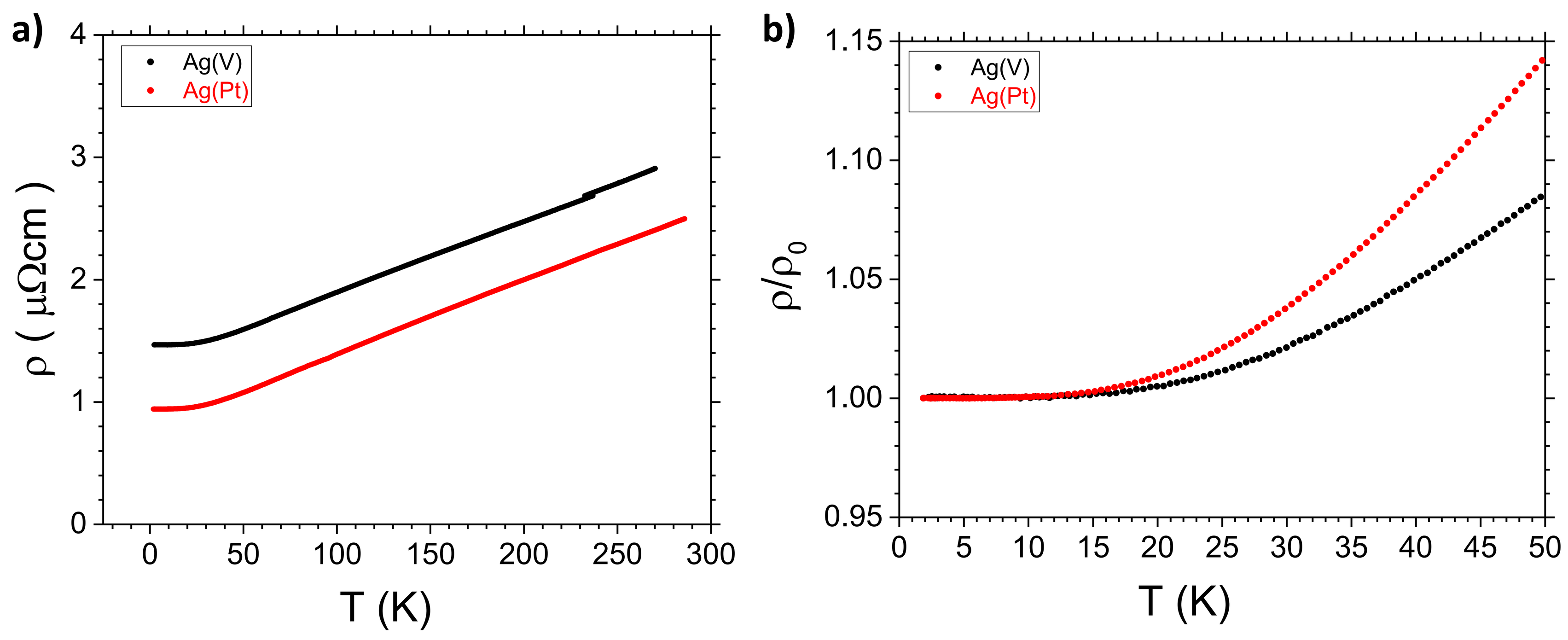

Fig.2 - **a)** Comparison of ρ for the two different doped devices as a function of temperature. **b)** Data at low temperatures normalised to the minimum ρ.

Non-Local Measurements

- A current was applied across the right hand side of the device, whilst the voltage across the left hand side was measured. A pure spin current was generated by the applied current which diffused along the central nanowire creating a potential difference at the second electrode. This was measured as a 'non-local' voltage.
- An IV measurement was made at a range of applied magnetic fields (applied in plane, parallel to the electrodes). Two distinct states were observed - dependent on the magnetic alignment of the two ferromagnetic electrodes. The difference between the two states is ΔR_S.

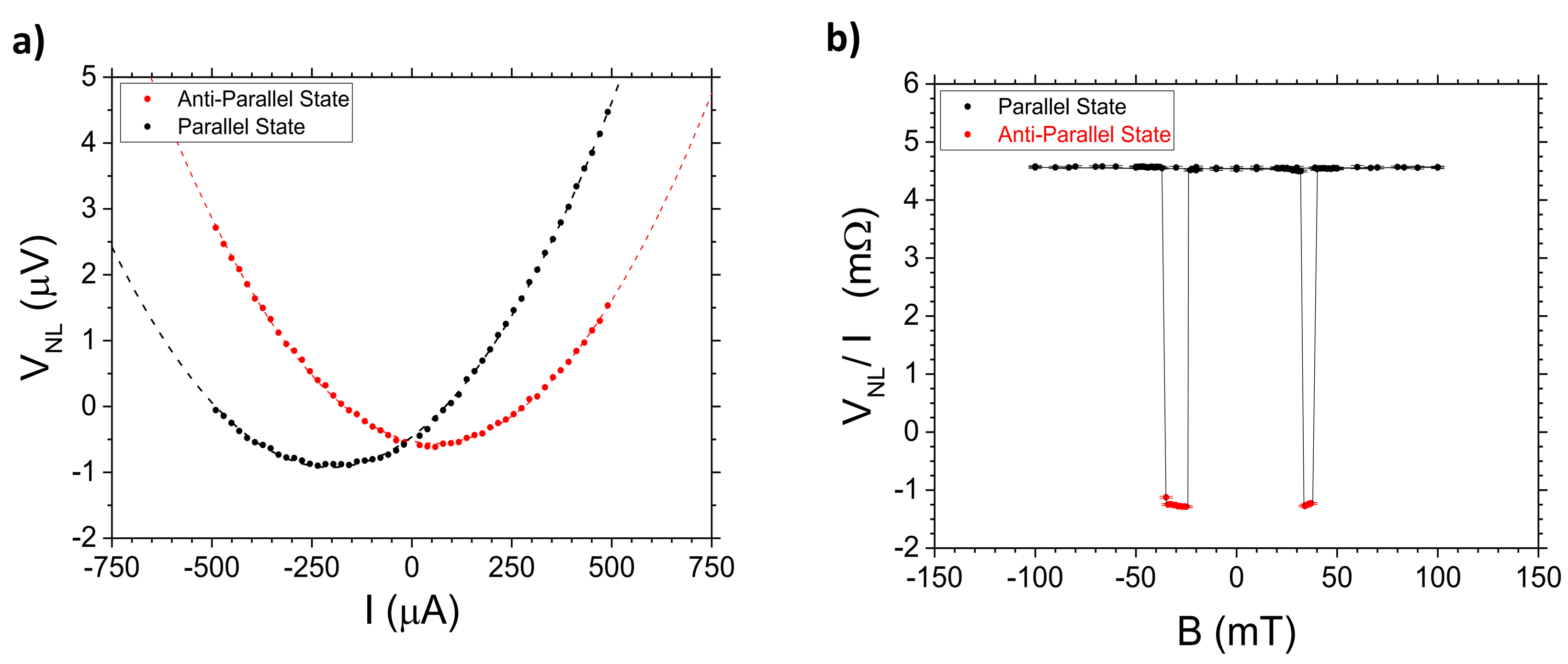

Fig.3 - **a)** IVs of the two different states that are observed in the magnetic alignment. The dashed lines are quadratic polynomial fits. **b)** The linear term from the quadratic fit plotted against the strength of the applied magnetic field. The black lines are there to indicate the sweep with B.

References

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