Spin-orbit torques in atomically-engineered metallic multi-layers

The spin-orbit interaction provides exciting opportunities to control spins by an electric means due to its relativistic nature. The generation of spin-orbit Hamiltonians can be governed by the symmetry of sample systems, such as by the crystalline lattice point group and by the local inversion breaking at an interface. This project's aim goes beyond these conventional concepts by attesting whether it is possible to generate any spin-orbit Hamiltonians from "artificial" lattice stacks.

The current state-of-the-art in thin-film growth technologies achieves layer-by –layer growth in many different film stacks. These technologies have underpinned the development of research fields, such as low-dimensional electron transport in III-V semiconductor epitaxial hetero-structures where the band engineering at the atomic scale plays an enabling role [1].

Here we will transfer this approach to the field of spin-orbit transport and nano-magnetism. We aim to grow metallic thin-film multi-layers with atomically-controlled thicknesses to manipulate the spin-orbit interaction. The spin-orbit interaction is a short-range interaction, hence requiring such a spatial modulation of that extreme length-scale.

With this final goal, the first step we took during this visit was to focus on the growth of candidate samples to achieve epitaxial growth of specific stacks. Ni-Pt multi-layers were found to grow epitaxially prior to this visit thanks to Dr Seki. Their growth conditions in relation to the film crystallography as well as magnetic properties were studied in detail. Successful samples (not yet with atomically-controlled thicknesses) were brought back to UCL, where we performed spin-transfer-torque ferromagnetic resonance (STT-FMR) to check if we can establish a methodology to characterise spin-orbit transport on these multi-layer samples. Below we summarise highlights from our research.

Fig.1 shows reflection high-energy electron diffraction (RHEED) patterns of epitaxial Ni /Pt multi-layers. Ni and Pt films can growth epitaxially on top of each other and can be a candidate of artificial lattice stacks used in this project. Magnetic properties were characterised by vibrating sample magnetometory (not shown).

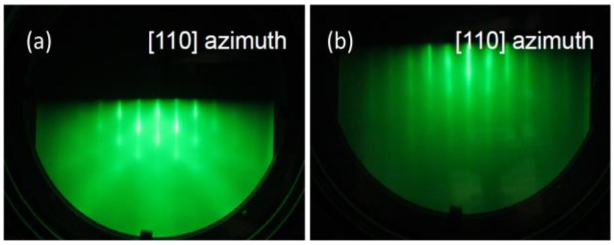

Fig.1: RHEED patterns taken after the growth of (a) the Ni and (b) Pt films. Both are taken along the [110] direction.

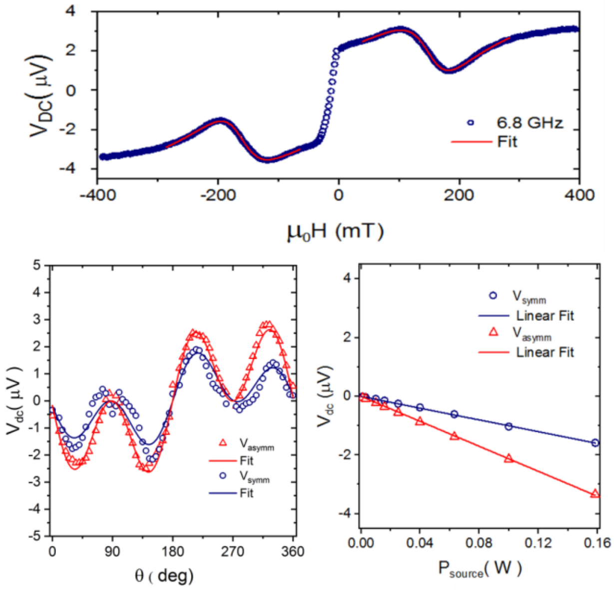

Fig.2: (a) FMR scan using the UCL STT-FMR set-up, together with a fit curve. The microwave frequency was set at 6.8 GHz. (b) Angle plots of both symmetric and anti-symmetric lineshape amplitudes (V_{sym} and V_{asym}) with model fit curves. (c) The power dependence of these amplitudes.

After the visit, STT-FMR experiments have been performed for these samples. Figure 2 displays a typical FMR voltage profile together with plots of the amplitudes as a function of angle and microwave power. These measurements can reveal magnetic properties (anisotropy and damping) and spin torque characteristics such as the spin-Hall angle.

During this short period of time, we rapidly combined our research strengths and demonstrated a promising start. This will act as a springboard for our primary research objective.

References

[1] e.g. B. J. van Wees et al., Phys. Rev. Lett. 60, 848 (1988).

[2] L. Liu et al., Phys. Rev Lett. 106 036601 (2011).

Keywords: spintronics, spin transfer, spin current

Hidekazu Kurebayashi (University College London)
E-mail: h.kurebayashi@ucl.ac.uk
https://www.ucl.ac.uk/spintronics