doi:10.1017/S1431927622008972

Microsc. Microanal. 28 (Suppl 1), 2022

Towards the In-situ Detection of Spin Charge Accumulation at a Metal/Insulator Interface Using STEM-EELS Technique

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Magnonics is an emergent field within spintronics research whereby a spin-wave (or magnon) is propagated controllably in nano-dimensional magnetic structures allowing to build a new generation of devices for data processing and storage. In addition, it was recently demonstrated that can be utilised to convert spin to charge currents and vice versa, a critical step for integration of spin and charge devices. Despite recent progress, many challenges hinder the practical development due to the lack of fundamental understanding of these processes at the nanoscale in the vicinity of interfaces. In particular, one of the main questions is to understand the spin-to-charge conversion at the ferromagnet or anti-ferromagnet/metal interfaces in bilayer based devices. To investigate this phenomenon, we choose a system consisting of Yttrium Iron Garnet (YIG)/platinium (Pt) bilayer, a widely and intensively used materials system in spin-to-charge conversion where the magnon created by a thermal gradient creates spin accumulation at the YIG/Pt interface, which subsequently diffuses into the nonmagnetic Pt, and via inverse spin Hall effect (ISHE) creates a voltage signal in the Pt layer [1]. Many studies have shown that the morphology [2], chemistry and atomic structure of this interface is critical for maximising the spin transmission. In this work, we aim to correlate the atomic structure to the spin-to-charge conversion properties in a working device using in-situ heating scanning transmission electron microscope (STEM) and high resolution electron energy loss spectroscopy (EELS).

We take advantage of state-of-the-art monochromated STEM, which offers the ability to map materials and atomic structures with an angstrom size electron beam and an energy resolution for EELS under 10meV, a technique which was recently suggested could lead to the mapping of magnons at the atomic scale [3]. First, we fabricate by lithography techniques holey electron transparent silicon nitride (Si_3N_4) membranes Fig.(1.a) where a focused ion beam (FIB) lamella is electrically connected to a specific heater geometry allowing local Joule heating to create a gradient of temperature along it Fig.(1.b). Second, we measure by plasmon energy expansion thermometry (PEET) [4], a nanoscale temperature mapping EELS technique, the temperature at the metal contact as well as the temperature gradient along the FIB lamella. Finally, we map the YIG/Pt interface to characterize the structural and chemical environment of the interface.

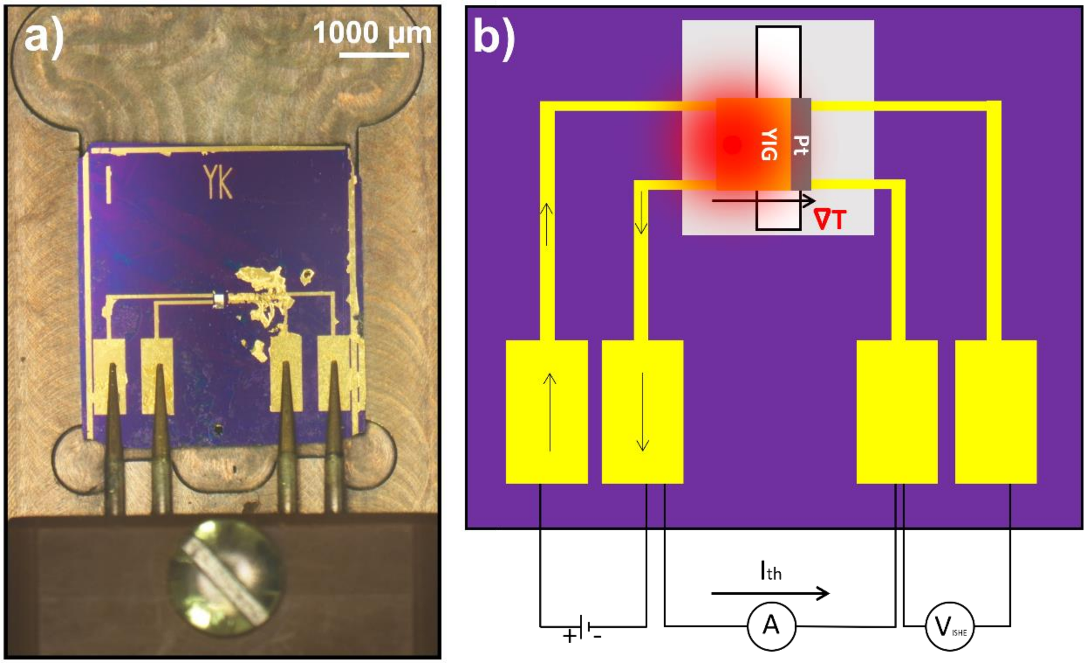

Figure 1. a) A photograph of a homemade silicon nitride membrane with four electrical contacts. b) A schematic showing the local Joule heating on a Pt/YIG FIB lamella for in-situ heating STEM-EELS experiments.

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https://doi.org/10.1017/S1431927622008972 Published online by Cambridge University Press