Voltage-based magnetization switching and reading in magnetoelectric spin-orbit devices

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The integration of logic and memory in spin-based devices, such as the recent magnetoelectric spin-orbit (MESO) proposal by Intel [1], could represent a post-CMOS paradigm. The MESO device consists of a memory element (a ferromagnet, FM) with a reading module based on spin-orbit effect and a writing module based on magnetoelectric effect. In this talk, I will show our recent efforts towards the realization of a MESO device.

A key player for the reading module is the spin Hall effect (SHE), which allows to electrically create or detect pure spin currents in a non-magnetic material. We have developed a novel and simple Pt/CoFe nanodevice to readout the in-plane magnetic state of the FM element using SHE [2]. The spin-orbit based detection allows us to independently enhance the output voltage (needed to read the in-plane magnetization) and the output current (needed for cascading circuit elements) with downscaling of different device dimensions, which are necessary conditions for implementing the MESO logic [1].

For the writing module, the best candidate is multiferroic $BiFeO_3$ which can be used to switch the magnetization of an adjacent CoFe element with an electric field [3]. We have fabricated Pt/CoFe nanodevices on a multiferroic $BiFeO_3$ layer and achieved voltage-based magnetization switching and reading at room temperature [4]. Switching is performed by application of a voltage pulse to the $BiFeO_3$, which reverses its ferroelectric and antiferromagnetic state. Through interfacial exchange coupling, the CoFe magnetization is also reversed. SHE in the Pt/CoFe nanodevice is then used to probe the magnetization direction of the CoFe element. Additionally, we show PFM and MFM experiments where magnetization switching is imaged after each voltage pulse applied. We discuss future strategies that need to be followed for the implementation of MESO-based logic circuits [4].

References:

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