All-optical switching in spintronic devices

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PhD may follow: Yes

Summary :

Spintronics, or spin electronics, revolutionized the field of magnetic data storage in the 1990's thanks to the manipulation of spin properties of devices instead of, or in addition to, charge degree of freedom. Spintronics was triggered by the discovery of Giant Magnetoresistance and led to a new generation of hard disks for data storage, of magnetic field sensors and of non-volatile memories called MRAM. It contributed largely to the new development of the Internet Of Things (IOT). However, despite these major innovations, spintronic technologies have reached a ceiling and need now a major breakthrough to be faster, more scalable as well as more energy efficient. UltraFast Opto-magneto-spintronics is an emerging field of research that combines the ideas and concepts of magneto-optics and opto-magnetism with spin transport phenomena, supplemented with the possibilities offered by photonics for ultrafast low-dissipative manipulation and transport of information. Both light and spin currents can control magnetic order, though the mechanisms as well as the corresponding time scales and energy dissipations differ.

We intend to demonstrate that the study of polarised light interacting with magnetic stucture in spintronic devices will lead to a better understanding of the fundamental physics behind light-matter interaction and will potentially lead to another revolution in the field of IOT including magnetic data storage, memory, logic, computing, sensor technologies. Particularly, we intend to show that the use of polarized light as a new degree of freedom may provide a way toward more efficient spintronic devices.

Full description :

The discovery of magnetization reversal by femtosecond laser pulses in thin ferrimagnetic Gd/Fe/Co films, give the possibility to improve the write speed and reduce power consumption of such spintronic memory. All-optical switching (AOS) can be achieved in the femtosecond regime, promising terabit-per-second magnetic recording, at femtojoule per bit switch energies. Most of the optically switchable magnetic materials are rare-earth (RE)-transition metal (TM) systems, such as GdFeCo, TbCo, TbFe alloys, Tb/Co and Ho/Co multilayers, but some RE-free TM multilayers like Co/Ir heterostructures are also observed to be possibly switched by laser pulses. So far, AOS with a single pulses was only observed on amorphous GdFeCo alloys, but it was also predicted on TbCo alloys by Moreno et al. [6] through an atomistic spin model.

Since TbCo has larger perpendicular magnetic anisotropy (PMA) or out-of-plane magnetic anisotropy than GdFeCo, which can help increase the stability of stacks and improve the scalability, it is an ideal candidate for optical switchable magnetic RAM (MRAM). Perpendicular anisotropy, instead of in-plane anisotropy, can provide large energy barrier [7, 8], which enables thermally stable elements beyond 45 nm technology node. And the perpendicular magnetic tunneling junctions (MTJs) can be pattern into circular shape rather than elongated shape. This facilitates manufacturability at smaller technology nodes. Besides, this can also reduce the dipole field interaction between neighboring cells, which contributes to increase the storage density.

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Development of rare earth/ferromagnetic multilayers of Pt/Co or Tb/Co are the starting points to bring magneto-optic interaction to the field of spintronics. MTJ fabrication will explore various scenarios of photonics-assisted switching, where the optical pulses are used for heating up the MTJ, while simultaneously sending an electrical â€˜write' current through the MTJ. The developed materials are to be optimized and integrated as an optically-switched layerstack. The aim is to realize an optically switchable magnetization layer in an MTJ stack, having a switching fluence comparable with state of the art for single layers. Taking advantage of the expertise of the laboratory in this field, we propose to participate in the growth of materials by sputtering, to characterize their magnetic and electrical properties. The magnetic stacks will then be nanostructured in our clean room in the form of electrically contacted nanometer pillars. The optical characterization of the MTJ stack will be done in collaboration with Radboud University using top-side illumination, using lensed fibers or high numerical aperture microscope objectives and/or SNOM. This gives the required parameters for integration with and illumination from the photonic layer. This internship or project is a part of a European Commission project: Spintronic-Photonic Integrated Circuit platform for novel Electronics (SPICE). Its objective is to realize a novel integration platform that combines photonic, magnetic and electronic components. It proposed new spintronic-photonic memory chip demonstrator with 3 orders of magnitude higher write speed and 2 orders of magnitude lower energy consumption than state-of-the-art spintronic memory technologies, which future enables petabit-per-second processor-memory bandwidths and highly energy-efficient exascale datacenters with reduced carbon footprint.

Requested skills :

nanosciences, nanotechnologies, solid state physics, basis of electronics