Extended Abstracts of the 2014 International Conference on Solid State Devices and Materials, Tsukuba, 2014, pp934-935

Engineering materials for all-optical helicity-dependent magnetic switching

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Abstract

The possibility of manipulating the magnetization state of a system without applying an external magnetic field have attracted growing attention over the past fifteen years. In particular, optical magnetization switching by ultrashort laser pulses has strong implications for future magnetic information memory and storage technologies. In this talk, we explore the optical manipulation of the magnetization in engineered magnetic materials. We review the status of the current knowledge on all-optical helicity dependent switching form a material-specific point of view and formulate three basic empirical rules that allow to design magnetic materials whose magnetization can be switched by means of circularly polarized laser pulses.

1. Introduction

Magnetization reversal using circularly polarized light provides a way to control magnetization without any external magnetic field and has the potential to revolutionize magnetic data storage [1]. Until very recently, all-optical helicity-dependent magnetic switching (AO-HDS) was demonstrated only for a relatively small class of materials. GdFeCo, a rare earth-transition metal (RE-TM) alloy with modest perpendicular magnetic anisotropy (PMA) [1-3], is probably the mostly considered material system. Crucially, for ultra-high density data storage, optically recordable magnetic materials exhibiting larger perpendicular magnetic anisotropy are needed. Staying in the class of rare earth-transition metal alloys, the most straightforward solution would be to replace Gd with Tb, since Tb has a significant orbital momentum. Indeed, ferrimagnetic Tb_xCo_{1-x} alloy films exhibit strong perpendicular magnetic anisotropy and have been already used in conventional magneto-optical recording.

2. Content

In this contribution, we study the feasibility of AO-HDS on Tb_xCo_{1-x} films which exhibit a strong PMA, varying the Tb composition from x=12% to x=34%. We have found evidence for all-optical magnetization switching for different Tb_xCo_{1-x} ferrimagnetic alloy compositions (see Fig. 1)

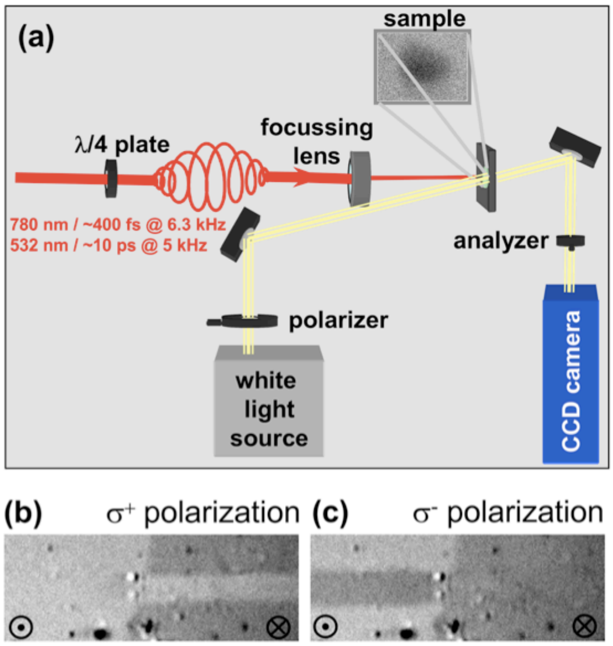

Figure 1. **All-optical helicity-dependent magnetic switching experiment** (from [4]). (a) Schematic of the AO-HDS setup. (b) and (c) Demonstration of AO-HDS of a $Tb_{26}Co_{74}$ film. Two out-of-plane oriented domains show up in the image as black and white contrast. By swiping a laser pulse with fixed circular polarization over the sample, a stripe domain was written (b). Afterwards, the circular polarization was inverted and the domain previously written could be deleted while a stripe domain of opposite orientation appeared (c).

using femtosecond- and picosecond-laser pulses. Moreover we have demonstrate all-optical switching for films with anisotropy fields reaching 6 T corresponding to anisotropy constants of $3x10^6$ ergs/cm^3 [4]. Our results show that all-optical switching depends on both the Tb concentration and the properties of the exciting laser pulse. Moreover, optical magnetization switching is observed only for alloy compositions where the compensation temperature can be reached through sample heating. These experiments demonstrate the potential of the use of circularly polarized light for magnetic data storage technology and provide a crucial piece of information for understanding the physics of optical switching.

In the last part of this contribution, we will give an overview over very recent studies [5] where we have demonstrated that AO-HDS can be observed not only in selected RE–TM alloy films but also in a much broader variety of materials, including RE–TM alloys, multilayers and heterostructures. We further show that RE-free Co–Ir-based synthetic ferrimagnetic heterostructures designed to mimic the magnetic properties of RE–TM alloys also exhibit AO-HDS. The common denominator of the diverse RE–TM structures showing AO-HDS is two ferrimagnetic sublattices showing distinct temperature dependences that can be magnetically compensated at a selected temperature, which should lie above room temperature.

2. Conclusions

The presented results challenge present theories of AO-HDS and provide a pathway to engineering materials for future applications based on all-optical control of magnetic order.

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