Instytut Fizyki Molekularnej
Polskiej Akademii Nauk

Rozprawa doktorska

Oddziaływania pomiędzy warstwami ferromagnetyczną i ferrimagnetyczną oraz w obrębie ferrimagnetycznej warstwy poddanej strukturyzacji magnetycznej

mgr inż. Łukasz Frąckowiak

Promotor: dr hab. inż. Piotr Kuświk

Poznań, 2021

Abstract

For many years, thin magnetic films with perpendicular magnetic anisotropy have been studied by many research groups due to their unique potential applications in IT (hard drives, M-RAM, logic circuits), spintronics based sensor, and in magnonic structures for data transmission. They constitute the research focus of this doctoral dissertation, which has two major parts: (i) interactions between ferromagnetic layers (F) and Rare Earth-Transition Metal (RE-TM) ferrimagnetic layers (FI) created as multilayered structures (RE/TM), and (ii) interaction within the ferrimagnetic multilayer RE/TM after magnetic patterning.

The studies of interactions in F/FI and F/Au/FI structures, (F = $(Au/Co)_{2(3)}$, FI = $(Tb/Co)_6$, $(Tb/Fe)_6$) demonstrate the ability to control the switching field of F layers in a wide range (from -0.8 T to 0.8 T). Changes to the switching field are caused by coupling between the F and the FI layers (exchange bias like interaction). The strength of this interaction depends mainly on the concentration of the Rare Earth in the RE/TM multilayer (controlled by sublayer thickness ratio of RE to TM) and the sequence of layers around the non-magnetic spacer. Changing the spacer surroundings from Co/Au/Co to Co/Au/Tb affects not only the value of the interaction between FI and F layers, but also the nature of this coupling (from ferromagnetic to antiferromagnetic). This is visible as a change in the sign of the switching field for the F layer. For a 1-nm Au spacer thickness surrounded by Co, the switching field of a TM (RE) dominated FI multilayer changes from positive (negative) to negative (positive). F/FI systems with an Au wedge spacer exhibit an oscillatory character of coupling between F and FI layers as a function of Au thickness, which suggest existence of an RKKY-like interaction.

The second part of this dissertation explains that local bombardment with He^+ ions allows to engineer a two-dimensional periodic lattice of magnetic domains in the FI multilayer. The fabrication of such structures is possible because magnetic deactivation after ion bombardment is greater for Rare Earth atoms than for Transition Metals The preferential oxidation of Tb after ion bombardment is shown to be responsible for the magnetic deactivation of Tb in the Tb/Co multilayers. The effectiveness of this process depends on the ion dose. The most unique magnetic properties occur when the magnetic deactivation of Tb atoms is large enough to change the sublattice dominance from Tb+ to Co+. For this case, there are no domain walls in a multi-domain state. Such domain structures are very stable because the multidomain state reduces magnetostatic energy, and the absence of domain walls ensures that this energy reduction is not compensated by a simultaneous increase in exchange and anisotropy energies. This dissertation presents a detailed description of the magnetization reversal process of such structure, paying particular attention to the differences with another type of magnetically structured FI layers for which the same sublattice domination occur in protected and exposed areas.

An additional achievement of this dissertation is the development and experimental validation of an algorithm to calculate the distribution of elements of a two-component alloy after co-sputtering from two targets.