Abstract

Controlling the spin degrees of freedom in magnetic systems is interesting due to a large number of stable magnetic states that can contribute to the increase of the capacity and functionality of magnetic memories and logic circuits. Extensive research in the field of spintronics is carried out seeking a method of information recording competitive to the currently used, based on semiconductor structures. One of the basic building blocks from which new spintronic devices can be created are memory elements constructed on the basis of magnetic tunnel junctions (MTJs).

Typical MTJs are composed of electrodes with an in-plane magnetization. However, MTJs with perpendicular magnetic anisotropy (p-MTJs) have great advantages over the in-plane ones, due to their high tunnel magnetoresistance ratio (TMR), high thermal stability and low critical current for current induced magnetization switching. Therefore, the experimental determination and understanding of magnetic anisotropy and mechanisms of its control in ferromagnetic thin films is crucial towards the MTJ system design for future use in electronic applications.

Despite intensive research on the improvement of MTJ, the physical mechanisms leading to the formation of PMA are still not fully understood. The search for mechanisms leading to perpendicular magnetic anisotropy in the ultra-thin magnetic layers was the theme that inspired the author to carry out the research described in the presented dissertation.

This thesis investigates the physical phenomena inducing the perpendicular magnetic anisotropy in epitaxial structures of the ferromagnetic-metal / isolator (FM/I) and systems with the tunnel junction structure type - FM/I/FM. Therefore, the research was focused on the influence of: the type and thickness of the magnetic layer and insulator, the type of the adjacent layer and finally, the electronic structure of the surface of the magnetic layer.

The subject of the research were heterostructures deposited by molecular beam epitaxy – MBE method, consisting of thin layers of 3*d* transition metals, such as Co and $Co_{0.9}Fe_{0.1}$, separated by MgO layers. In order to create FM/I/FM heterostructures with optimal tunnel junctions parameters with perpendicular magnetic anisotropy, the effect of magnetic layer

thickness and the type of adjacent layer on the surface anisotropy on the FM / I interface were investigated.

A new method of preparing thin layers with a perpendicular magnetic anisotropy was developed by introducing the atomically thin Au layer into the metal-ferromagnetic/insulator interface. The analysis of XPS measurement revealed the reduction of oxygen atoms into the Co layer on the Co/MgO interface after the introduction of Au monolayer.

The magnetic properties of the cobalt/hydrocarbon interface were investigated by magnetometry and ferromagnetic resonance techniques. It was demonstrated that the surface energy of Co film could be significantly increased at the cobalt/organic interface and direct an equilibrium magnetization perpendicular to the film plane.

Finally, the interaction between the two magnetic layers, separated by a thin insulating MgO layer, in the Mo/Au/$Co_{0.9}Fe_{0.1}$/Au/MgO(t_{MgO})/Au/$Co_{0.9}Fe_{0.1}$/Au structure, and the impact of this effect on the magnetic anisotropy of the $Co_{0.9}Fe_{0.1}$ layers has been presented. The results of the FMR and magnetometry investigations have demonstrated that the magnetic anisotropy of the bottom $Co_{0.9}Fe_{0.1}$ layer depends on the MgO spacer thickness. It was shown, that the magnetization is out-of-plane down to t_{MgO} of about 0.8 nm, and below this thickness, the coexistence of perpendicular and in-plane easy direction of magnetization is observed.

20.02.2018

Kinga Lasek