Warszawa, 21.07.2015

Author: Ewelina Milińska
Supervisor: prof. Andrzej Wawro
Institute of Physics
Polish Academy of Sciences

Magnetic properties of structured systems containing ultrathin Co layer

Investigated magnetic nanodots as well as other objects with reduced sizes have physical properties that differ from volume material (bulk) owing to the confinement of some characteristic lengths and the significant contribution of atoms forming the edges or surfaces. The aim of this work is to describe the factors affecting the static and dynamic properties of epitaxial magnetic nanodots. The investigated structures are induced in an ultrathin, continuous Co layer, deposited on a structured buffer. The dots, ranging from a few hundred nanometers to a micron in lateral size, display a perpendicular direction of magnetization to the sample plane. A monodomain magnetic state is a unique feature of investigated nanostructures. It is most likely the effect of the low amount of structural defects.

The aim of this work is to describe the influence of geometrical and structural factors on magnetic properties and on reversal mechanisms of the dots. Among them are: the shape and size of the dots, a stronger magnetic anisotropy at their edge and structural defects. Consequently, intentional modifications of parameters such as the dot size and type of interfaces allow for desired changes of the properties of fabricated structures. Another concern of this work is to determine the magnetic properties of reference layers for the structured system: Au/Co/Au and Mo/Co/Au. The determination of the factors responsible for the observed differences in magnetic anisotropy allows one to understand the reason for changes in magnetic properties of ultrathin layers deposited on a structured buffer. An additional purpose is to check whether, in multilayer systems, Mo/Co is a possible way of inducing magnetic moments in atoms Mo, as a result of the proximity of cobalt atoms to the nonmagnetic in bulk atoms Mo.

The molecular beam epitaxy (MBE) sample fabrication method allows the control of the characteristic parameters of the dots, such as: lateral size, surface density or magnetization orientation. The magnetization configuration and the domain structure is investigated by: magnetooptical magnetometry (MOKE) and magnetic force microscopy (MFM). In this work, properties of the interfaces Mo/Co and Au/Co, which are substantially responsible for magnetic structuring, are investigated by structural methods and synchrotron techniques (RHEED, XRD, XRR, XANES and XMCD). The experimental results are compared with the simulated ones by micromagnetic calculations (using software such as OOMMF and LLG). The results of the simulations enable describe the influence of parameters, which cannot be estimated directly from the experiment.

The PhD thesis consists of 10 chapters. The first and second chapters contain a range of information taken from literature about structural and magnetic properties of patterned and thin film systems, as well as the introduction to mechanisms of a magnetic moment induced on nonmagnetic (in volume) atoms. The third chapter outlines the physical phenomena used in the experimental methods, while the fourth chapter describes details of experiments and equipment used by the author. Chapter five presents a description of the reference samples based on previously published works as well as on original results. In the sixth chapter an analysis of magnetic property reference layers is presented. The seventh chapter is devoted to the analysis of the induction of the magnetic moment in nonmagnetic in volume atoms Mo, carried out on the basis of results from synchrotron research (XMCD). In chapters 8 and 9 the results of experimental studies dedicated to the magnetic properties of epitaxial nanosized dots and their reversal of magnetization processes, are shown. The impact of size on the characteristic parameters describing the dots (i.e. H_C) is also mooted. Chapter 10 extensively presents the results of the micromagnetic simulations of magnetization reversal processes for homogeneous in volume dots, *core-edge* dots, and dots with defects. A summary and discussion of proposed further research is to be found at the end of this doctoral thesis. In appendix A, the characteristic energies for K and L edges used in synchrotron research are depicted as well as a description of the code program that simulates absorption spectra of Co atoms in phase *fcc* and *hcp*. Appendix B contains a description of how to simulate micromagnetic problems. A part of input file of the sample program is shown as the example. Appendix C provides a list of the author's publications and presentations.