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Magnetic nanoparticles on periodic iron oxide templates: Control of magnetism using particle substrate interaction and external electric field

Continuous development of new technologies stimulate the search for materials that have special functional properties. Often common materials gain required properties by physical processing, for example by reducing their size to the nanometer scale. It is important to be able to precisely control the size, shape and, consequently, also properties of the obtained nanosystems. Nanomaterials exhibit the unique catalytic, optical, electronic, magnetic properties, which allows their use in various advanced technologies. There are numerous techniques for the preparation of nanomaterials, but many of them do not provide control over the size and structure of the nanoparticles, which determine they properties. In this context studies of model systems in nano-science are of primary importance, because they give access to fundamental physico-chemical mechanisms responsible for a specific functionality of the nanomaterial. The aim of the project is to study such model systems, which are expected to meet magnetic (e.g. such as in the hard drives of our computers) functions. The first important task in the project is to produce magnetic metal and alloy nanoparticle systems that fulfill these functions. We consider such materials as iron, cobalt or nickel and their alloys with noble metals, gold, platinum or palladium. These materials will be dispersed to the nanoparticles that contain from several to several thousand atoms. In such small objects, gold, which is a synonym of an inert and non-magnetic metal, becomes chemically active permanently magnetized. A small size of the magnetic nanoparticles is a big advantage in the miniaturization of electronic devices. To produce such small particles we will use surface processes that can be compared with the formation of an regular array of the water-droplets that would be formed on a hot pan having a regular grid of pits. Our "pan" will be a surface of iron oxides, on which, in a special self-organization process that uses vacuum techniques, a periodic structure of the chemical inhomogeneity will form "pits" for the metal atoms. The entire process must be carried out in the vacuum (comparable to the outer space vacuum) to avoid uncontrolled effects of pollution and to investigate the nanoparticles that are sensitive to external factors in the "sterile" conditions. The vacuum environment is also necessary for the experimental techniques sensitive to an extremely small amount of the studied material utilizing interactions of electrons and X-rays with the surface. A special role play here microscopic methods, which allow the surface imaging with atomic resolution (e.g. scanning tunneling microscopy) and methods using synchrotron radiation, available in the recently commissioned National Synchrotron Radiation Center "Solaris"

The regular arrays of the metallic nanoparticles that are characterized in terms of size, shape and basic magnetic properties will be the objects of further research aimed at determination of different functionalities. For the ferromagnetic metal (Co, Fe, Ni) nanoparticles, forming a network of nanomagnets we will study the processes of their orientation in the external magnetic field and the conditions in which the orientation of the nanomagnets remains stable, which ensures that the information stored on a magnetic hard disk also remains stable. In the modern electronics called spintronic, instead of electron charge the electron spin is used. For such systems it is important that one can control magnetic properties by applying the voltage, i.e. by an external electric field, and the mastering of this process is one of the project tasks. Although the results of the project will not immediately transfer to applications, they should show alternative methods of producing nanosystems and explain the correlation between the size of the nanoparticles, the type of material and the ability to perform specific magnetic functions.