# Scientific Network "New materials for magnetoelectronics": subjects, tasks and the people

The Scientific Network "New materials for magneto-electronics – MAG-EL-MAT" established in the first months of 2003 received financial support from the State Committee for Scientific Research (KBN). The key objective of the Network is to focus on the theoretical and experimental search for modern magnetic materials and to provide explanation of some related physical phenomena.

The main tasks of MAG-EL-MAT include studies into the electronic and magnetic properties of a vast class of nanoscopic materials, such as thin films, multilayers, composites, molecular systems (including carbon nanotubes) and quantum dots. Particular attention is given to the magnetic phenomena in micro-junctions, GMR (giant magnetoresistance), TMR (tunnel magnetoresistance), spin accumulation, spin injection and current-induced switching of magnetization. The underlying physical mechanisms responsible for those phenomena are related to the electronic band structure, electron-electron interactions (Coulomb blockade, Kondo effect), and interactions of electrons with elementary excitations (e.g. spin waves, phonons etc.). The research activity is also oriented towards the magnetic and nanostructured materials for the applications in novel electronics.

Investigations are currently being carried out by 49 research groups (about 300 members), and are particularly focused on the use of electron spin degree of freedom. This is of great importance because of the cognitive purpose of the research as well as from the practical point of view as the conventional silicon-based electronics is now facing barriers of fundamental nature, which hinder further miniaturisation. A wide range of topics are in our current interests:

(i) *Magnetic thin films and layered metallic structures.* The GMR is attractive owing to its application ability as a magnetic field sensor and a recording head. The present aim is to obtain layered structures exhibiting large GMR values accompanied by low magnetic saturation or switching fields. The issues include the influence of sublayer topology, morphology and thermal treatment on the amplitude and the field sensitivity of the GMR effect. One of the goals is the understanding of the magnetic behaviour and spin dependent electronic transport in thin films and multilayers which, being nanopattern elements, are capable of serving as magnetic sensors, M-RAMs (Magnetic Random Access Memory) and magnetic recording devices. Hence, complex studies of artificial nanostructures such as magnetic hetero-structures (granular films or layered granular structures), soft magnetic nanocrystalline multilayers, low-dimensional magnetic nanostructures are being conduced.

(ii) *Surface effects in novel magnetic materials.* Keen interest is given to "photonic crystals". These are periodic structures composed of two types of transparent dielectric materials forming a "macrocrystal", with lattice constant ranging from 0.1 μm to 1 cm, showing a "photonic" energy gap, in which light propagation is forbidden. The promising prospects in this field allow taking up a theoretical research of systems analogue to the photonic structures, but composed of magnetic materials – the "magnonic crystals".

(iii) *Magnetic nanostructures.* They involve electric and magnetic mesoscopic systems of peculiar geometry, e.g. carbon nanotubes, ring-shaped systems as well as single and coupled quantum dots. Some of them have already found applications (flat displays, portable field-effect based Roentgen apparatus, current rectifiers, chemical and magnetic-field sensors, single electron transistor etc.). In particular, issues of the electron transport through nano-structures, depending on their internal structure, the type of electrodes used and the interface conditions, are being dealt with. Other issues studied involve the response of the nanostructures to the external magnetic field, the proximity effects in nanostructure/superconductor systems, and the influence of the structural disorder, the spin-orbit interaction and the electron spin relaxation on the electron transport.

(iv) *Electron and hole transport in the doped transition metal oxides.* Recent experiments have shown a sharp drop of anisotropic magnetoresistance in calcium-doped yttrium-iron garnet thin films. An explanation is proposed concerning the spin dependent charge transfer in the yttrium-iron garnets doped with valence-uncompensated ions. The influence of the external magnetic field, both on the superexchange coupling between the spins attached to the orbital ground eigen-states of the iron-oxygen clusters as well as on the spin-conditioned charge transfer between those of different and the same symmetry, are analyzed.

(v) *First principles computations.* Investigations of physical properties of solids are carried out by *ab initio* methods. In particular, the spin-polarized LMTO method is used to calculate the band structures, partial densities of states, spin and orbital magnetic moments, total energy, and the optical and magneto-optical properties. It is possible to find anisotropy of spin- and orbital-moments as well as the magnetocrystalline anisotropy.

(vi) *Intermetallic compounds and alloys.* The current interest is the electronic structure and magnetic properties of strongly correlated electron systems which exhibit Kondo-lattice, heavy-fermions, non-Fermi liquid and unconventional superconductivity, as well as giant magnetocrystalline anisotropy etc. Currently, efforts are being made to find the mechanism behind these abnormal phenomena and the prospective applications of the compounds and alloys studied. For instance, thermoelectric materials can be used for power generation or refrigeration using direct conversion of heat and electricity.

Several new activities and contacts established *via* the MAG-EL-MAT Network are already functional, ranging from bilateral contacts and preparations of joint research projects to larger scale programmes, conducted predominantly within the framework of the European scientific agencies.

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