Preface

Recent progress and development of *spin electronics* has underlined the need for gathering leading research groups in the field in a scientific network in order to disseminate the latest achievements and to ensure scientific know-how exchange. The scientific network **“New materials for magnetoelectronics – MAG-EL-MAT”** was established in the first months of 2003 and was granted financial support for the years 2003-2004 from the State Committee for Scientific Research (KBN) in autumn 2003. The key objective of the Network is to focus on the theoretical and experimental search for modern magnetic materials and to provide explanation of related physical phenomena.

The main tasks of **MAG-EL-MAT** include studies of 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 magnetic phenomena in micro-junctions which contain ferromagnetic additions or are placed in a magnetic field. Among others, the studies cover GMR (giant magnetoresistance), TMR (tunnel magnetoresistance), spin accumulation, spin injection and current-induced switching of magnetization. The underlying physical mechanisms responsible for these phenomena are related to the electronic band structure of the components forming the microjunction, 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 magnetic and nanostructured materials for the applications in novel electronics. Efforts are made to build a scientific capacity of the Network to serve as a potential research partner for the leading research groups.

Currently, investigations carried out by 47 research groups (about 270 members) are particularly concentrated on the use of the spin degree of freedom as well as the electric charge of electrons. This is of great importance, both for cognitive reasons and from the practical point of view, because the conventional silicon-based electronics is now facing barriers of fundamental nature, which hinder further miniaturisation.

The first **MAG-EL-MAT** Members Meeting held in Będlewo on 26 to 28 October 2003, gathered 43 participants from 16 Polish institutions (universities, research centres and institutes of the Polish Academy of Sciences) who discussed a wide range of topics in the following areas:

(i) 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 electron transport through nanostructures, depending on their internal structure, the type of electrodes used and the interface conditions, are dealt with. In the case of ferromagnetic electrodes, special attention is put on the GMR and spin polarization of electrical current. Other issues studied involve the response of nanostructures to the external magnetic field, the proximity effects in nanostructure/superconductor systems, and the influence of structural disorder, spin-orbit interaction and electron spin relaxation on the electron transport.

(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”. They can be expected to find applications.

(iii) 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 a different and the same symmetry, are analysed.

(iv) 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. Extended advanced calculations of complex systems (up to 100 atoms per unit cell) with the use of supercell technique enable one to model the microstructure of the interface layers and of the short and long range chemical disorder of the alloys.

(v) Intermetallic compounds and 4f- and 5f- metal based 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 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 the direct conversion of heat and electricity. The determination of magnetic properties (including their magnetic structure) and the electronic structure of ternary rare-earth based compounds enables one to find correlations between the electronic and magnetic structures.

(vi) Magnetic thin films and layered metallic structures. The GMR is attractive owing to its application ability as magnetic field sensors and recording heads. 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 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 (*e.g.* heads, HDD-discs and magneooptical discs). Magnetic heterostructures show a relationship between the microstructure and the magnetic properties, including low-dimensional magnetic nanostructures. Hence, complex studies of artificial nanostructures such as magnetic heterostructures (granular films or layered granular structures), soft magnetic nanocrystalline multilayers, low-dimensional magnetic nanostructures (emphasizing the relationship between microstructure and magnetic properties) are conduced.

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 mainly within the framework of the European scientific agencies.

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