Smart Materials for Ranging Systems

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Smart Materials for Ranging Systems

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PREFACE

The problem of determining the location of an object, which is usually called ranging, attracts at present much attention in many different areas of applications, among them in ecological and safety devices. Electromagnetic waves along with sound waves are widely used for this purpose. Familiar examples of ranging systems are radar, sonar, GPS positioning, speed meters, etc.. Most are echo-type of devices, generating a wave and interpreting its echo from the object of interest. GPS is a cooperative system, in which the receiver observes timing signals from sources at known locations, and locates itself in reference to them. Passive ranging makes use of waves generated by the object to be located that are picked up by an observer. As indicated, there are three kinds of ranging systems, successively described as echo, cooperative and passive systems. Echo ranging is by far the most common method in practice. The observer at a certain point emits a wave of some physical nature at a certain time. When the outgoing wave front strikes the object, a scattered wave front is launched, which is detected at the observer point a certain time interval later. In special cases, the observer is able to determine the direction of the received wave. This, of course, is the principle of radar and echoscopy. The observed object in echo ranging is passive and takes no active part in the procedure. In cooperative ranging, from the other hand, the object takes an active part. In one form of cooperative ranging, the object emits waves that contain time information. Two fixed stations with clocks synchronized with that of the object note the time delay of the received wave and from the two distances thereby determined the object can be located. If needed, the stations can radio back the evaluated position. In the second form, the object receives waves from two fixed stations and subsequently determines its position from the distances to the two stations. Of course, in three dimensions, three distances are necessary. The GPS system uses the second option, with the peculiar circumstance that the 'fixed' stations are actually moving in orbits. But their positions can be accurately evaluated at any time. Cooperative ranging places great demands on clocks, especially when carried out with electromagnetic waves. Timing sound waves is less critical. Passive ranging, finally, makes use of waves generated by the object to be located that are picked up by an observer. The wave used in this application may be generated in the normal action of the object, and not necessarily generated for location purposes. An example is the location of a boat from its propeller noise, or a whale from its singing. The fundamental data in these applications are the relative times, the time delays, at which the signals are picked up at the different stations. Smart material devices in which sensing, actuating, and control functions are integrated are urgently needed

for the realization of practical devices. Magnetic field measurements and the imaging of its spatial distribution are valuable tools in the related range of applications, including navigation systems, resource exploration drilling, spacecraft attitude control systems and assessments of the impact of ‘space weather’ caused by cosmic particles. In addition to these macroscopic applications, the microscopic approach should be mentioned. The position of micro particles, even on an atomic scale can be observed by scanning tunnelling microscopy. Examples are the atomic force microscope (AFM) and the magnetic force microscope (MFM).

Application of the underlying ideas needs the design of appropriate “smart” materials as a first step. This ARW outlines magnetic research that hopefully will help to transform scientific ideas into practical system designs. The workshop’s focus was on:

- an up-to-date knowledge of the latest results of solid state physics which is indispensable for a deep insight in material properties;
- advanced techniques for material preparation, for nano-size samples in particular, which is the key for many modern applications;
- the integration of different features in one composite which marks the new generation of smart devices;
- sophisticated detection and measuring techniques which open new horizons for advanced applications, in particular on the propagation of magnetic waves;
- the dynamics of magnetic structures in materials with unusual magnetic and superconducting structures.

The different aspects of new materials with specific magnetic, electric and elastic properties were discussed during the workshop in order to obtain a general and consistent view on the potentialities for application in design and manufacturing of smart materials. As a result of the workshop we mention the progress that was reported in the fabrication and understanding of in-situ formation and characterization of solid state structures with specified properties, as well as in the observation and study of the mobility of magnetic structures and of the kinetics of magnetic ordering transitions. Looking from a different perspective, one of the outcomes of the ARW is the emphasis on the important role that collective phenomena like spin waves in systems with a magnetically ordered ground state, or critical currents in superconductors could play at the design of magnetic-field sensitive sensor materials. The lectures presented covered the following relevant topics:

1. Nano-technology problems were addressed in talks by J. Bartolomé (Magnetic dynamics of Co nanospheres) and J. Kliava (Nanoparticles in oxide glasses).
2. Strongly correlated electron systems including high- T_c superconductors were discussed in talks by S. Ovchinnikov (Theory for transition metal oxides), G. Petrakovskii (Magnetism of 2D spin systems),

S. Maleyev (Theory of cubic magnets with Dzyaloshinskii-Moriya interaction), V. Eremenko (Intrinsic inhomogeneity aspect of sensor units), M. Chiba (NMR in copper metaborate), A. Sherman (Magnetism of copper perovskites), V. Mitskan (Singlet formation of 2D magnets), M. Korshunov (Superconductivity of cuprates), J. Franse (Quantum criticality in the $U(Pt,Pd)_3$ system), Yu. Izyumov (The periodic Anderson model) and I. Lubutin (Magnetism of iron oxides under pressure).

3. Magnetism of molecular magnets in view of new perspectives for electronic applications was presented in a talk by G. Romanenko (Phase transitions in hetero-spin systems).

4. Materials with colossal magnetoresistance for application in different types of sensors in manganites in particular were addressed in talks by I. Troyanchuk and V. Shah (Magnetism of multilayered magnetic films).

5. SQUID sensors as high-sensitivity devices for a variety of applications were presented in a talk by S. Bondarenko (SQUID-based magnetic microscope).

6. Optical properties of electronic and magnetic systems were discussed in talks by R. Hicken (Electron relaxation in metals by femtosecond ellipsometry) and R. Pisarev (Nonlinear optical spectroscopy).

7. Ferromagnetic materials exhibiting shape memory effects and superelasticity under action of a magnetic field turn out to have a great potential for applications. This problem was discussed in a talk by A. Vasiliev (Shape memory alloys of the Ni-Mn-Ga type).

8. Magnetostrictive materials with potentialities for sensing unit applications were considered in presentations of H. Szymczak (magnetostriction of manganites) V. Eremenko and V. Sirenko (Structural study of magnetostrictive superconducting compounds)

The meeting was well organised and took place in the House of Scientists of the Academy of Science in Krasnoyarsk, situated in a spacious area of an outlying district of the city of Krasnoyarsk where both the Academy of Science and the University of Krasnoyarsk are located. In total, thirty participants took part in this NATO-ARW. It was a great experience for most participants of the workshop to discover a new centre of academic research that was until recent years closed for visitors from the West and that turned out to be well equipped and involved in sophisticated research in the field of interest of the workshop.

The editors

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