C9. Commission on Magnetism (1957)

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Activities

* One of the most important activities of C9 is to organize the International Conference on Magnetism (ICM), which is held every three years under the auspices of IUPAP. The last one, the 19th ICM, took place in July 2012 in Busan, Korea. The 20th ICM will be held in July 2015 in Barcelona, Spain. The venue of 21th ICM in 2018 has been decided to be in San Francisco, USA.

* The ICM Magnetism Award and Neel Medal, and the IUPAP Young Scientist Awards in the field of Magnetism are presented at ICM. The call for nominations for these Awards has been made in August 2011. The winners have been selected by the C9 Committee and have been presented at the 19th ICM in Korea. The ICM Magnetism Award and Neel Medal was dedicated to Prof. Sadamichi Maekawa (Japan) and to Prof. Yoshinori Tokura (Japan). The IUPAP Young Scientist Award was given to Dr. Suchitra Sebastian (UK).

New Developments in Magnetism

Magnetism is a traditional and broad field of study in physics. It is also familiar in daily life.For example, magnets may be found stuck on the door of a kitchen refrigerator. Magnetic materials are valuable not only as magnets but as electronic materials. In the past, the electron’s spin and charge mostly were studied separately. A revolution in magnetism has emerged from the combination of charge and spin properties.

*** Spintronics [1]:**
Nowadays information technology is based on semiconductor and ferromagnetic materials. Information processing and computation are performed using electron charge by semiconductor transistors and integrated circuits. On the other hand, the information is stored on magnetic high-density hard disks by electron spins. Recently, a new branch of physics and nanotechnology, called magneto-electronics, spintronics, or spin-electronics, has emerged, which aims to simultaneously exploit both the charge and the spin of electrons in the same device and describes the new physics raised. One of its tasks is to merge the processing and storage of data in the same basic building blocks of integrated circuits, but a broader goal is to develop new functionality that does not exist separately in a ferromagnet or a semiconductor.

In the field of spintronics, the flow of electrical charges as well as the flow of electron spin, the so-called spin current, are manipulated and controlled together. Whereas charge current flows without decay (owing to the fundamental charge conservation), spin current decays on a length scale of less than a few micrometers.In other words, it exists only on a nanometer scale. Therefore, recent progress in the physics of magnetism and the application of spin current has progressed in tandem with the nanofabrication technology of magnets and the engineering of interfaces and thin films.

*** New quantum phases of matter:**
Discovery of new materials, and purification and microfabrication of materials provide opportunities to study new quantum phases of matter. In the following, some of them which have recently been developed are given.

a) Topological Insulators [2]: Topological insulators are insulating materials that conduct electricity on their surface via special surface electronic states. The surface states are topologically protected, which means that unlike ordinary surface states they cannot be destroyed by impurities or imperfections. Topological insulators are similar to the quantum Hall state in that they exhibit "topological order". Unlike the quantum Hall state, which is only seen when a strong magnetic field is present, topological insulators occur in the absence of a magnetic field. In these materials the role of the magnetic field is played by spin-orbit coupling. This analogy between spin-orbit coupling and a spin dependent magnetic field provides a way to understand the simplest two-dimensional topological insulator; quantum spin Hall state, which occurs when the spin-up and spin-down electrons, which feel equal and opposite spin-orbit "magnetic fields", are each in quantum Hall states. Recent measurement of electrical transport in a quantum well structure made by sandwiching a thin layer of mercury telluride between layers of mercury cadmium telluride suggests the possibility of the topological insulating state.

b) Multiferroics [3]: The well-established ferroic orderings, ferroelectricity, ferromagnetism, and ferroelasticity, can be switched by their conjugate electric, magnetic and stress fields, respectively. Cross coupling allows those ferroic oderings to also be tuned by fields other than their conjugates; in magnetoelectric multiferroics, a promising new toroidal ordering of toroidal moments, which should be switchable by crossed electric and magnetic fields. Spiral-antiferromagnetic ground state of Cr_2BeO_4 results in a small ferroelectric polarization.The oxide $BiFeO_3$ is another example of multiferroic materials, which shows an antiferromagnetic order and is ferroelectric. Multiferroics continue to reveal novel and unanticipated physics, and the potential applications now stretch far beyond electrical control of ferromagnetism.

c) Quantum Criticality: The quantum critical point, where the transitions occur, is present only at absolute zero temperature, but its influence nevertheless is felt in a broad regime of "quantum criticality" at nonzero temperatures, and it is the key to understanding a variety of experiments such as quantum spin systems and heavy fermions. The copper oxide compounds (the cuprates) such as $La_{2-x}Sr_xCuO_4$ which display high-temperature superconcuctivity are another example. In the stoichiometric limit, the cuprates are good insulators that display the antiferromagnetic order. By varying the relative concentration of elements, one can dope the materials with mobile charge carriers and turn them into good metals. Along the way, high-temperature superconductivity emerges. More recent examples are the iron-based pnictide compounds such as $BaFe_2(As_{1-x}P_x)$, which display a similar set of phases.

In the recent magnetism, presented are not only a wealth of studies of a variety of magnetic materials but also a new pathway towards the control of magnetism. This paradigm is epitomized by a flood of new concepts, which introduces a new front in the evolution of traditional research in magnetism.

Prefaces:
[1] S. Maekawa: Nature Materials 8, 777 (2009).
[2] C. Kane and J. Moore: Phys. World, Feb. 2011, page 32.
[3] N.A. Spaldin, S. W. Cheong and R. Ramesh: Phys. Today, Oct. 2010, page 38.

[4] S. Sachdev and B. Keimer: Phys. Today, Feb. 2011, page 29.