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Editorial

Applied Superconductivity and Magnetism

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A magnetic field, which is one of the more important physical parameters, allows the properties of materials to change. The materials, such as semiconductors, metals and superconductors, with the exception of insulators, show distinct responses to a magnetic field. The magnetoresistance, Hall effect, cyclotron resonance, de Haas–Van Alfen effect, etc., are observed only in magnetic fields. Currently, strong magnetic fields up to 30 T are achieved with combined magnetic systems (resistive + superconducting sections). Conduction-cooled superconducting magnets are also now available for long-term experimentation without cooling them by liquid helium in fields up to 20 T. Conduction-cooled superconducting magnets have opened up a new field in science, especially in material processing technology. Strong field technology is progressing rapidly, and static strong fields over 20 T may be used to explore high-T_c superconductors.

Overall, superconductivity and magnetism are important research fields in experimental and theoretical physics. As is known, conventional electromagnets can supply DC magnetic fields only up to about 2 T in small volumes (about of 10 cm^3). At the same time, superconducting magnets allow higher fields to be produced with lower power utilization than non-superconducting ones. This is because superconducting materials have very high values of critical current densities, compared to the operating current density of conventional normal metals of the same size (the difference is as much as 100 times). This means that the superconducting magnets consume no power when working at a high current density without an iron core. Due to these properties, superconducting magnets offer lower power costs, stronger magnetic fields, and higher gradients in large operating volumes. From this point of view, Kamerlingh-Onnes was the first to explore the potential of the zero resistivity state for electrical applications in the years after the discovery of superconductivity.

Superconductors are promising for application in many technologies. They open up many possibilities if high-T_c superconductors, which maintain their superconducting properties in very strong fields, are used. Although conduction-cooled superconducting magnets had been developed, they are not yet widely used. High-T_c superconducting magnets are still a representative demonstration of their practical applications, for example, in power engineering. However, strong static magnetic fields over 30 T will push the research frontier forwards, and it is expected that new phenomena will be discovered in the fields of superconductivity and magnetism under extreme conditions combined with high pressures and ultra-low temperatures.

A long superconducting wire is needed to fabricate a superconducting magnet. It is an important technical question how high-T_c superconductors can be manufactured as a long wire that is wound into a coil shape. In particular, kilometer-long high-T_c superconducting wires based on $Bi_2Sr_2CaCu_2O_8$ (Bi2212) and $Bi_2Sr_2Ca_2Cu_3O_{10}$ (Bi2223) can be fabricated by use of the powder-in-tube (PIT) method. Until now, the design of strong field superconducting magnets, which can supply 20 T at 4.2 K, and conduction-cooled superconducting magnets operating at 20 K, are produced using Ag-sheathed, Bi-based high-T_c superconducting wires. Moreover, bulk high-T_c superconducting materials are already used for actual current leads. In addition, high-T_c bulk materials are applied for

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bulk magnets, such as in magnetic levitation support devices, magnetic bearings, flywheels, and motors.

The magnetic properties of superconductors, which play a key role in superconducting magnet applications, are studied by means of different experimental techniques and theoretical models. Some new versions of these are presented in this issue. To this end, it collects the experience gained with the design and operation of the superconducting materials for large-scale applications, and outlines the physical principles of superconductivity, its application in magnet technology, and its relation to the theory of magnetism. The contributions presented are original and come from research and development work performed in physics laboratories. Besides this, this issue covers important aspects of magnetic field generation for laboratory experiments, and the specific experimental techniques that have been developed for experiments with strong magnetic fields. With the development of new materials, superconducting magnets have become available for many applications, namely, from the laboratory to industry. Nowadays, most of the research in strong magnetic fields is done with superconducting magnets that are commercially available with fields up to 30 T. It should be mentioned that the most convenient magnet for laboratory use is the cryogen-free superconducting magnets that provide simple operation conditions. However, the challenge of substantially increasing the magnetic field has not yet been met for wide applications. It turned out to be more difficult than expected to make efficient use of the new high-temperature superconductors, and the anticipated development of new materials has not yet been realized. As a result, fundamental aspects and theory, and advances in material synthesis, processing and properties are featured in this Special Issue, as well as current developments in superconducting components and devices.

Superconductivity has a growing impact on our daily lives. Its use in numerous applications is already challenging many areas, issues, and concepts. Much of the superconducting technology that exists today has constantly evolved to be useful for practical technologies. We urge the presentation of new results from superconducting technologies that will spark discussion on how they can be used to drive innovation in superconductivity, and also of magnetism theory, which is inextricably linked to the theory of superconductivity.

Overall, it should be underlined that this Issue is designed to provide detailed coverage of the major current results of theory and the applications of superconductivity and magnetism, and we present many areas that are still being developed. Therefore, this issue brings cutting-edge research in many fields of applications. Many universities, research institutes and companies are working to develop superconducting applications, and considerable progress has been made. Thus, this issue will represent helpful tools for all researchers interested in all aspects of basic, applied superconductivity and magnetism.

This Special Issue aims at promoting original and high-quality papers on superconductivity from a multidisciplinary perspective. In particular, the Guest Editors will consider papers on superconductivity and magnetism. The issue also welcomes papers on classical topics.