Focus on Magneto-Science

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FOREWORD

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Yoshifumi Tanimoto
Hiroshima University, Higashi-Hiroshima 739-8526, Japan

Eric Beaugnon
CNRS/CRETA BP, 166 Cedex 9, Grenoble 38042, France

Tsunehisa Kimura
Kyoto University, Sakyo-ku, Kyoto 606-8502, Japan

Sumio Ozeki
Shinshu University, Matsumoto 390-8621, Japan

Magnetite, a natural magnetic material, was discovered in China several thousand years ago. Since then, many ancient people have been fascinated by the interesting properties of magnetite. Similarly, many scientists have dreamed of manipulating chemical, physical and biological phenomena using magnetic fields. Despite the long time that has passed since the discovery of magnetite, this dream has only recently been accomplished.

Magnetism, an important physical property of materials, is of three types: diamagnetism, paramagnetism and ferromagnetism. The magnetic susceptibilities of diamagnetic, paramagnetic and ferromagnetic materials are in the order of -10^{-10}, $+10^{-8}$ and $+10^{-2}$ m^3 mol^{-1}, respectively. Note that most commonly used materials such as water and benzene are diamagnetic; air is paramagnetic. The magnetic energy of diamagnetic and paramagnetic (magnetically weak) materials under a magnetic field of 1 T, which is the maximum field generated by a tabletop electromagnet, is very small compared with the thermal energy at room temperature. Therefore, it is difficult to believe that a magnetic field less than 1 T markedly affects the chemical and physical phenomena of magnetically weak materials.

Recently, the progress of superconducting magnet manufacturing technology has enabled us to freely use strong magnetic fields of 10 T or more in our laboratories. Because magnetic energy is proportional to the square of the magnetic flux density, the magnetic energy at 10 T, for example, is 100 times greater than that at 1 T, indicating that the effect of a 10 T magnetic field on magnetically weak materials becomes so great that magnetic phenomena, which cannot be observed in a 1 T field, are very clear in a 10 T field. Consequently, many interesting phenomena have been observed. For example, it was demonstrated that water in a vessel could be separated into two parts by applying strong horizontal magnetic fields to create the so-called Moses effect. Reportedly, diamagnetic materials such as water and wood can be levitated by applying vertical magnetic fields: magnetic levitation. These phenomena are interpreted in terms of magnetic force.

Although the effect of a magnetic force has been well investigated both theoretically and experimentally, before these reports it was difficult to imagine that water could be separated or levitated using magnetic fields, simply because the magnetic force generated by a tabletop electromagnet is not strong enough to demonstrate these phenomena clearly. The magnetic phenomena occurring under a 10 T field markedly differ from those under a 1 T field: strong magnetic fields of approximately 10 T present researchers with a new interdisciplinary field of science, encompassing physics, chemistry and biology, which will also be useful for technological development. Taking these benefits into account, we adopted the term ‘magneto-science’ (basic and applied), to refer to the investigation of magnetic field effects (MFEs) on physical, chemical and biological phenomena in order to differentiate this new interdisciplinary field from traditional ones.

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In consideration of the important role of magneto-science in the 21st century, this focus issue contains 16 articles selected from the International Conference on Magneto-Science (ICMS2007), which was held in Hiroshima, Japan in November 2007. The selected papers describe various studies of MFEs ($\leqslant$ 16 T) in hard, soft and biological materials. Topics such as the magnetic processing of alloys or hard materials, spin chemistry and spin dynamics, magneto-electrochemistry, the magnetic processing of soft materials, the applications of magnetic fields to analysis, and magneto-biology are addressed to delineate the frontiers of magneto-science.

We hope that this focus issue will help readers to understand several aspects of the frontiers of magneto-science.