Investigating R&D Committee on Development of Functional Materials Using Nanoscale Magnetic Materials

Technical Committee on Magnetics

1. Objective

Magnetic materials have a wide range of applications, including energy industry technologies (e.g., motors and generators), large-capacity non-volatile information storage devices, power-saving and high-sensitivity sensors, and reservoir computing and artificial intelligence (AI). As the improving characteristics of such magnetic materials helps enhance the performance of several devices, new material development has been actively pursued based on metallurgical findings. On the other hand, there has been active research on surpassing conventional material limits by applying nanoscale fine-processing techniques established through semiconductor device development and atomic-level film-forming control techniques. Thus, manufacturing of nanostructures and material synthesis formerly impossible using metallurgical techniques has been realized. The "Investigation Committee on Structural and Organizational Analysis and Creation of Nanoscale Magnets" (July 2016 to June 2019) has developed new methods for fabricating nanostructures with new, high-functional physical properties, and has studied the trends in the analysis technology for such nanostructures. As a result, it has become clear that increasing progress in the development and application of materials and devices using the new physical properties and functionality of nanoscale magnetic substances will be expected in the future.

The committee proposed herein (July 2019 to June 2022) will investigate new physical phenomena, leading to the manifestation of novel physical properties in nanoscale magnets based on past research activities, and will investigate the possibility of device application and expected performance. To clarify the optimum interfacial and nanoscale structures with new, high-functional physical properties, further progress in analysis techniques is needed, and the latest technological trends will be investigated. The development trends of novel methods to create nano-microstructures will continue to be examined. In addition, information will be exchanged, and the committee will consider the status of device and machine development to develop new physical properties and functions. We propose to set up this committee to comprehensively identify the trends in the development of functional materials for nanoscale magnets.

2. Background and internal and external research activities

Controlling magnetic and spin-transport properties of nanoscale magnets is a key technical issue that influences the performance of next-generation devices such as magnetic random access memory (MRAM), spin transistors, spin-torque oscillator elements, and spin arithmetic elements. For example, spin flow, which generates spin angular momentum without Joule loss, can be used to invert and oscillate magnetization or to read-out magnetization to save power. Therefore, methods for generation and detection of spin flow have been actively developed worldwide. Although spin flow generation using the spin hole effect of a substance with large spin orbit interaction is the present convention, rare substances, e.g., platinum, are indispensable; thus, new principles and mechanisms for rare substance-free spin flow generation are required for real devices. In studies of interest, spin flow has been generated using the Rashba interface of nonmagnetic oxides and the nonequilibrium and nonuniform spin scattering of surface acoustic waves. In recent times, pioneering reports of generating spin flow comparable to that of platinum using copper and its oxides, which are considered unsuitable for spin flow generation, have been published by research groups in Japan. These findings are expected to revolutionize spin device materials. However, certain issues remain unaddressed, and hence, new measurement techniques that quantitatively examine the correlation between interface structure and spin scattering mechanism are required. Against this background, completely new technology to extract spin transport parameters at junction interfaces—based on microscopic theory and on measurement of the spin Hall magnetoresistance effect, which is sensitive to the spin scattering mechanism of the junction interface and the noise measurement of spin transport phenomenon—is also being developed. In addition, material evaluation using large synchrotron radiation facilities and electron microscopes, and techniques for analyzing the microstructure and structure of nanoscale magnets, are making remarkable progress. These technologies are excellent for evaluating physical microstructures and compositions. Crystal and magnetic domain structures can be observed in the same field of view. In addition, *in-situ* observation equipment and techniques suitable for high temperatures and strong magnetic fields crucial for developing devices have been established. They are expected to significantly contribute to the understanding of the principles of physical properties and functions of nanoscale magnetics.

3. Investigative matters

(1) Novel spin flow generation methods for nanoscale magnets and analytical techniques for elucidating the expression mechanism of these methods
(2) Methods for controlling and creating structures and organizations for nanoscale magnetic materials
(3) Development of functional materials using nanoscale magnets and device applications

4. Expected effects

(1) Understanding of magnetic and spin transport property control techniques for nanoscale magnetic materials
(2) Understanding of spin flow generation techniques for nanoscale magnetic materials and proposal of new application fields
(3) Understanding of R&D trends in nanoscale magnets and clarification of future guidelines

5. Term of investigation

July 2019 to June 2022 (3 years)

6. Committee members

Position	Name	Affiliation	Member/Non-member category of IEEJ
Chairperson	Yukio Nozaki	Keio University	Member
Member	Hiroyuki Awano	Toyota Technological Institute	Non-member
〃	Nobuyuki Inaba	Yamagata University	Non-member
〃	Hironaga Uchida	Toyohashi University of Technology	Member
〃	Yasushi Endo	Tohoku University	Member
〃	Daiki Oshima	Nagoya University	Non-member
〃	Satoshi Okamoto	Tohoku University	Member
〃	Yoshitaka Kitamoto	Tokyo Institute of Technology	Member
〃	Tetsunori Koda	National Institute of Technology, Oshima College	Member
〃	Nobukiyo Kobayashi	Research Institute for Electromagnetic Materials	Non-member
〃	Hiroshi Sakuma	Utsunomiya University	Member
〃	Katsuaki Sato	He used to work for Japan Science and Technology Agency.	Member
〃	Tsutomu Sinagawa	Osaka Research Institute of Industrial Science and Technology	Non-member
〃	Mutsuko Jimbo	Daido University	Member
〃	Satoshi Sugimoto	Tohoku University	Member
〃	Takeshi Seki	Tohoku University	Non-member
〃	Makoto Sonehara	Shinshu University	Member
〃	Masaaki Takezawa	Kyushu Institute of Technology	Member
〃	Yasushi Takemura	Yokohama National University	Member
〃	Shigeki Nakagawa	Tokyo Institute of Technology	Member
〃	Isao Nakatani	National Institute for Materials Science	Non-member
〃	Masaki Nakano	Nagasaki University	Member

Position	Name	Affiliation	Member/Non-member category of IEEJ
Member	Hikaru Nomura	Osaka University	Non-member
〃	Syuichiro Hashi	Tohoku Gakuin University	Member
〃	Singo Hirose	National Institute of Advanced Industrial Science and Technology	Non-member
〃	Naoyuki Fujita	National Institute of Technology (KOSEN), Nara College	Member
〃	Sho Muroga	Akita University	Member
〃	Shin Yabukami	Tohoku University	Member
〃	Kazuo Yayoi	National Institute of Technology (KOSEN), Ibaraki College	Member
〃	Kosuke Yoshimoto	Daido Steel Co., Ltd.	Non-member
〃	Xiaoxi Liu	Shinshu University	Non-member
Secretary	Takashi Hasegawa	Akita University	Member
〃	Masashi Matsuura	Tohoku University	Member
Assistant secretary	Kazuto Yamanoi	Keio University	Non-member

7. Activity schedule

Committee meetings: 4 times/year; Secretariat: 3 times/year

8. Reporting format

Planning to hold a themed session at Annual Conference of Society A.

Reason:

Research on nanoscale magnetism and spintronics requires the fusion of physical findings from basic research and advanced technology development for practical application and is actively discussed across industries, academia, and government. The items to be investigated include synergistic effects with mechanical phenomena, which have been neglected in conventional studies and may lead to unprecedented electronic device applications. Thus, a ripple effect on fields and researchers beyond conventional frameworks can be expected. For the aforementioned reasons, non-member commercial researchers have been invited to join us; thus, we can expect an increase in the number of participants and believe that high-quality reporting of research results will be possible by conducted “themed sessions at Annual Conference of Society A,” where the trends in the latest basic and applied research can be presented.