Investigating R&D Committee on Research and Development Trends and Applications of Next-Generation Permanent Magnets

Technical Committee on Magnetics

1. Objective

Permanent magnets, which had been recognized as an important material for "environmental and energy problems" in the late 1990s and early 2000s, started attracting interest with the "elemental strategy" over the last 10 years or so, involving research laboratories of universities and public institutions. Discussions about permanent magnets in academic societies has become very popular. The "Research and Development Trend Investigation Committee on High-Performance Permanent Magnets (April 2016 to March 2019)" of the IEEJ, which is the predecessor to this committee, clarified the situation, including the high coercivity and Dy-saving of Nd-Fe-B based magnets, and the rare earth resources and applied technology related to them. In addition, using recent evaluation and analysis techniques and based on progress in electronic theory and computational science, the committee investigated methods for elucidating the coercive force mechanism of permanent magnets. However, suitable methods have not yet been identified, and problems still remain. On the other hand, new magnet materials, e.g., de-rare-earth magnets under development in many organizations, and new process technologies for realizing them must be identified in future.

Thus, the proposed investigation committee will examine the academic and practical aspects of high-coercivity Nd-Fe-B sintered magnets to realize Dy usage reduction technology and observe the trends in the development of other permanent magnet materials in the form of Nd-Fe-B hot-deformed magnets, rare earth-bonded magnets, ferrite magnets, non-Nd-Fe-B sintered magnets, and new magnet materials represented by $NdFe_{12}N_x$ compounds; moreover, it will investigate the process technology, evaluation and analysis techniques, and theories supporting this material development. In addition, it will proceed to research and investigate technological trends with regard to the application of permanent magnets in motors and research and investigate rare earth resource problems, which include recycling.

Committee activities involving investigation and research as described above can be of significance for investigation committees in this field within the IEEJ. Thus, we propose its establishment.

2. Background and internal and external research activities

The research and development of high-performance permanent magnet materials is supported by large-scale domestic and overseas projects (e.g., JST's Basic Research for Co-creation by Industry and Academia, ESICMM, MagHEM, etc.). Nd-Fe-B sintered magnets encompass (1) the development of material creation process technology such as "grain refinement" and "grain boundary phase control by grain boundary diffusion/Ga addition," contributing to improved coercive force in Nd-Fe-B sintered magnets using high-resolution electron microscopy, neutrons, and radiation, and (2) the development of simulation technology and magnetic domain structure observation technology using large-scale computers, assuming the academic rethinking of so-called new creation-type magnetization based on the results of (1). Several themes can be addressed, including (1) searching for techniques to improve the coercivity of Nd-Fe-B sintered magnets, which are still significantly separated from $Nd_2Fe_{14}B$ phase anisotropy fields, and (2) problems in applying Nd-Fe-B sintered magnets having newly developed fine-grained structures (e.g., magnetizing techniques, etc.).

Other than Nd-Fe-B sintered magnets, development is anticipated in (1) Nd-Fe-B hot-deformed bulk magnets, which have gained attention from first-time installation as Dy-free magnets in hybrid vehicles (HEVs), and (2) high-performance Nd-Fe-B anisotropic bonded magnets and Sm-Fe-N bonded magnets (isotropic and anisotropic), which have enabled breakthroughs in ferrite magnet application fields. While Ca-La-Co M-type ferrite magnets are the latest materials to attract notice from the viewpoint of suppressing eddy current loss in permanent magnets themselves owing to high resistance, and although rare earth magnets have been known longer, research into new high-performance magnet materials is worth considering, including Sm-Fe-N sintered magnets at the development stage of introducing new material creation processes and Sm-Co sintered

magnets attempting to enhance saturation magnetic polarization. Further development is expected in next-generation rare earth magnets, including high-saturation magnetic polarization and high-anisotropic magnetic field $SmFe_{12}$ ［$Sm(Fe, Co)_{12}$］ compounds, which have been suggested by identifying magnetic properties based on computational analysis of crystalline structures and constituent elements and verified through experiments.

3. Investigative matters

As a result, the proposed investigation committee shall focus on the following items:

1) Development trends, including the application of high-coercivity Nd-Fe-B magnets with Dy-content reduction technology
2) Development trends, including the application of high-performance ferrite magnets and bonded magnets
3) Development trends in new magnetic materials (e.g., $NdFe_{12}N_x$ compounds, $SmFe_{12}$[$Sm(Fe, Co)_{12}$] compound, s $L1_0$ type Fe-Ni, square Fe-Co base alloys, creation of manganese (Mn)-based permanent magnetic material, etc.), and new material creation processes (e.g., Sm-Fe-N sintered magnetic, etc.)
4) Research and development trends in evaluation and analysis technologies for permanent magnets, electron theory, and computational science
5) Trends in research and development, including the required performance of magnets in applications such as permanent magnet motors and required techniques (e.g., magnetizing techniques) while installing motors
6) Trends in the development and supply of rare-earth resources and research and development of magnet recycling technologies

4. Expected effects

1) Provide information on high coercivity Nd-Fe-B magnets that have realized Dy-addition reduction technology
2) Provide information on high-performance ferrite magnets and bonded magnets
3) Provide information on magnet materials developed through the establishment of new process technologies
4) Provide information on evaluation and analysis techniques, electron theory, and computational science for permanent magnets
5) Ascertain status of applying several permanent magnets in applications such as HEV and EV driving and prospects of permanent magnet application trends
6) Provide information on rare earth resources and magnet recycling technologies

5. Term of investigation

April 2019 to March 2022 (3 years)

6. Committee members

Position	Name	Affiliation	Member/Non-member category of IEEJ
Chairperson	Masaki Nakano	Nagasaki University	Member
Member	Toyonori Ariizumi	Toei Industry Co., Ltd.	Member
〃	Nobuyuki Inoue	Inoue Giken Co., Ltd.	Non-member
〃	Tadakatsu Okubo	National Institute for Materials Science	Non-member
〃	Ken Ohashi	Shin-Etsu Chemical Co., Ltd.	Non-member
〃	Satoshi Okamoto	Tohoku University	Member
〃	Kazuhiro Ogawa	Nissan Motor Co., Ltd.	Member
〃	Kunio Okumura	Tokyo Magnet Engineering Co., Ltd.	Non-member
〃	Nobuhiro Katayama	Toda Kogyo Co.	Member
〃	Isao Kitagawa	Hitachi, Ltd.	Member
〃	Kurima Kobayashi	Shizuoka Institute of Science and Technology	Member

Position	Name	Affiliation	Member/Non-member category of IEEJ
Member	Tetsuji Saito	Chiba Institute of Technology	Member
〃	Shinya Sakurada	Toshiba Corporation	Member
〃	Nobuo Sasaki	Tamakawa Co., Ltd.	Member
〃	Munekatsu Shimada	He used to be a professor at Hirosaki University.	Member
〃	Masahiko Shimamura	Japan Electric Measuring Instruments Manufacturers' Association	Member
〃	Terumitsu Shirai	He used to work for Japan Electric Meters Inspection Corporation.	Member
〃	Satoshi Sugimoto	Tohoku University	Member
〃	Kenichiro Suwa	TDK Corporation	Member
〃	Kenta Takagi	National Institute of Advanced Industrial Science and Technology	Member
〃	Tomohiro Tanaka	Fujitsu, Ltd.	Non-member
〃	Sigeho Tanigawa	He used to work for Technology Research Association of Magnetic Materials for High-Efficiency Motors.	Member
〃	Masaaki Tokunaga	He used to work for Hitachi Metals, Ltd.	Member
〃	Motoichi Nakamura	Adamant Namiki Precision Jewel Co., Ltd.	Non-member
〃	Hiroaki Nisio	Osaka University	Member
〃	Hayato Hashino	Daido Steel Co., Ltd.	Member
〃	Takashi Hasegawa	Akita University	Member
〃	Akio Hasebe	Musashi Energy Solutions Co., Ltd.	Member
〃	Satoshi Hirosawa	National Institute for Materials Science	Member
〃	Masakatsu Fukuda	He used to work for Mitsubishi Steel Mfg. Co., Ltd.	Member
〃	Hirotoshi Fukunaga	Nagasaki University	Member
〃	Teruhiko Fujiwara	Tokin Corporation	Non-member
〃	Michitaka Hori	Nihon Denji Sokki Co., Ltd.	Member
〃	Kenichi Machida	Osaka University	Member
〃	Masashi Matsuura	Tohoku University	Member
〃	Hideki Matsuda	Sumiko Kunitomi Denshi Co., Ltd.	Non-member
〃	Chisato Mishima	Aichi Steel Corporation	Member
〃	Mineo Muraki	JFE Techno-Research Corporation	Non-member
〃	Hideto Yanagihara	University of Tsukuba	Non-member
〃	Takehiro Yamaoka	Hitachi High-Tech Science Corporation	Non-member
〃	Osamu Yamada	MinebeaMitsumi Inc.	Member
〃	Hitoshi Yamamoto	KRI, Inc.	Member
Secretary	Takeshi Nishiuchi	Hitachi Metals, Ltd.	Member
〃	Masaaki Takezawa	Kyushu Institute of Technology	Member
Assistant secretary	Gaku Obara	Meiji University	Member

7. Activity schedule

Committee meetings 4 times/year; Secretariat 4 times/year; Technical Meetings: 2 times/year (including co-sponsorships)

8. Reporting format

The results will be reported in a symposium at IEEJ Annual Meeting.

Reason:

Studies on permanent magnets involve combining academic knowledge from researchers at universities and public institutions and practical knowledge from commercial researchers and developers. Corporate power is the main factor promoting research and development in the field of permanent magnets, and cooperation with relevant corporations is

indispensable in compiling meaningful investigative results. The permanent magnet market trends may undergo major short-term changes. Thus, it appears important for this committee to provide research results promptly.

The results of research will be reported in detail via cooperation with regular corporations, i.e., inviting non-member commercial researchers to become members—which is expected to increase the number of members—and organizing a symposium of IEEJ Annual Meeting for promptly presenting investigative results.