IEEE MAGNETICS NEWSLETTER

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Editor: Jia Yan Law

Magnetic Water treament

Navigating the Blue: Sea turtle's magnetic Odyssey

Atsufumi Hirohata's Presidency Journey

The Career's Perspectives Behind our 2025 IEEE Cledo Brunneti Award Winners

Transition from Academia to the Industry

Newsletter Editorial Board

Jia Yan Law
Editor (Email)

Jia Yan currently holds a tenure-track Emergia fellowship at University of Seville, Spain. Her research interests include functional high-entropy alloys, magnetocalorics, magnetic materials, and additive manufacturing. She has been an IEEE Senior Member and Editor of the IEEE Magnetics Society Newsletter since 2022.

Martin Lonsky
Associate Editor (Email)

Martin currently works as a senior process engineer at Nexperia Germany where he focuses on power semiconductor devices. Previously, he was a research scientist at the University of Illinois at Urbana-Champaign and Goethe University Frankfurt. His interests lie in materials physics, magnetism, and spintronics. Aside from experimental research, he is interested in computational methods and how to incorporate them into undergraduate science and engineering curricula. In addition, he enjoys writing and communicating science. He is a member of the IEEE Magnetics Society since 2020.

Brad Dodrill
Associate Editor for Industrial Liaison (Email)

Brad graduated with a degree in Physics from The Ohio State University in 1982. After completing 2 years of graduate studies in Physics and Electrical Engineering, he joined Lake Shore Cryotronics in 1984 as a Research Scientist. Throughout his career, Brad has played a pivotal role in various positions, from Systems Applications Engineer to VP of Applications. He's a Senior Scientist now, with a remarkable record including co-editing a book and holding three U.S. patents. Brad's expertise has taken him all over the world, delivering lectures at universities and technical conferences on cutting-edge topics such as vibrating sample magnetometry and AC susceptometry.

Ana Isabel Jimenez Ramirez
Graphic designer intern (Email)

Ana Isabel is currently a PhD student at the University of Oviedo, Spain, specializing in the study of magnetic nanomaterials. Her research focuses on materials with high spin polarization for spintronics applications, with a particular emphasis on Heusle alloy nanowires and thin films. She is passionate about advancing the field of spintronics through innovative approaches in material science.

IN THIS ISSUE

Note from the Editor

In this issue, we showcase a collection of articles featuring both our industrial and academic members. We are proud to highlight the MagSoc members who have been honored with the 2025 IEEE Cledo Brunetti Award in recognition of their extraordinary achievements. Explore other featured articles such as magnetic water treatment and the use of magnetoreceptors by sea turtles. Additionally, don't miss our heartfelt interview with our outgoing president, who shares inspiring reflections and hopes for our Society. And contact Brad for advertising packages in the newsletters!

CONTENTS

About the Newsletter

The purpose of the Newsletter of the IEEE Magnetics Society is to publicize activities, conferences, workshops and other information of interest to Society members, sister societies and other people in the area of applied magnetics.

Contributions are solicited from Society and sister society members, Officers & other volunteers, conference organizers, local chapters, and other individuals with relevant material. The Newsletter is published quarterly on the Society website at: http://www.ieeemagnetics.org.

From the President

Atsufumi Hirohata

Welcome to the December issue of our *IEEE Magnetics Newsletter*. Since these are my last remark as the president of the IEEE Magnetics Society, I would like to thank all of you for your continuous support. It has been a great honour to work with my team, the Administrative Committee (AdCom) and our support teams, Simply Vintage and Conference Catalysts, and more. This has been a very exciting and enjoyable experience!

When I stood for the secretary/treasurer election, I promised to commit to four issues to continue our success, (1) broader memberships, (2) more collaborations with our sister societies, (3) greater industrial involvement, and (4) database creation. Thanks to your support and contributions, (1) the society managed to increase its memberships to 4659 by 75% as compared with those in 2022, 2663. We succeeded to reverse the declining trend in our memberships. For issue (2), we started informal lunch discussions with our sister societies at the Intermag and Magnetism and Magnetic Materials (MMM) conferences.

We have also started to work closely with the Commission on Magnetism (C9) of International Union of Pure and Applied Physics (IUPAP) by sending our representative to their management meeting. As you may have seen, we will jointly celebrate the "Year of TMR" (tunnelling magnetoresistance) next year. Regarding issue (3), we started to organise an Industry Day at the Intermag in Rio de Janeiro this year, which attracted almost 200 participants and will continue at the coming Joint MMM-Intermag in New Orleans in January 2025. Guohan Hu kindly agreed to lead this event as the chair of Industry Engagement created under the Membership Committee. (4) The database of our past conferences have been created and maintained by Rie Umetsu. Any future conference organisers can access it through our support provided by Simply Vintage. I believe these activities will be continued and expanded by the next president, Ron Goldfarb.

On Thursday, 14 November, our Administrative Committee (AdCom) had an online meeting to discuss our activities and budget. Regrettably, our budget next year will be very tight, which may restrict some of our initiatives. I apologise for any inconvenience caused by this circumstance. Please note that at their meeting on 23 and 24 November in Dallas, Texas, the IEEE Technical Activities Board (TAB) made it clear that we may be able to run our budget in deficit up to 1% of our reserves. I trust this will relieve our financial constraint at some level.

Prior to this regular AdCom meeting, we had a series of online discussions to reform our Mid-Career Award guidelines proposed by Adekunle Adeyeye, distinguished lecturer (DL) programme presented by Hendrik Ohldag, continuous support for the Task Force on Rebooting Computing discussed by Pedram Khalili, and so on. It is worth noting that our DL programme will become a two-year term beginning next year. This change is based on strong demands from DL candidates from industry and in different career stages, which may not allow them to take much time for travelling in one year. Now, instead of having 4 DLs for one year currently, we will select 3 DLs every year to two-year staggered terms. This means we will have 6 active DLs each year, which clearly offers a broader choice for those who plan to invite them. Hendrik also plans to arrange presentations by DL candidates to a selection committee.

In the week following our AdCom meeting, I attended the IEEE TAB meeting in Dallas, Texas. Our nonpolitical initiative on Magnetism in Ukraine was approved, which allows us to continue to support our members in Ukraine who currently suffer from difficulties. We plan to make our member support broader to include our members in other hardship regions next year.

The MagSoc sponsored two important conferences in this period. The first one was the Magnetic Recording Conference (TMRC) held in Berkeley, California, between 5 and 7 August. TMRC attracted 100+ participants with a focus on solid state magnetic memory and recording technologies for >3 Tbits/in^2 to respond to the requirements for the current

Big Data era. The second one was the Magnetic Frontiers Conference on Magnetic Materials and Motors for Green Energy Applications held between 15 and 19 September in Darmstadt, Germany. The organisers, Oliver Gutfleisch, Johan Paulides, and Claire Donnelly, and their team made great efforts to attract 100+ participants. The program included a laboratory tour and networking event as well as an excursion to Kloster Eberbach, where "The Name of the Rose" was filmed. There were many participants from industry including a keynote speaker, Masato Sagawa. This event served as a hub to connect many academic researchers, creating a strong collaborative and cooperative culture.

The Conference Executive Committee held their online discussion and voting in September, approving the following small conferences to be supported.

Financially sponsored (100% support by the society):

- International Symposium on Integrated Magnetics 2025 (iSIM 2025) to be held on 12 and 13 January 2025 in New Orleans, Louisiana, USA, as a satellite conference of the coming Joint MMM-Intermag.

Financially supported (grants provided by the society)

- Spanish School of Magnetism "Current research in magnetism and magnetic materials: From fundamentals to applications" held between 25 and 29 November in Seville, Spain.

The Standards Subcommittee led by Philip Pong has been actively organising its meetings online in August and September to start to develop IEEE standards on magnetism. They identified three technical subcommittees—materials, sensors, and spintronics, which had their individual meetings. Their general meeting was held on 27 September, attracting about 40 participants. We all look forward to learning more on their development!

The Oral History *ad hoc* committee led by Liesl Folks released two new interviews recently. Chi-Feng Pai interviewed Ching-Ray Chang of the National Taiwan University, who organized Intermag in Taipei in 2011 and made significant theoretical contributions on spintronics and quantum phenomena. Please watch it and the others to learn more!

More good news comes from our Beijing Chapter led by Xiufeng Han: This chapter was re-established on 17 September. The Beijing Chapter was the main body to organise Intermag 2015 in Beijing, China, and it continues to lead research on magnetism. Ming Yuan also established a Student Branch at the Zhejiang Ocean University. In addition, the Austrian Chapter was established on 17 November chaired by Amalio Fernandez-Pacheco. We wish all the best for them and look forward to seeing their activities in the coming years!

I made some analysis on our flagship conferences. As shown in Fig. 1, one can find three distinctive periods. By plotting the number of abstract submissions (top) and abstracts accepted (bottom) as a bar, these three periods can be defined by their abstract rejection rates to be ~15%, ~25%, and ~15% (see Fig. 1 top-left). Initially our conferences rejected 10%–15% of the abstracts submitted, but they could not accommodate some abstracts for the Joint MMM-Intermag, where a higher rejection was introduced.

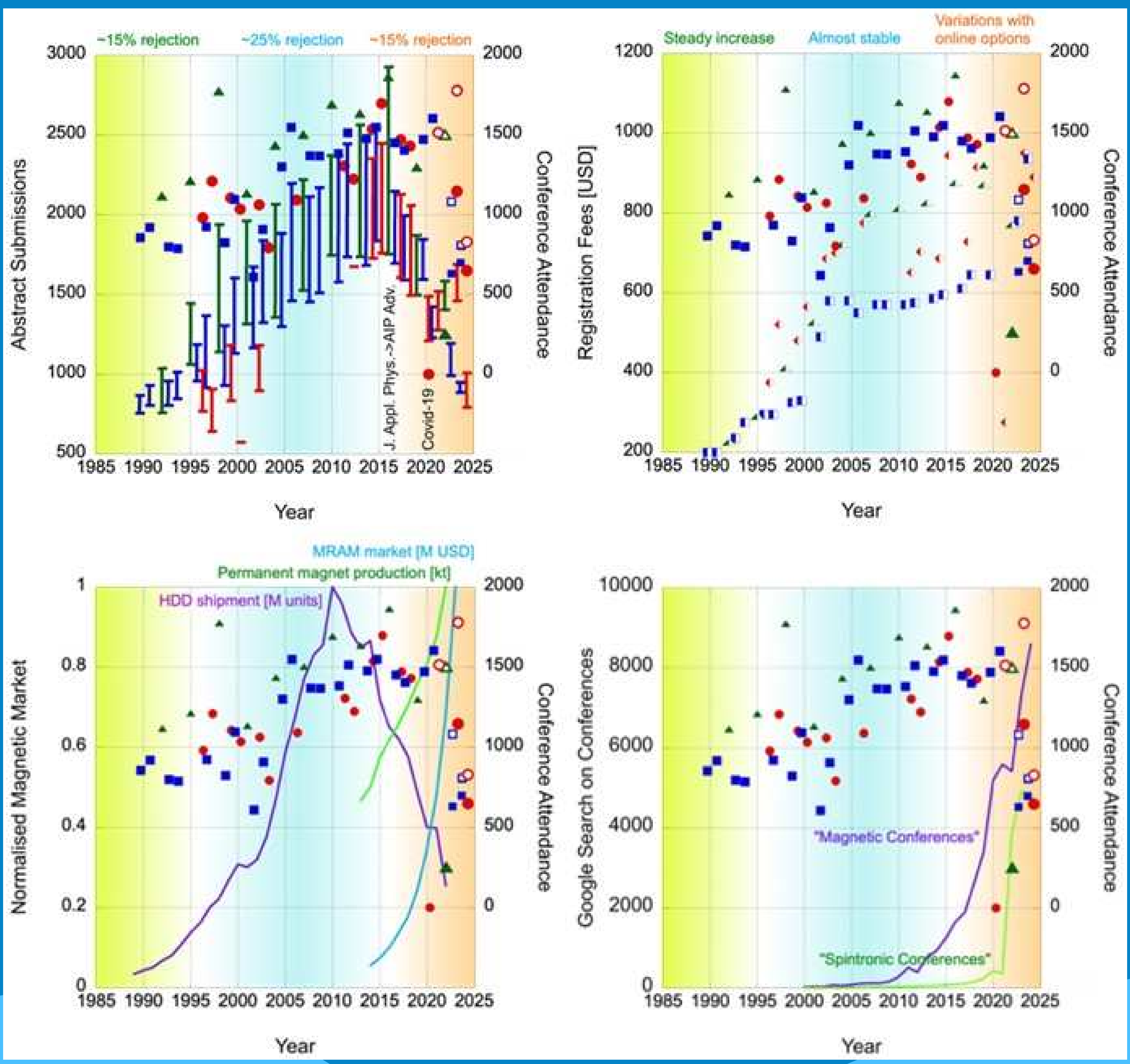

Fig. 1 Conference attendance in the last 35 years with (top-left) abstract submission and acceptance bars, (top-right) full registration fees shown as half-filled symbols, (bottom-left) major magnetic market size as solid lines, and (bottom-right) number of conferences appearing in Google searches each year. Red, blue, and green data represent those for Intermag, MMM, and Joint MMM-Intermag, respectively. Open and closed symbols correspond to the attendance with and without online participants. Purple, light green, and light blue lines show hard disk drive (HDD) shipment, permanent magnet production, and magnetic random-access memory (MRAM) market trends.

Following the steady increase in abstract submissions, the rejection rates increased up to ~30%, with the conference attendance peaking at the Joint MMM-Intermag 2016 in San Diego, California, USA. Afterwards, the abstract submission decreased and was severely affected by the Covid-19 pandemic in 2020. In this recent period, both the abstract submissions and conference attendance fluctuated randomly, making our conference planning difficult. Accordingly, the conference registration fees in these three periods increased steadily, remained almost constant, and then increases again, as shown in Fig. 1 top-right.

These three periods and the corresponding trends follow reasonably well with the hard disk drive shipments by an approximately five-year delay (see Fig. 1 bottom-left). Similar trends may be anticipated based on the associated funding. On the other hand, our conferences do not seem to attract those working on permanent magnets (and their associated applications, including motors and electric systems) and magnetic random-access memory.

In response, the coming Joint MMM-Intermag plans to organise two symposia on the topics related to electric systems and one symposium covering both applications. Please check them out!

Additionally, as our strategic planning group reported to the AdCom in May this year, some of our members' interests have not been covered well, such as magnetism applied in transportation, communications, aerospace, plasma, superconductivity, and testing. These should be covered in the abstract categories in our future conferences.

The Intermag 2021 Conference Chair, Bernard Dieny, commented that some fraction of participants may have decided to attend more focused meetings directly related to their research interest. Google searches on "magnetic conferences" (purple line) and "spintronic conferences" (green line) support such a trend as a very crude approximation.

Note that some conferences may have been counted multiple times, and some conference-related activities, such as our posts on social networks (thanks to Diana Leitão and her team) and proceedings (thanks to Tom Thomson and his team) also have been counted. Even so, the number of searched items may be correlated with the number of conferences on magnetism / spintronics organised in a selected year. These small focused meetings show steady increases in their numbers since 2010 and further increases after the Covid-19 pandemic.

This means we need to organise more "interdisciplinary" topics at our symposia in our conferences.

One trial is to have an overarching topic of "Magnetics for Future Transportation—from Memory to Motors" at the Joint MMM-Intermag. This will be the first attempt to organise a symposium on a broad topic covering underrepresented topics in magnetism.

I believe such a symposium will offer an ideal opportunity to find new collaborations / topics for your research in the coming years. In addition, we may need to consider

scheduling some of these smaller meetings as satellite conferences to our flagship conferences.

We may need to include a local person who is responsible for such coordination.

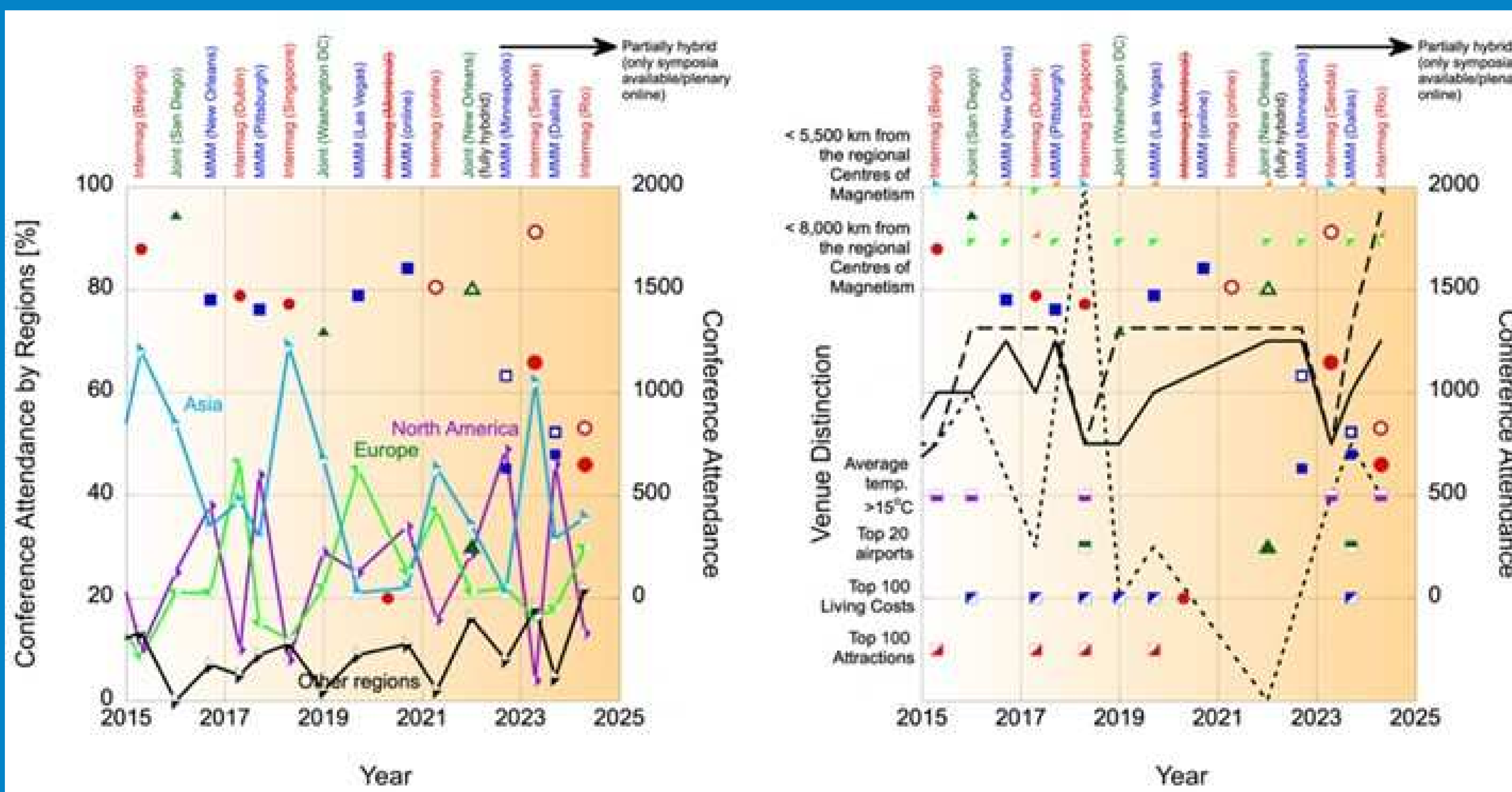

Fig. 2 Conference attendance in the last 10 years with (left) attendance from the North America, Europe, Asia, and the Other regions shown as half-filled symbols in purple, light green, light blue, and black, respectively, and (right) venue distinctions, including (a) world top 100 tourist attractions, (b) top 100 cities with high living cost, (c) world top 20 airports, (d) average temperature over 15°C, and (e–f) distance from the regional Centers of Magnetism (CoM, see the April 2024 issue) within (e) 5,500 km and (f) 8,000 km. Red, blue, and green data represent those for Intermag, MMM, and Joint MMM-Intermag. Solid, dashed, and dotted lines were calculated by total venue distinctions (a-b+c+d+e+f), weighted distance from CoMs (e in the same region with the conference venue+e in the different regions+f), and venue attractiveness (a+b+c+d), respectively.

In order to extract any trends in recent conferences, conference attendance by regions, i.e., North America, Europe, Asia, and the rest of the world, is plotted in Fig. 2 left panel. I would like to thank all the conference chairs who kindly sent me their data. For Intermag, local participation dominates the conference but with a strong base contribution from Asian countries. For MMM, North Americans dominate, but the actual number has decreased by almost a half as compared with attendance over 10 years ago. The reduction in Asian participants at the MMM and Intermag in the United States is mainly caused by visa issues, particularly for those from China and India (for example, there were only 2 on-site participants from India at MMM in 2022).

Overall, Asian participants tend to dominate by almost 75% more than the other regions (41%/604 participants on average with a minimum of 225 participants at MMM 2022), followed by North Americans (26%/346 participants on average with a minimum of 71 participants at Intermag 2023) and Europeans (24%/333 participants on average with a minimum of 144 participants at Intermag 2023). Note that the other regions, including South America and Pacific regions, have been increasing their participation at our conferences, which is good news for us because it proves our initiatives to expand our horizon initiated by Manuel Vázquez have been working well. To resolve these issues,

we may need to reconsider the cycle of our Intermag locations to count the joint conference as the one in the Americas

(*i.e.*, from the current cycle of Americas, Europe, and Asia/Pacific for Intermag plus the Joint MMM-Intermag in North America to the former rotation between Europe and Asia/Pacific for Intermag plus the Joint MMM-Intermag in North America with possible expansion to the Americas).

The conference venue may play an important role to attract many participants. As shown in Fig. 2 right, we considered several features of the venues, such as tourist attractiveness, cost of living, accessibility to the nearby airports, weather, and distance from places our members are located. Unfortunately, there does not appear to be a clear trend, but we understand that local support / participation holds the key for the Intermag outside of North America. We may need to

consider linking with the local universities / community for the MMM by arranging a satellite event and / or a laboratory tour,

possibly through the local person in the conference organisation. The other important factor is to

avoid organising our conference close to the other major international conference(s).

For example, this year, our Intermag was held between 5 and 10 May, which was within two months of the International Conference on Magnetism (ICM) held between 30 June and 5 July in Bologna, Italy, by IUPAP. Such a "conflict" can be avoided by close collaborations with our sister societies as mentioned at the beginning of this remark (note that we are in discussion with IUPAP to sign a sister society agreement). We may also need to seek a smaller venue (with a reduced room-blocking contract at a conference hotel), including a university where at least 6–8 parallel sessions can be run with a large poster / exhibition hall.

As my last request, please visit our society website on a regular basis to check our activities and updates. Please do not hesitate to contact the officers, AdCom members, and Committee Chairs whenever you have any questions, comments, and/or suggestions, especially new initiatives! Please feel free to circulate this newsletter to your colleagues who are interested in becoming a member and/or volunteer of our society. I wish you and the society all the best and look forward to seeing you all at the coming Joint MMM-Intermag Conference to be held between 13 and 17 January 2025 in New Orleans, Louisiana, USA!

Atsufumi Hirohata can be contacted via email: atsufumi.hirohata.d1@tohoku.ac.jp

Call for Associate Editors of the *IEEE Transactions on Magnetics*

The IEEE Transactions on Magnetics (*TMAG*) is seeking to build its editorial expertise and would welcome new applicants for the role of Associate Editors (AEs). AEs are key contributors to the publication process, and this role offers the opportunity to develop your professional profile in the magnetics community. In order to provide high-quality editorial support for *IEEE TMAG*, AEs are expected to hold a Ph.D. in a relevant field and have at least 5 years of experience, and/or a minimum of 10 years in journal publishing. They should also have reasonable prior experience as reviewers or possibly as AEs in related journals. The selection criteria are based on the candidate's research and reviewing experience in any of the following topics:

- Applied Magnetism,
- Biomagnetism,
- Computational Electromagnetics,
- Computational Magnetism,
- Electrical Machines
- Electromagnetic Devices
- Electromagnetism,
- Material Modeling,
- Magnetic Materials,
- Magnetic Recording,
- Magnetism in Solids,
- NDT,
- Numerical Methods,
- Signal Processing,
- Magnetism Theory.

The AEs (especially those from industry or government) should have no conflict of interest with their roles and job responsibilities.

Interested candidates can send a brief CV via an email to the TMAG Editor-in-Chief with the subject "TMAG AE Candidate" by January 31, 2025.

New Senior Members

The listed members of the IEEE Magnetics Society were recently elevated to the grade of Senior Member.

September 2024

Amalio Fernandez-Pacheco

Yunpeng Zhang

Rui He

November 2024

VSK Murthy Balijepalli

Howard Evans

Vito Puliafito

Saburo Tanaka

Hao Zeng

For more information on elevation to Senior Member, visit the IEEE Senior Member Grade Webpage.

REGISTRATION IS OPEN

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PROGRAM HIGHLIGHTS

- Industry Day (Monday)
- 12 Symposia
- Tutorial: *Symmetry in Magnetism*
- Young Professionals Lightning Talks
- Workshop: *Overview of Permanent Magnets, Soft Magnets, and Biomagnetism Areas of Magnetism for the Non-Expert*
- Students in Magnetism Networking Event
- Evening Session: *The Science and History of Rock n' Roll*
- Workshop: *Overview of Spintronics, Magnetodynamics, and Coupled Magnetics Areas of Magnetism for the Non-Expert*
- Women in Magnetism Networking Event and Workshop
- Meet the Speakers
- Panel: *21st Century Permanent Magnets - How to Take it to the Next Level?*
- Mentoring Workshop
- IEEE Awards Ceremony and Plenary Session
- Sensors and Outreach Group Challenges
- Standards in Magnetism

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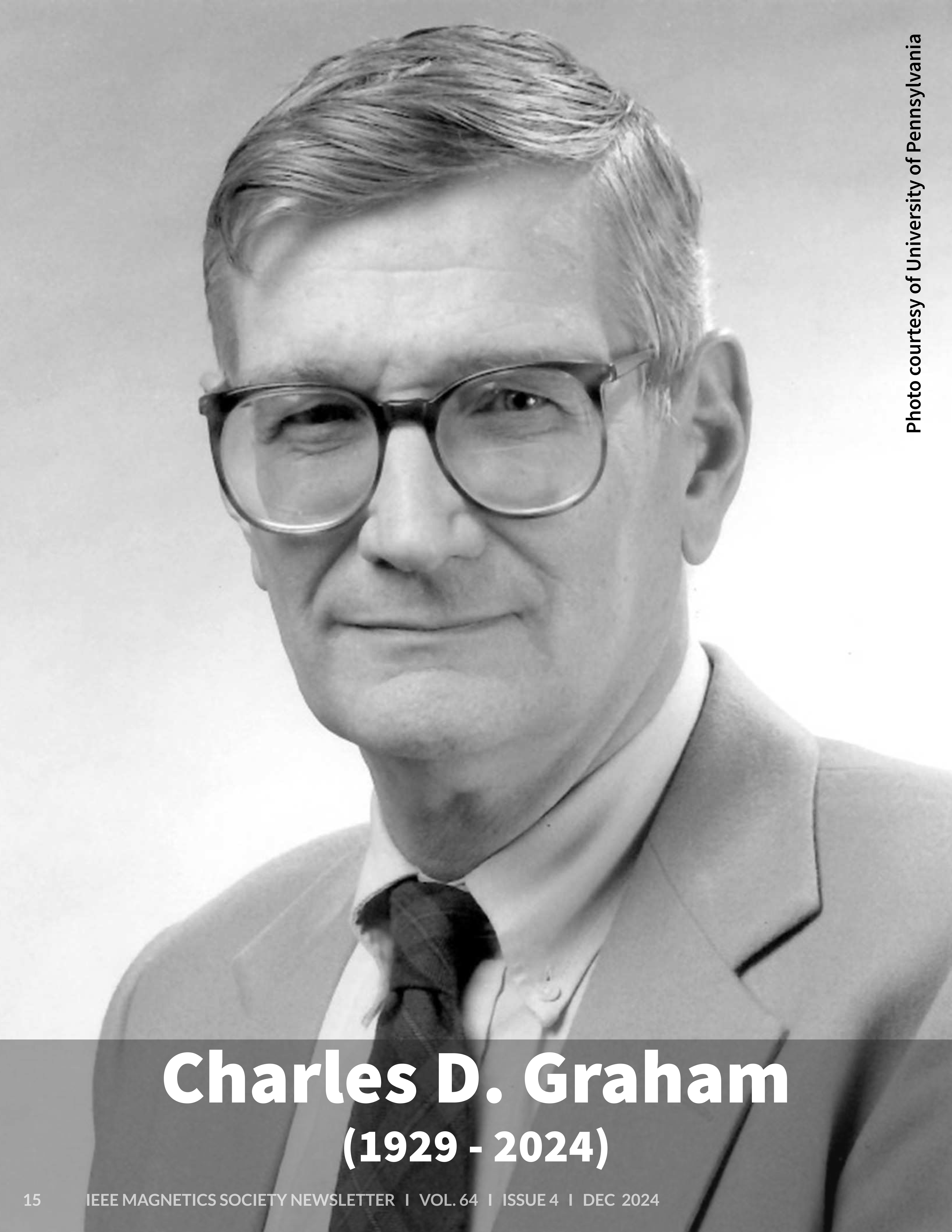

Photo courtesy of University of Pennsylvania

Charles D. Graham

(1929 - 2024)

Charles D. Graham, known to his friends and colleagues as Chad, died on March 18, 2024. He was 94 years old.

Chad received the bachelor's degree in metallurgical engineering with distinction from Cornell University in 1952, where he was the editor-in-chief of the *Cornell Daily Sun* during his senior year. An undergraduate internship at General Electric Company introduced Chad to Charles P. Bean and magnetic materials.

He went on to earn the Ph.D. in physical and theoretical metallurgy in 1954 as a Fulbright Scholar at the University of Birmingham, studying under Drs. Robert Cahn and Robert Maddin. His thesis topic was on the recrystallization of aluminum.

After his time at Birmingham, he worked as a research metallurgist at the General Electric Research and Development Center from 1954 to 1969. Chad was a visiting professor at the University of Pennsylvania in 1969 and became a permanent faculty member in 1970, a position he held until 1997 in the Department of Materials Science and Engineering.

Chad's research focused on magnetic materials and measurements, domain structures, amorphous alloys, and permanent magnets. He authored over 120 papers, book chapters and held several patents. He coauthored the second edition of B. D. Cullity's famous book, *Introduction to Magnetic Materials*, and edited the second edition of Soshin Chikazumi's *Physics of Ferromagnetism*. Some of his favorite coauthors were Takeshi Egami, Bryen E. Lorenz (1946-2022), and Philip J. Flanders (1927-2021).

Chad was a Senior Member of the IEEE and a member of ASM International (formerly known as the American Society for Metals). He served as the chair of the IEEE Magnetics Society's Conference Executive Committee and chair of the Conference on Magnetism and Magnetic Materials. He was a visiting scholar at the University of Tokyo, Cardiff University, the University of Bath, and the University of Birmingham.

Perhaps Chad's greatest gift was his ability to write and explain complicated subjects with great clarity. This made him a much sought-after editor and advisor. His research topics usually had a pragmatic slant, perhaps because of his industrial background. That approach was a big advantage for those of his students who considered corporate careers. While it is a worn cliché to refer to someone as a scholar and a gentleman, that term fit Chad particularly well.

- Stanley R. Trout,
Spontaneous Materials, Denver, Colorado

- Alison Graham, Wynnewood, Pennsylvania

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Brad Dodrill

(Newsletter Associate Editor for Industrial Liaison, brad.dodrill (at) lakeshore.com)

IEEE Magnetics Society
Distinguished Lecturers for 2025

Artificial Intelligence-Assisted Design and Fault Diagnosis of Electric Motors for Green Transportation

Min-Fu Hsieh
Department of Electrical Engineering, National Cheng Kung University (NCKU), Taiwan

The impact of artificial intelligence (AI) is rapidly growing and is increasingly pivotal across a wide range of disciplines, from innovative scientific research to practical, everyday applications. The powerful capabilities of AI—spanning data analysis, predictive modeling, and beyond—equip researchers and professionals with unparalleled tools to tackle complex problems, push the boundaries of scientific discovery, and elevate productivity to unprecedented levels. This talk will explore the integration of AI in diagnosing motor faults and advancing motor design, highlighting how AI can significantly enhance the reliability and performance of electric motors in green transportation. It will delve into the use of machine learning and deep learning models to predict and prevent motor failures (e.g., inter-turn short-circuits, demagnetization, and bearing faults) [1]-[3], which is essential for ensuring safety and reliability in transportation and industry. Furthermore, the talk will highlight AI-driven innovations in motor design [4], such as noise-reduction, offering insights into how AI can revolutionize traditional motor systems and contribute to ongoing improvements in predictive maintenance and design practices.

[1] A. Mohammad-Alikhani, B. Nahid-Mobarakeh, and M. F. Hsieh, "One-Dimensional LSTM-Regulated Deep Residual Network for Data-Driven Fault Detection in Electric Machines," IEEE Trans. Industrial Elect. vol. 71, no. 3, pp. 3083-3092, Mar 2024.
[2] A. Mohammad-Alikhani, B. Nahid-Mobarakeh, and M. F. Hsieh, "Diagnosis of Mechanical and Electrical Faults in Electric Machines Using a Lightweight Frequency-Scaled Convolutional Neural Network," IEEE Trans. Energy Conver., early access, Nov 2024, doi: 10.1109/TEC.2024.3490736.
[3] K. J. Shih, M. F. Hsieh, B. J. Chen, and S. F. Huang, "Machine Learning for Inter-Turn Short-Circuit Fault Diagnosis in Permanent Magnet Synchronous Motors," IEEE Trans. Magn., vol. 58, no. 8, 8204307, Apr 2022.
[4] M. F. Hsieh, L. H. Lin, T. A. Huynh, and D. Dorrell, "Development of Machine Learning-Based Design Platform for Permanent Magnet Synchronous Motor Toward Simulation Free," IEEE Trans. Magn., vol. 59, no. 11, 8204307, Aug 2023.

Min-Fu Hsieh (IEEE M'02–SM'11) received the B.Eng. degree in mechanical engineering from National Cheng Kung University (NCKU), Tainan, Taiwan, in 1991, followed by the M.Sc. and Ph.D. degrees in mechanical engineering from the University of Liverpool, U.K., in 1996 and 2000. From 2000 to 2003, he was a researcher at the Electric Motor Technology Research Center, NCKU. In 2003, he joined the Department of Systems and Naval Mechatronic Engineering at NCKU as an Assistant Professor and was promoted to Full Professor in 2012. Since 2017, Prof. Hsieh has been with NCKU's Department of Electrical Engineering, where he became a Distinguished Professor in 2022. He has served as the Publication Co-Chair and Guest Editor-in-Chief for several IEEE Intermag conferences. Prof. Hsieh is an Editor for *IEEE Transactions on Magnetics* and an Associate Editor for *IEEE Transactions on Industry Applications*. He currently holds roles as International Relations Coordinator and member of the Technical Committee of the IEEE Magnetics Society. His research interests include electric machine design, drive systems, and mechatronics.

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New Materials and Interface Effects in Charge and Spin Transport in Magnetic Heterostructures

Guenter Reiss
Department of Physics, Bielefeld University, Bielefeld, Germany

Magnetic heterostructures are key devices for spin electronics. Their preparation requires a combination of thin film deposition with sub-angstrom control, field-annealing, and nanopatterning. If fully functional, they can help fundamental research on new materials [1] and effects as well open applications in sensors, memory, logic, and oscillators [2]. An introduction will present examples of basic effects and their applications [2]. We then will discuss several novel materials and interface-induced effects occurring in magnetic heterostructures: The growth of altermagnetic thin films and their integration in magnetic tunnel junctions with barriers such as RuO_2 are at present intensively investigated due to their potentially spin-split band structure and related spin currents. X-ray analysis reveals a high crystalline quality of the films with or without twinning depending on the choice of the substrate. When integrated with an MgO tunnel barrier and a ferromagnetic counter-electrode, signatures of a tunneling magnetoresistance strongly depend on the bias voltage and are not yet fully understood. When integrated with ferromagnets ($Ni_{80}Fe_{20}$) or heavy metals (Pt), an analysis based on the 2ω method shows the presence of torques in accordance with a spin current at the interface. When replacing the altermagnet by a ferromagnet, the heavy metal can show a proximity-induced ferromagnetism at the interface [3], which substantially influences the results of well-known phenomena such as the spin Seebeck [3], anomalous Nernst, or anomalous Hall effects. Examples will be discussed using metallic as well as insulating ferro- or ferrimagnets and recipes for disentangling the many effects will be given.

[1] M. M. Qaid, C. Ballani, F. Syrowatka, T. Peters, G. Reiss, G. Buettel., U. Hartmann, and G. Schmidt, "Tunable Gilbert Damping and Magnetization in B-rich $Fe_{1-x}B_x$ Thin Films," Phys. Rev. Appl., vol. 8, 034404, Mar 2024.

[2] A. Elzwawy, H. Pişkin, N. Akdoğan, M. Volmer, G. Reiss, L. Marnitz, A. Moskaltsova, P. Gurel, and J.-M. Schmalhorst, "Current Trends in Planar Hall Effect Sensors: Evolution, Optimization, and Applications," J. Phys. D: Appl. Phys., vol. 54, 353002, Jun 2021.

[3] P. Bougiatioti, C. Klewe, D. Meier, O. Manos, O. Kuschel, J. Wollschläger, L. Bouchenoire, S.D. Brown, J.-M. Schmalhorst, G. Reiss, and T. Kuschel, "Quantitative Disentanglement of the Spin Seebeck, Proximity-Induced, and Ferromagnetic-Induced Anomalous Nernst Effect in Normal-Metal–Ferromagnet Bilayers," Phys. Rev. Lett., vol. 119, 227205, Nov 2017.

Guenter Reiss received the Diploma in Physics in 1984 and the Ph.D. in Physics in 1989 at the University of Regensburg. Following his postdoctoral work at the University of Regens¬burg and the IBM T. J. Watson Research Center in Yorktown Heights, New York, he joined the Leibniz-Institut für Festkörper- und Werkstoffforschung (IFW) in Dresden, where he was head of the thin film section from 1992 to 1997. In 1997, he accep¬ted a full professorship at Bielefeld University. His main research directions are new materials and devices for spin electronics and applications in memories and sensing systems. He received the Gaede Award of the German Vacuum Society in 1994. In the physics educa¬tion program at Bielefeld University, he has developed courses that connect magnetism with semiconductor physics and modern microelectronics. He served in committees of the IEEE Magnetics Society and the German Research Foundation (DFG) and co-organized a spring meeting of the German Physical Society (DPG).

Contact: guenter.reiss@uni-bielefeld.de

Tailoring Magnetic Spin Textures in $La_{0.7}Sr_{0.3}MnO_3$-Based Micromagnets

Yayoi Takamura
Department of Materials Science and Engineering, University of California, Davis, U.S.A.

The development of next-generation computing devices based on spintronics and magnonics requires an understanding of how magnetic spin textures can be tailored in patterned magnetic materials.

Within the wide range of magnetic materials available, complex oxides such as ferromagnetic (FM) $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) and antiferromagnetic (AF) $La_{1-x}Sr_xFeO_3$ (LSFO) provide an ideal platform for tailoring magnetic spin textures when lithographically patterned as nano/micromagnets. This unique tunability arises due to the strong interactions among charge, spin, lattice, and orbital degrees of freedom. In this talk I demonstrate how an intricate interplay exists between shape and magnetocrystalline anisotropy energies as well as exchange coupling interactions at LSMO/LSFO interfaces. Therefore, the resulting AF and FM spin textures can be controlled using parameters such as the LSMO and LSFO layer thicknesses, micromagnet shape, and temperature [1]-[3]. These spin textures are imaged using x-ray photoemission electron microscopy for a variety of shapes (circles, squares, triangles, and hexagons with their edges oriented along different low-index crystallographic directions) with and without their core regions removed ("donut structures"). LSMO nanomagnets are also patterned into artificial spin-ice (ASI) structures [4]-[5], where large arrays of nanomagnets are arranged in geometries where all the magnetic interactions cannot be satisfied simultaneously. While one might expect shape anisotropy to dictate Ising states in the nanomagnets, the unique combination of magnetic parameters associated with LSMO enables the formation of both Ising and complex spin textures (CSTs) based on the nano-island width and spacing. These CSTs consist of single and double vortices and alter the nature of dipolar coupling among nanomagnets, giving rise to exotic physics in the ASI lattices. These studies demonstrate that complex oxides provide a unique platform for engineering FM and AF spin textures for next-generation spin-based devices.

[1] Y. Takamura et al., "Spin-Flop Coupling and Exchange Bias in Embedded Complex Oxide Micromagnets," Phys. Rev. Lett., vol. 111, 107201, Sep 2013.

[2] M. S. Lee et al., "Tailoring Spin Textures in Complex Oxide Micromagnets," ACS Nano, vol. 10, pp. 8545-8551, Sep 2016.

[3] M. S. Lee et al., "Controlling Antiferromagnetic Domains in Patterned $La_{0.7}Sr_{0.3}FeO_3$ Thin Films," J. Appl. Phys., vol. 127, 203901, May 2020.

[4] R. V. Chopdekar et al., "Nanostructured Complex Oxides as a Route Towards Thermal Behavior in Artificial Spin Ice Systems," Phys. Rev. Mater., vol. 1, 024401, Jul 2017.

[5] D. Sasaki et al., "Formation of Complex Spin Textures in Thermally Demagnetized $La_{0.7}Sr_{0.3}MnO_3$ Artificial-Spin-Ice Structures," Phys. Rev. Appl., vol. 17, 064057, Jun 2022.

Yayoi Takamura received the B.S. degree in materials science and engineering from Cornell University, Ithaca, NY, USA, in 1998, and the M.S. and Ph.D. degrees in materials science and engineering from Stanford University, Stanford, CA, USA, in 2000 and 2004, respectively.

She was a Post-Doctoral Researcher with the University of California at Berkeley, Berkeley, CA, USA, with Prof. Yuri Suzuki. In July 2006, she joined the Department of Materials Science and Engineering, University of California at Davis, Davis, CA, USA, where she has been the Department Chair since July 2020. Her research interests include the growth of complex oxide thin films, heterostructures, and nanostructures, and the characterization of the novel functional properties associated with their interfaces.

Prof. Takamura was a recipient of the NSF CAREER Award, the DARPA Young Faculty Award, and the 2020 University of California at Davis, College of Engineering Mid-Career Research Award. She was the General Chair of the 2022 Magnetism and Magnetic Materials (MMM) Conference in Minneapolis, MN, USA; the Program Co-Chair of the 2017 MMM Conference in Pittsburgh, PA, USA; and a Member-at-Large of the American Physical Society's Topical Group on Magnetism and Its Applications (GMAG). She served as Membership Chair of the IEEE Magnetics Society and is Associate Chair for Conference Finances of its Conference Executive Committee. She is an editor for the *Journal of Alloys and Compounds* and is a member of the Editorial Advisory Board for the *Journal of Applied Physics*.

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Readers are to refer to *IEEE Transactions on Magnetics* for full information.

FEATURED

Our MagSoc Members Awarded with the

2025 IEEE Cledo Brunetti Award

for outstanding contributions to nanotechnology and technologies for microsystem miniaturization

"For contributions to the development and commercialization of embedded Spin-Transfer-Torque Magnetoresistive Random-Access Memory (STT-MRAM) technology."


Guohan Hu
IBM Research
Daniel Worledge
IBM Research
Gwan-Hyeob Koh
Samsung

Please describe the award you're receiving in your own words—why it is significant, and what accomplishment(s) led to this recognition.

- Daniel

This award recognizes our technology development of embedded Spin-Transfer Torque Magnetoresistive Random Access Memory (STT-MRAM). Embedded means that the memory is embedded on the same chip as logic and other functions, to make a custom design at a foundry. Embedded STT-MRAM and embedded Resistive Random-Access Memory (RRAM) have now replaced embedded Flash below the 28 nm node

STT-MRAM Applications

SRAM—Static Random Access Memory
DRAM – Dynamic Random Access Memory
eFlash – embedded Flash memory
eDRAM – embedded DRAM
eMRAM – embedded MRAM
GPS – Global Positioning System

Embedded Non-Volatile

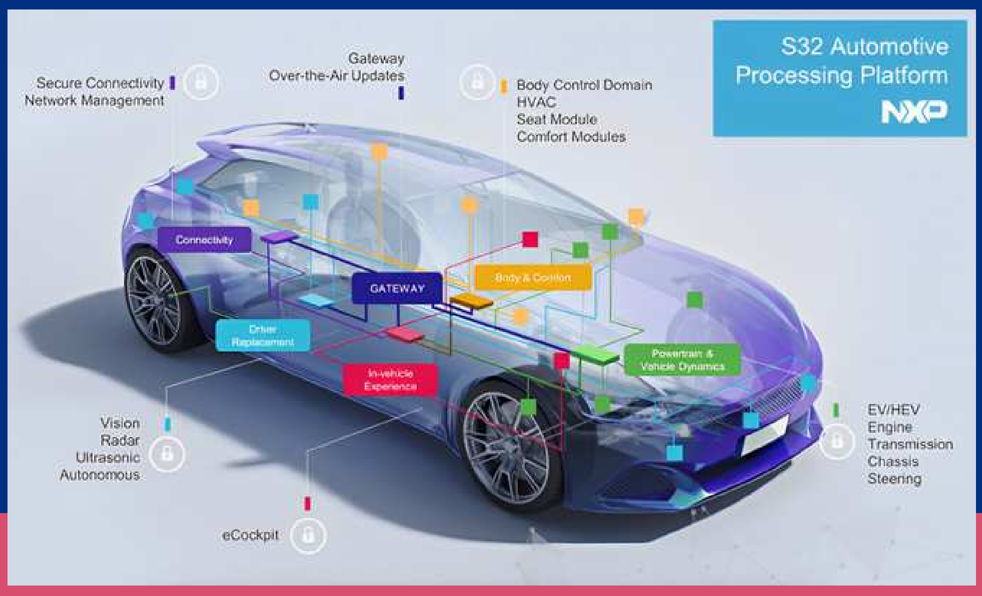
Application examples

Replace NOR eFlash to store:

- Microcontroller code
- Encryption key storage
- Trimming and calibration

Key requirements

- -40 °C – 105/125/150 °C
- 1 – 256 Mb
- 30 ns read, 200 ns write
- Low endurance: 10^6



Standalone

Application examples

- Replace battery-backed SRAM or DRAM
- Buffer for hard disk drive
- Replace DRAM

Key requirements

- 0 °C – 70 °C operation
- 256 Mb – 1 Gb and up
- 30 - 70 ns read/write
- High endurance (10^{10} - 10^{15})

at all of the advanced foundries (TSMC, Samsung, GlobalFoundries), and embedded STT-MRAM will be used for the next generation of automotive microcontroller units, at 14 nm and 16 nm. These are very powerful processor chips that will enable the transition to “software-defined vehicles,” including for hybrid vehicles, electric vehicles, and autonomous driving. It is particularly nice that this award recognizes our technology development (rather than our scientific research), since that is work that we usually can’t publish and don’t get to talk about. Since 2013, IBM and Samsung have had a Joint Development Program on STT-MRAM, and Samsung was first to market in embedded STT-MRAM, in 2019. This award is the result of a huge amount of hard work from a large team at Samsung and IBM over many years.

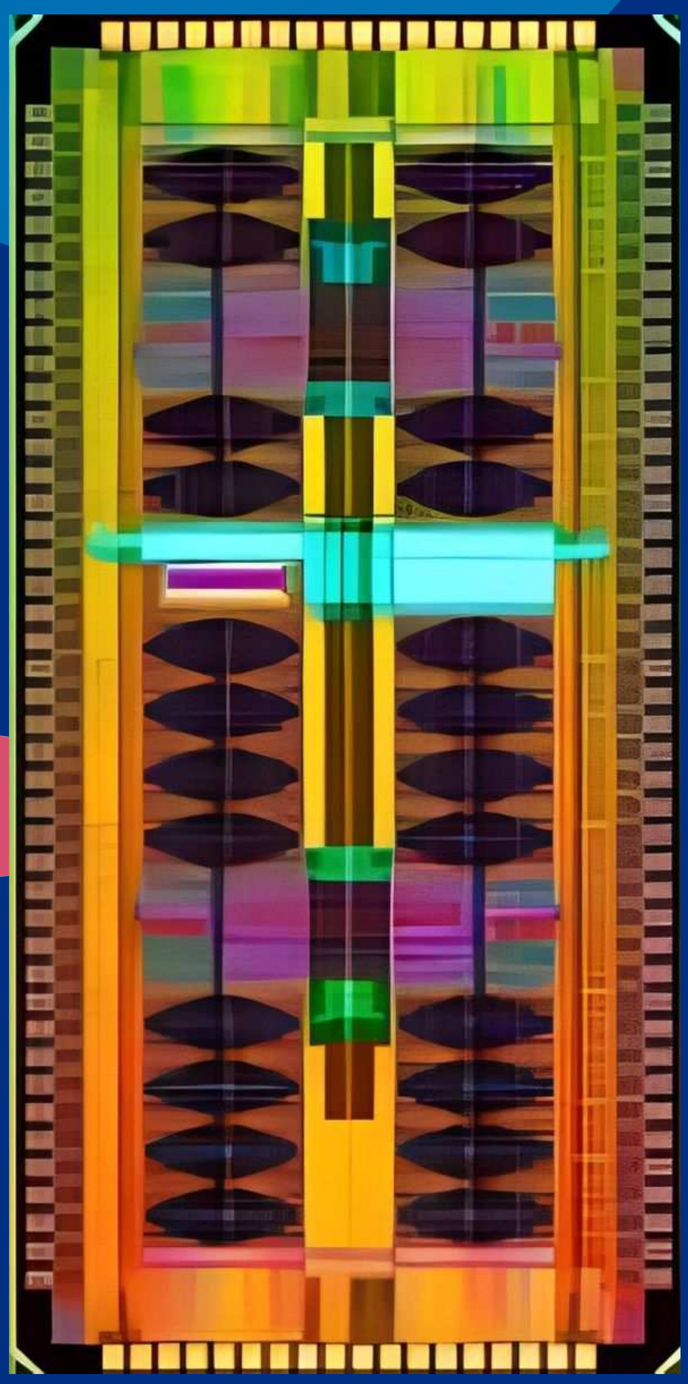
Last Level Cache

Application examples

- Fast dense memory for L3 or L4 cache
- Alternative to eDRAM

Key requirements

- 0 °C – 85 °C
- 1 Gb and up
- ~2 ns read and write
- Unlimited endurance (10^{18})



increasing difficulty

Mobile Cache

Application examples

Replace SRAM & eFlash as working memory for low performance & power apps:

- Internet of Things
- Implantables/wearables

Key requirements

- 0 °C – 85 °C operation
- 1 – 256 Mb
- 10 ns read/write
- High endurance (10^{12}- 10^{17})

- Gwan-Hyeob

MRAM is an emerging memory technology that began serious development in the early 2000s. It has generated significant interest due to its unique combination of features: operating speeds comparable to or faster than DRAM, non-volatility like flash memory, a longer operational lifespan than flash, a smaller cell size than SRAM, and lower standby power. These attributes make it promising for a wide range of applications.

This award recognizes contributions to the development of foundational and mass-production technologies for STT-MRAM, the current leading MRAM technology. Notably, it honors the successful commercialization of embedded STT-MRAM in 2019, which has broadened MRAM's adoption.

STT-MRAM Embedded Non-Volatile Memory Products

Samsung

- 1st to market in early 2019
  - 28 nm Sony GPS receiver
- 14 nm announced: 2024
- 8 nm & 5 nm planned for 2026 & 2027
- eMRAM replaces eFlash below 28 nm

TSMC

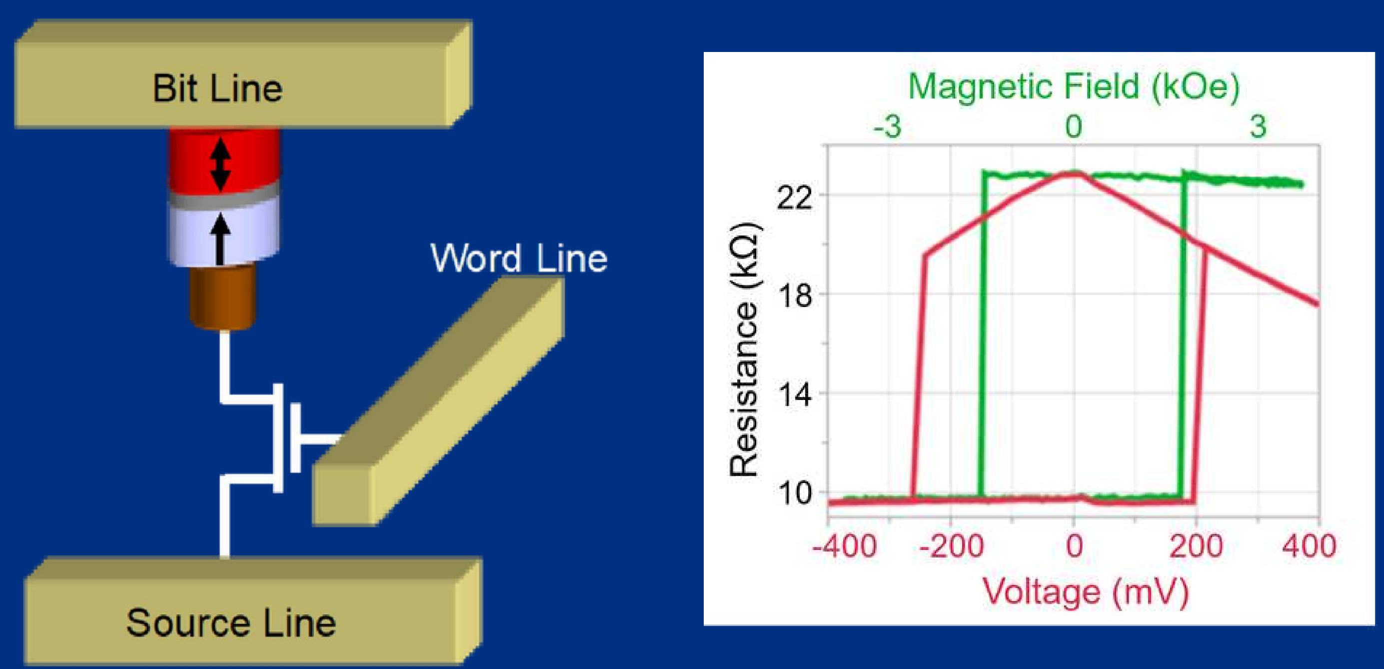
- 22 nm in production since 2020
  - Ambiq Apollo4 Blue System-on-Chip
- 16 nm sampling of NXP automotive microcontroller unit planned for 2025
- eMRAM and eRRAM replace eFlash below 28 nm

GlobalFoundries

- 22 nm in production
  - Sony GPS receiver
  - GreenWaves audio processor
  - Nordic ultra-low power System-on-Chip
  - Alif Semiconductor AI/ML microcontroller units
- eMRAM and eRRAM replace eFlash below 28 nm

Spin-Torque MRAM overview

- Switch single free layer by passing current through magnetic tunnel junction
- Angular momentum of spin polarized current transferred to free layer
- Switch to ‘0’ or ‘1’ by reversing current direction
- Read and write using the same transistor, at low and high voltage (*V*)
- Must avoid read disturbs at low *V* and breakdown of tunnel barrier at high *V*



D.C. Worledge and G. Hu, Nat. Rev. Elec. Eng. 1, 730 (2024)

Traditional embedded flash memory, commonly used as embedded non-volatile memory, faces challenges in process compatibility with logic processes below the 28 nm node, making further scaling difficult. Consequently, MRAM has become the most viable embedded memory option for advanced logic products at nodes below 28 nm.

In 2013, Samsung and IBM began collaborating, with IBM focusing on foundational technology development and Samsung focusing on production technology. This partnership enabled Samsung's foundry division to successfully launch products incorporating STT-MRAM on the 28 nm technology node. Currently, embedded STT-MRAM technologies for more advanced nodes like 14 nm and 8 nm are under development. Additionally, beyond traditional flash memory functions, MRAM is expanding into markets such as automotive and AI by offering functionalities similar to DRAM and SRAM.

- Guohan

To me, receiving the IEEE Cledo Brunetti award is not only a recognition of the technical contributions we, the awardees, have made to commercialization of embedded Spin-Transfer-Torque Magnetoresistive Random-Access Memory (STT-MRAM) technology but, more importantly, a recognition of the significance and potential of embedded STT-MRAM as an emerging memory technology. Personally, it has been incredibly rewarding to witness the entire process unfold, from early-stage research to a real-world product. The success of the STT-MRAM technology has been made possible by the collective efforts of many dedicated individuals in this field, and I feel very fortunate to be recognized for my contributions to the development of the first practical perpendicular magnetic tunnel junctions at IBM Research and for the subsequent collaborations between IBM and Samsung's MRAM teams.

Please provide a brief overview of your career path.

- Daniel

I have always loved math and am continually looking for interesting applied math problems to solve. As an undergraduate at UC Berkeley, I studied physics and applied math, and then decided to go into experimental condensed matter physics for my Ph.D. at Stanford, to increase my chances of getting a job once I graduated! I joined IBM Research in Yorktown Heights, NY, in 2000 as a post-doc in the MRAM program. I became the first-line manager of the MRAM Materials and Devices group in 2003 and the second-line manager of MRAM in 2013. Today I work in Almaden, managing the MRAM teams across Almaden, Yorktown Heights, and Albany, covering everything from basic materials development to 200 mm technology research and 300 mm technology development.

- Guohan

I graduated with a Ph. D degree in Materials Science and Engineering from Cornell University in 2002, where I studied magnetic oxide thin films grown by pulsed laser deposition. After graduation, I joined IBM Almaden Research Center as a postdoctoral researcher, working on metallic magnetic thin films grown by sputtering deposition for patterned magnetic recording media. I then worked as a staff engineer for about two years at Hitachi Global Storage Technologies (HGST) after IBM divested its hard disk drive business to HGST. In 2006, I joined the Magneto-resistive Random Access Memory (MRAM) group at IBM T. J. Watson Research Center as a research staff member, focusing on MRAM materials and devices, and I have been with IBM since. Over the past 18 years, my role in the MRAM program has evolved from an individual contributor on MRAM materials to leading the IBM materials and devices team and recently leading the IBM-Samsung MRAM Joint Development Alliance, while continuing my own technical work.

- Gwan-Hyeob

I earned my Ph.D. in Physics from Seoul National University in South Korea, focusing on high-temperature superconductors. After completing my degree, I wanted to work in a field more closely related to practical applications and everyday life, which led me to join the Semiconductor Research Center at Samsung Electronics, where I participated in DRAM development.

At that time, my supervisor was Dr. Kinam Kim, who later became the CEO of Samsung Electronics. Under his guidance, I learned a great deal about the mindset and approach required for technological development. In the early 2000s, there was a global surge of interest in new memory technologies, such as MRAM (Magnetic Random Access Memory) and PRAM (Phase-change Random Access Memory), which spurred intensive research worldwide.

Samsung also began to focus on new memory development, and I transitioned to new memory development from that time onward, taking on related responsibilities from R&D to mass production until 2022, when I moved to my current position at Sungkyunkwan University.

As a result of Samsung's efforts in new memory development, the company began mass production of PRAM for the first time in 2010, followed by the first mass production of embedded STT-MRAM in 2019. In recognition of these contributions to new memory development, I was promoted to Master (technical VP) in 2013 and later to Senior Vice President in 2020.

Share an interesting story or moment from your career that contributed to your success. This could be a failure that taught you a valuable lesson, an inspiring mentor or collaboration, or even a personal experience.

- Daniel

Bill Gallagher hired me into IBM Research as a post-doc in 2000. Bill was a great manager and technical leader. I didn't know anything about MRAM when I joined IBM, so I spent the first few months learning the basics from the experienced team members, like John Slonczewski, Jonathan Sun, Philip Trouilloud, and David Abraham. After about six months, I went to Bill and said that it was clear that basic physics would prevent Stoner-Wohlfarth MRAM from ever working (this was because the half-selected bits had their activation energy reduced very sharply with a magnetic field). Bill responded that that was probably true, but that we would need to invent our way out of it. And he was right! Over the years, we and others invented many things that eventually made MRAM work, first the Toggle MRAM that Everspin commercialized, and then STT-MRAM. It was a great example of taking a basic idea from research and focusing on the key problems that needed to be solved to make it a real technology.

When the IBM-Samsung MRAM Alliance was formed in 2013, it was a challenging time, as we needed to align two teams with completely different backgrounds and cultures, while still preserving each team's unique strengths. Bridging these differences required not only technical expertise but also a willingness to adapt and skills to communicate effectively. I feel this experience marked a pivotal point in my career growth, pushing me beyond my comfort zone, broadening my perspective, and providing invaluable opportunities to learn and grow. It taught me to balance open-mindedness with focus and to approach challenges with a growth mindset. Moreover, the strong bonds I formed with my IBM and Samsung colleagues during that time continue to enrich my career to this day.

- Guohan

- Gwan-Hyeob

When a new technology first emerges, there is often great anticipation; however, that initial enthusiasm can quickly fade, and the journey to finding applications, commercializing them, and bringing them to mass production is typically filled with countless challenges.

Samsung began focused development of MRAM in 2002 but soon concluded that the Field Switching MRAM technology of the time could not achieve the small cell sizes required, making cost reduction difficult and limiting it to niche markets.

Consequently, the MRAM development team was scaled back for a period. Later, however, the arrival of STT-MRAM technology allowed us to overcome the limitations of Field Switching MRAM and provided renewed hope for developing MRAM products on a larger scale. From that point onward, we started dedicated development of STT-MRAM technology and eventually accelerated this work through collaboration with IBM's Watson Research Center. Leveraging Samsung's mass production technology previously used for conventional memory, we were able to quickly advance MRAM mass production techniques, leading to the commercialization of embedded MRAM by Samsung's foundry division in 2019.

Throughout this process, we encountered numerous seemingly insurmountable obstacles, yet over and over again, through extensive thought and effort, we ultimately managed to resolve them.

One lesson I learned from semiconductor memory development is not to say "impossible" too readily. I've often witnessed technologies initially thought to be impossible ultimately being realized, and now, rather than calling something impossible, I say that it will take considerable time to develop.

On the other hand, I have also seen many cases where premature optimism over a new technology led to it remaining confined to the laboratory, unable to be implemented as an actual product. Therefore, we should neither declare something impossible too easily nor be overly optimistic about new developments.

Ultimately, I believe the right attitude is to maintain a conviction that something is possible, accept that numerous challenges lie ahead until it is achieved, and focus on how to solve those challenges with a realistic approach.

Key Advances in Spin-Transfer-Torqu

Device

1974

Slonczewski (IBM) and Julliere (INSA) invent the magnetic tunnel junction.

1995

Moodera (MIT) demonstrates first room temperature magnetic tunnel junctions.

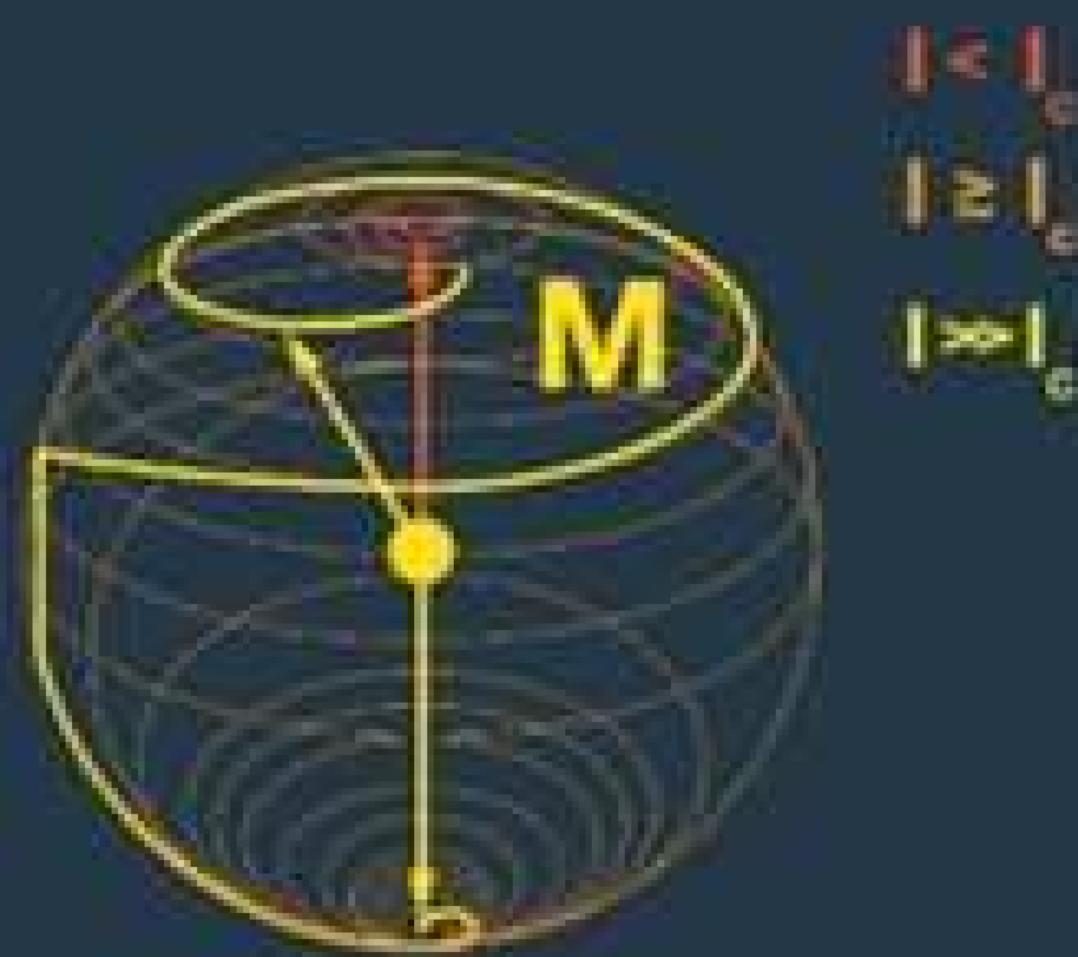
LOW RESISTANCE

HIGH RESISTANCE

Write

1996

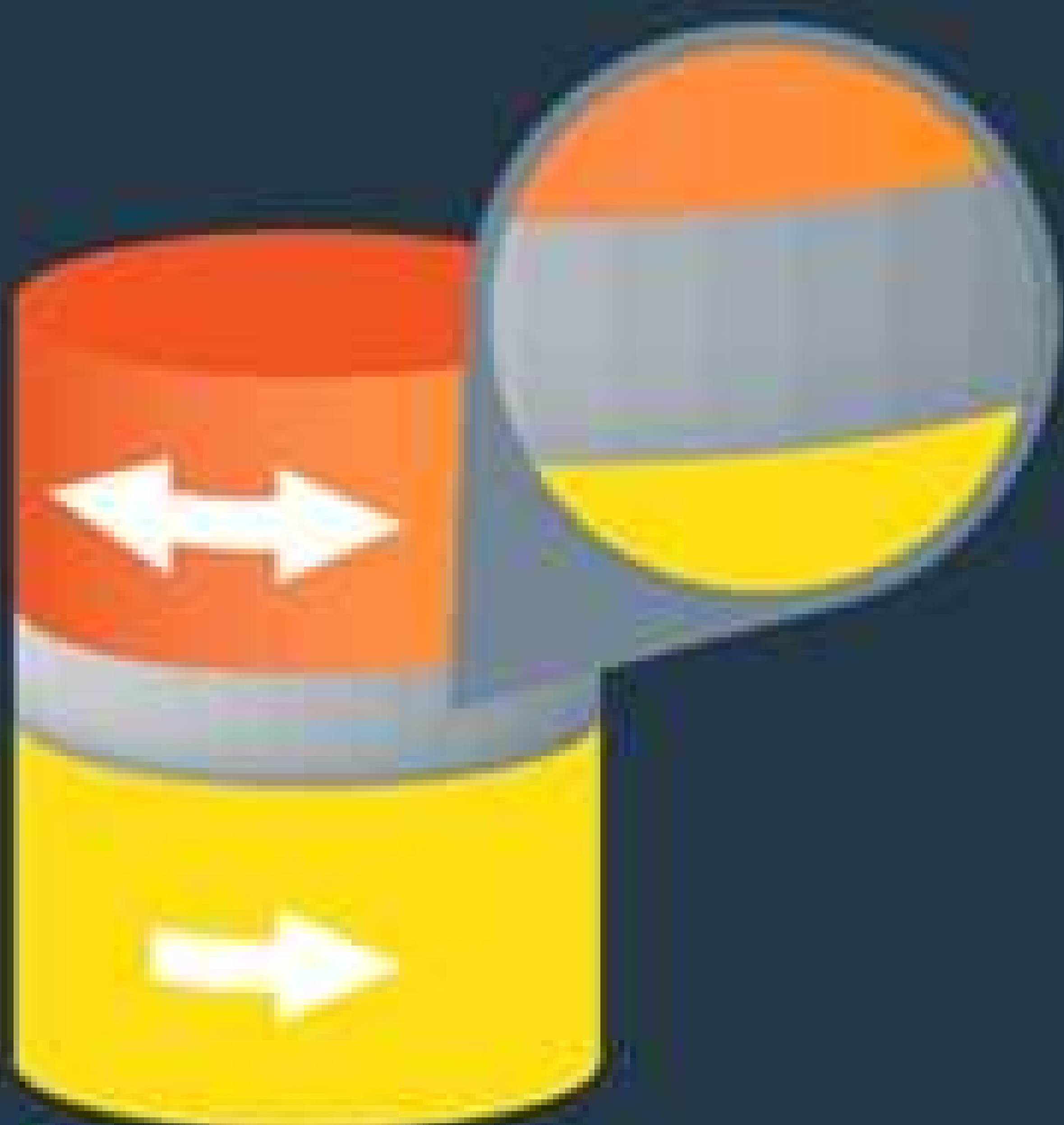
Slonczewski (IBM) invents spin-transfer-torque switching.



IBM Research

e MRAM

Read	Scaling
2004 Parkin (IBM) and Yuasa (AIST) publish discovery of high magneto-resistance in MgO tunnel junctions.	**2010** Worledge (IBM) and Ohno (Tohoku U.) demonstrate first perpendicular CoFeB tunnel junctions.



Infographic by StoryTK for IBM Research

How do you stay motivated and continue to innovate throughout your career?

I love to solve technical problems. It is a great pleasure to study something and learn about it and slowly come to understand it. It is exciting to do experiments and try new things, because you are always hoping you will discover something great. I also really enjoy collaborating with the very smart people at IBM Research—it is a wonderful thing to be able to walk down the hallway and talk to an expert on materials, or circuit design, or error-correction code. If I feel uninspired due to too much time spent on bureaucracy and other boring things, I will set aside some time to work on an interesting math problem—that has a 100% cure rate! Over the last few years, I have enjoyed spending some Think Friday afternoons learning about math and algorithms for machine learning, which is a very interesting topic. At the end of the day, you are responsible for making yourself happy at work.

- Daniel

What advice would you offer to those looking to enhance their technical expertise? What strategies or experiences helped you develop your own technical eminence?

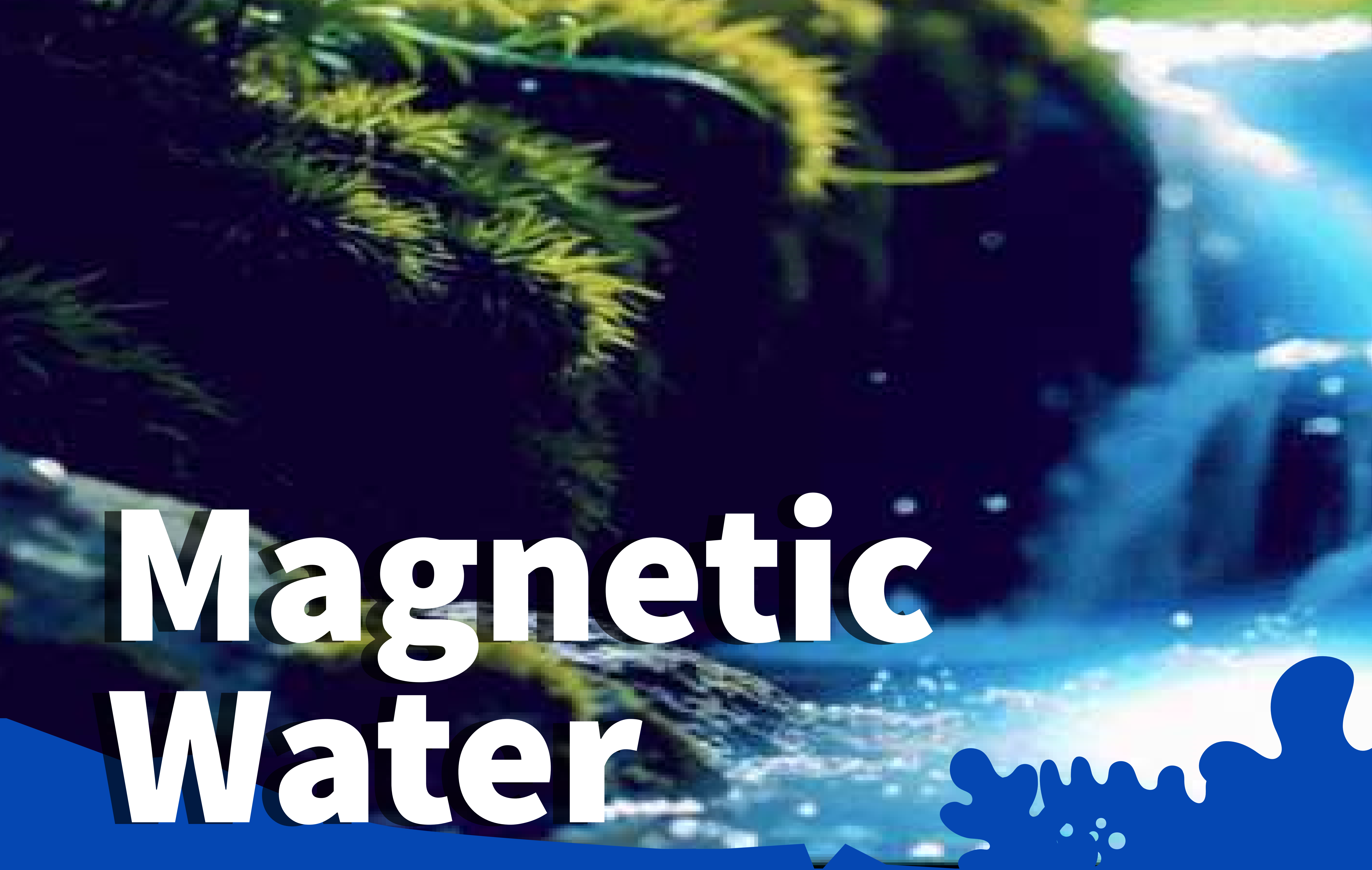
Here are some Lessons Learned from my career:

- Enjoy your work
- Focus on technical contribution
- Look at the data
- Fast turnaround matters
- Have a goal and drive toward it
- Don’t be an insect (be willing to learn new things as needed)
- Collaborate with experts
- Find a mentor
- Have a growth mindset
- Measure your value by internal use of your work and how much external users are willing to pay for it

- Daniel

- Guohan

Take the time and stay focused to build your 'core' technical strength. Learn from people around you to broaden your knowledge base. Find a career role model. Cultivate relationships with colleagues aligned in values and technical interests to navigate through challenges. Collaborate with people. And, lastly, give back to the technical community both inside and outside of your organization.



Magnetic Water Treatment

by Michael Coey
Trinity College, Dublin, Ireland

The hardness of freshwater from natural aquifers varies greatly from place to place, depending on the concentration of soluble cations in the millimolar range, especially calcium and magnesium. Conventionally, water hardness is expressed in weight parts per million (ppm) of an equivalent concentration of calcium carbonate with the same divalent cation charge. Values range from <50 ppm to >500 ppm.

Hard water is a blessing and a curse. It is most common in Africa and Europe, where almost half the groundwater is hard. The water is softer on average in North America and in Asia. Japanese groundwater is uniformly soft, rarely exceeding 100 ppm. Qualitative labels of the numerical ranges are not consistent in different countries. For example, in the United States, 70 ppm water is classified as 'moderately hard,' and 200 ppm is 'very hard'; the same waters in the UK and Ireland are 'moderately soft' and 'moderately hard,' respectively. Evian, a natural 312 ppm mineral water exported worldwide, is a convenient benchmark for hard water.

The basic response of water to a magnetic field $\boldsymbol{H}$ is an induced magnetization $\boldsymbol{M}$ that is isotropic and linear in field, proportional to the water's dimensionless magnetic susceptibility χ defined by

$$\boldsymbol{M} = \chi \boldsymbol{H}. \quad (1)$$

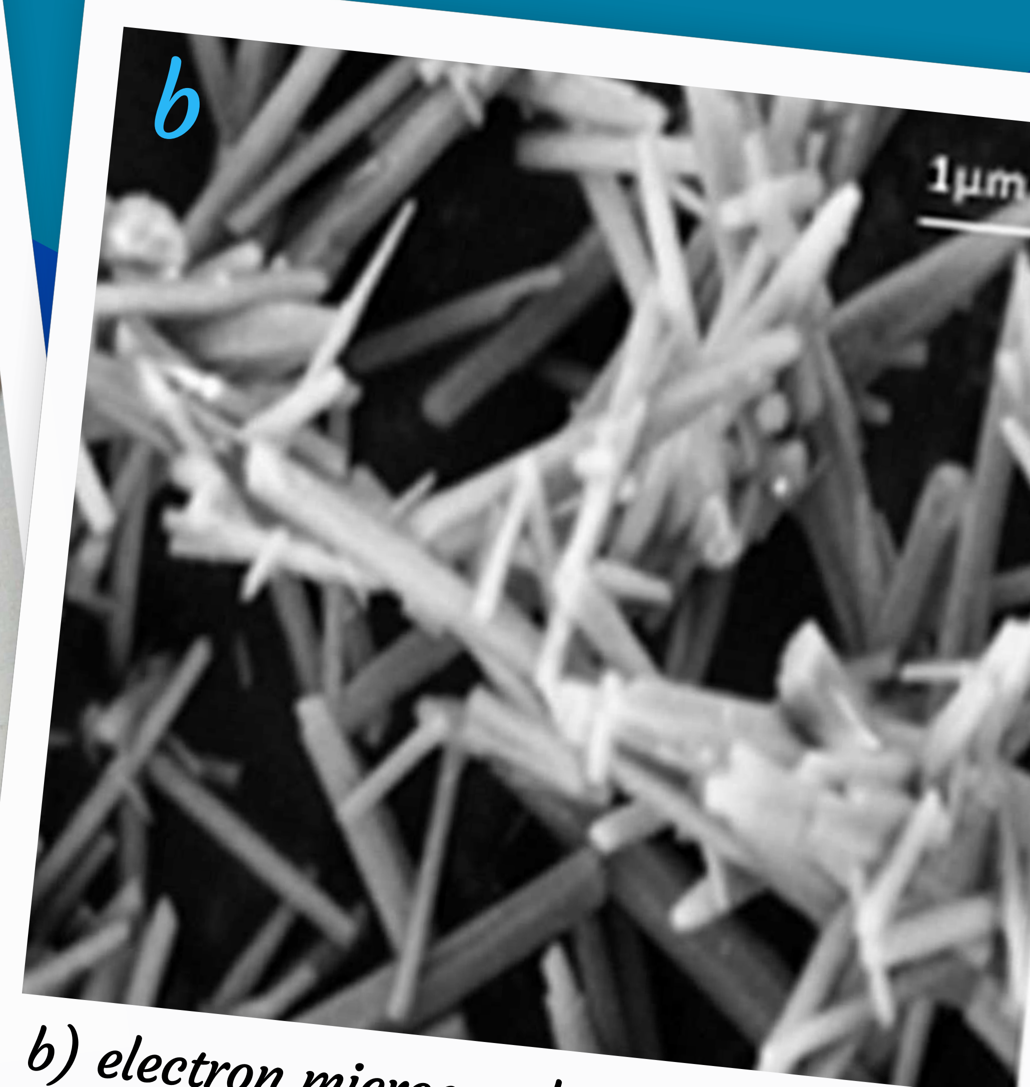
The susceptibility of pure water is small and diamagnetic, -9.0×10^{-6}, and independent of hardness; this is due to the induced orbital magnetism of paired electrons in closed shells directed opposite to the applied field $\boldsymbol{H}$. [1] There are no unpaired electron spins and negligible concentrations of paramagnetic ions such as Fe^{2+} in natural water.

Furthermore, the energy, denoted by

$$E_m = \tfrac{1}{2}\mu_0 \chi_{mol} H^2 \quad (2)$$

of a mole of water magnetized in a field $\boldsymbol{B} = \mu_0 \boldsymbol{H}$ of 1 T is 65 μJ/mole, or about eight orders of magnitude less than 23.3 kJ/mol, the strength of its weak hydrogen bonds. This elementary thermodynamic argument led the Russian electrochemist V. G. Levich [2] and many others to dismiss outright the idea that transient exposure to a magnetic field could have any perceptible effect on the physical or chemical properties of pure water.

Fig. 1 a) Limescale encrustation of a hot water pipe by several millmeters of calcite;



b) electron micrograph of the nonpolar aragonite polymorph that does not form hard scale [3], republished with permission.

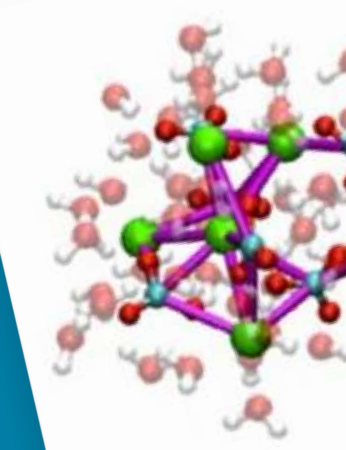
The most objectionable feature of hard water, and the one that magnetic treatment is supposed to prevent, is related to its 'temporary hardness'. Calcium carbonate dissolves into a mixture of Ca^{2+} cations and bicarbonate HCO^{3-} anions in water, but the solubility *decreases* with increasing temperature — not the normal situation. Supersaturation of hard water occurs at around 80 °C, where nuclei of calcium carbonate form, which grow into polar calcite crystals with a blocky shape that form layers of thermally insulating hard scale on the hot surface (**Fig. 1a**). The limescale is hard to remove and degrades the efficiency of domestic electric kettles and water heaters, as well as industrial boilers and heat exchangers. It is a big problem, wasting energy worth over billions of dollars a year.

A popular remedy entails a modest expenditure on permanent magnets. Unlike chemical water softening, no chemicals are added, and no chemical effluent is created. Crystalline calcium carbonate is still precipitated on heating, but with a different crystal structure that does not form hard scale.

In its simplest form, the treatment consists of passing the water through a nonuniform field produced by magnets surrounding an inlet pipe. The critical feature is the magnetic field *gradient*.

The treated water is later heated to the point where it becomes supersaturated when calcium carbonate is found to nucleate and crystallize in the form of nonpolar orthorhombic aragonite, a slightly less stable polymorph than calcite, but also a rock-forming mineral. The aragonite crystals are acicular (needle-shaped, **Fig. 1b**) and do not stick together to form hard scale; they are easily washed away from the heated surface. An investigation of half a dozen commercial devices that were claimed to be effective revealed that the permanent magnets were made of hexagonal ferrite or Nd-Fe-B, producing a nonuniform magnetic field of ~100 mT, with a field gradient of at most 100 T m^{-1}. Blind experiments conducted in 2000 convinced the author of the reality of the effect [4]. Both types of magnets were used, and it was established that the magnetic treatment remained effective for many hours after the water was treated — a magnetic memory. The magnetic treatment alleviates the limescale problem, avoiding the need to chemically soften the water supply because it somehow influences the nucleation of calcium carbonate at supersaturation.

For years, the problem was that nobody had any idea how the magnetic effect could be explained! Water is a liquid that is continually changing its structure, breaking and reforming bonds on a picosecond timescale. It seemed impossible to physicists and chemists alike that exposure to a rather feeble magnetic field for less than a second could imprint a memory on water that persisted for a week. It was thought that anyone claiming to have data to the contrary must be careless at best, and at worst deluded or a charlatan. Their claims were derided as 'unscientific' [5]. Some radically new insight into hard water was missing. Discretion was then the better part of valour.



The insight came with the publication of two Science papers in 2008 and 2009 which have been cited 2100 times. Denis Gebauer *et al* [6] and Emile Pouget *et al* [7]. They showed that there was something more to calcium carbonate dissolved in water at ambient temperature than anyone had suspected. Besides the hydrated Ca^{2+} and HCO_3^- ions in aqueous solution, they found tiny, nanometre-scale *solid* particles in suspension. These amorphous, hydrated nanoclusters of ions and counterions with an approximate composition of $CaCO_3H_2O$ were composed of a hydrated chain of about four $CaCO_3$ molecules and were later named DOLLOPs (Dynamically Ordered Liquid-Like Oxyanion Polymers). Present to some degree in any solution of $CaCO_3$, they are structurally-dynamic folded polymeric chains with dimensions of 1–2 nm, and their stability is a product of enthalpic conformational freedom, free energy of solvation, and Coulomb interaction energy (**Fig. 2**). DOLLOPS act as pre-nucleation clusters and help to lower the enthalpic barrier to crystallisation. They do not contribute to the conductivity of the water. In the new, non-classical theory of nucleation of calcium carbonate, their aggregation is thought to precede the formation of a dense liquid intermediate phase,

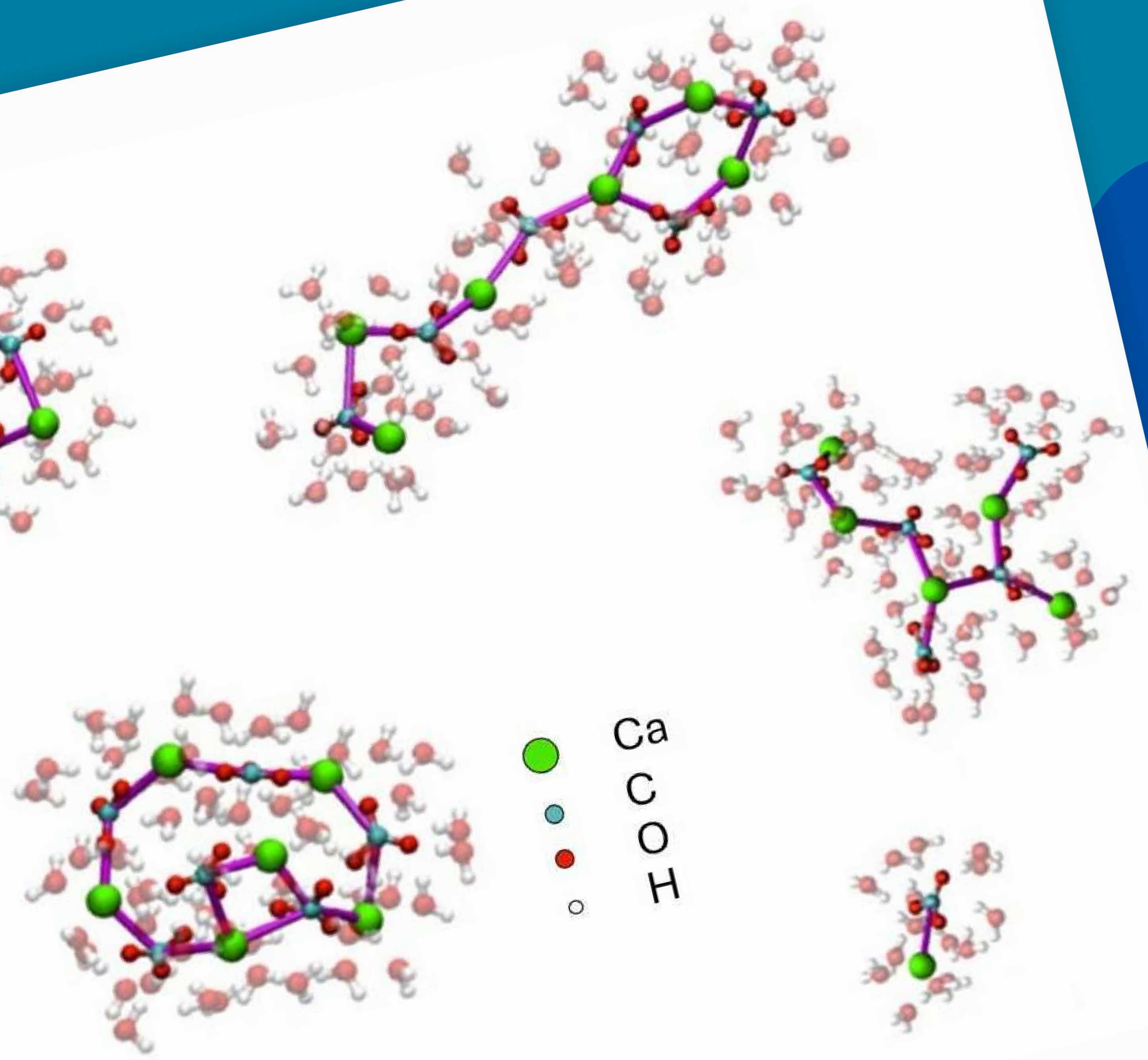


Fig 2. Some calculated DOLLOP structures at pH 9. At lower pH the structures include fewer CO_3^{2-} and more HCO_3^- anions (after Demichelis et al, [8]).

having no formal phase boundary with the solvent, which then transforms to an amorphous form of calcium carbonate that is dehydrated in a subsequent crystallisation step with no large energy barriers [9]. Details of the process are debated, but DOLLOPS provide us with the missing long-lived solid constituent of dissolved calcium carbonate that might carry an imprint of its magnetic history. How could this come about?

We know from magnetochemistry of examples where magnetic fields are far too small to influence the thermodynamics of a chemical reaction manage to control its outcome because of symmetry constraints imposed by quantum mechanics [10]. The examples usually involve a radical electron pair that can be converted from a triplet to a singlet state, allowing a reaction to proceed. The field induces electron precession at the Larmor frequency of 28 GHz/T. A complex radical-pair mechanism is invoked to explain magneto-reception in migratory birds, for example [10].

However, there are *no* unpaired electrons in a water molecule. The only spins belong to the two protons with spin ½ , which can adopt either a triplet *ortho* state with parallel alignment and total spin I = 1, or a singlet *para* state with antiparallel alignment and I = 0 (**Fig. 3**). The textbook example of nuclear magnetism is molecular hydrogen, H_2 , where the two atomic electrons are spin paired in a covalent bond, and the *ortho* and *para* nuclear isomers have distinct physical properties due to their slightly different energies; the *para* form is more stable by 1.46 kJ/mole (175 K) and has no rotational angular momentum in the ground state, whereas the *ortho* form has rotational angular momentum of $\hbar$. The isomer is easily isolated by cooling the gas. Nuclear spin moments, measured in nuclear magnetons μ_n, are minute compared to electron spin moments, measured in Bohr magnetons μ_B (the ratio of the magnetons is 1/1836, the ratio of the electron to proton masses), but each proton with nuclear spin ½ has a quantum of spin angular momentum of $\hbar$, just like an electron. The proton Larmor precession frequency f_p , also scaled by the mass ratio, is 42.6 MHz/T. In the same way *ortho* and *para* forms of water co-exist in water. The *para* form is more stable, but only by 34 K, and the isomers are very difficult to separate in the liquid state [12]. Picolitre samples of separated isotopes revert to 3:1 mixture within hours.

a

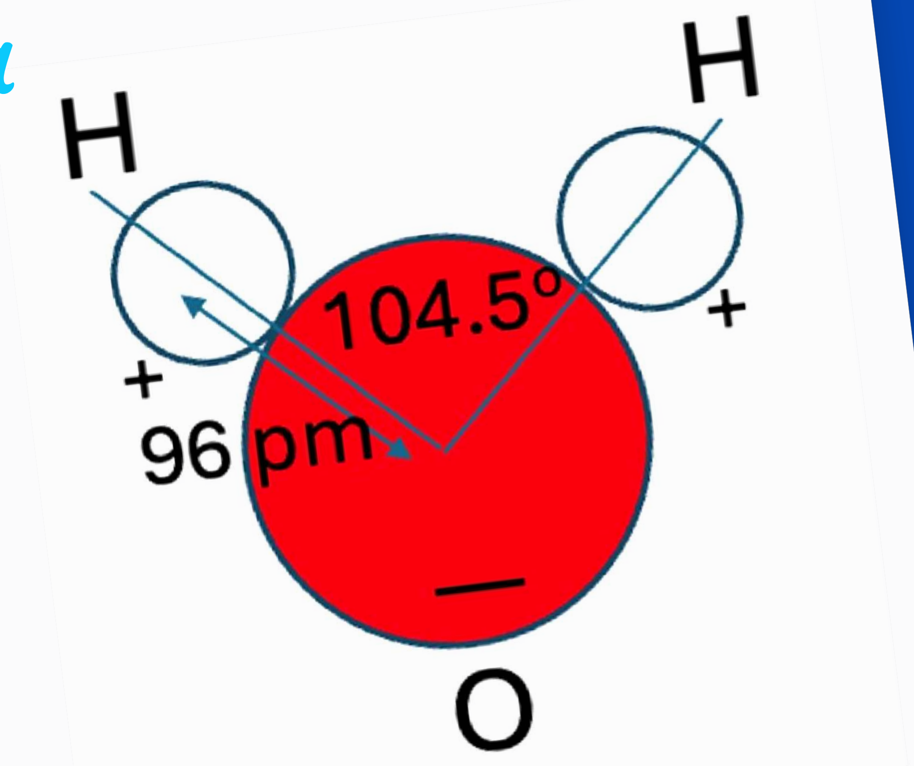
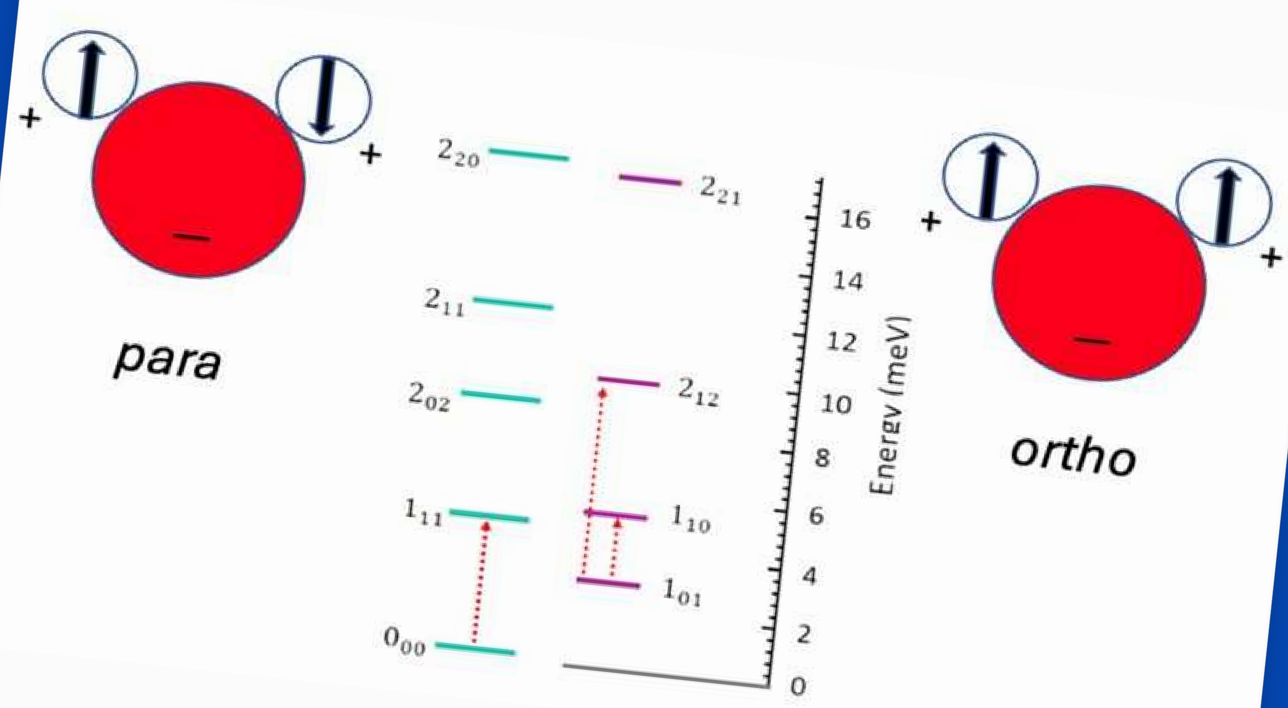


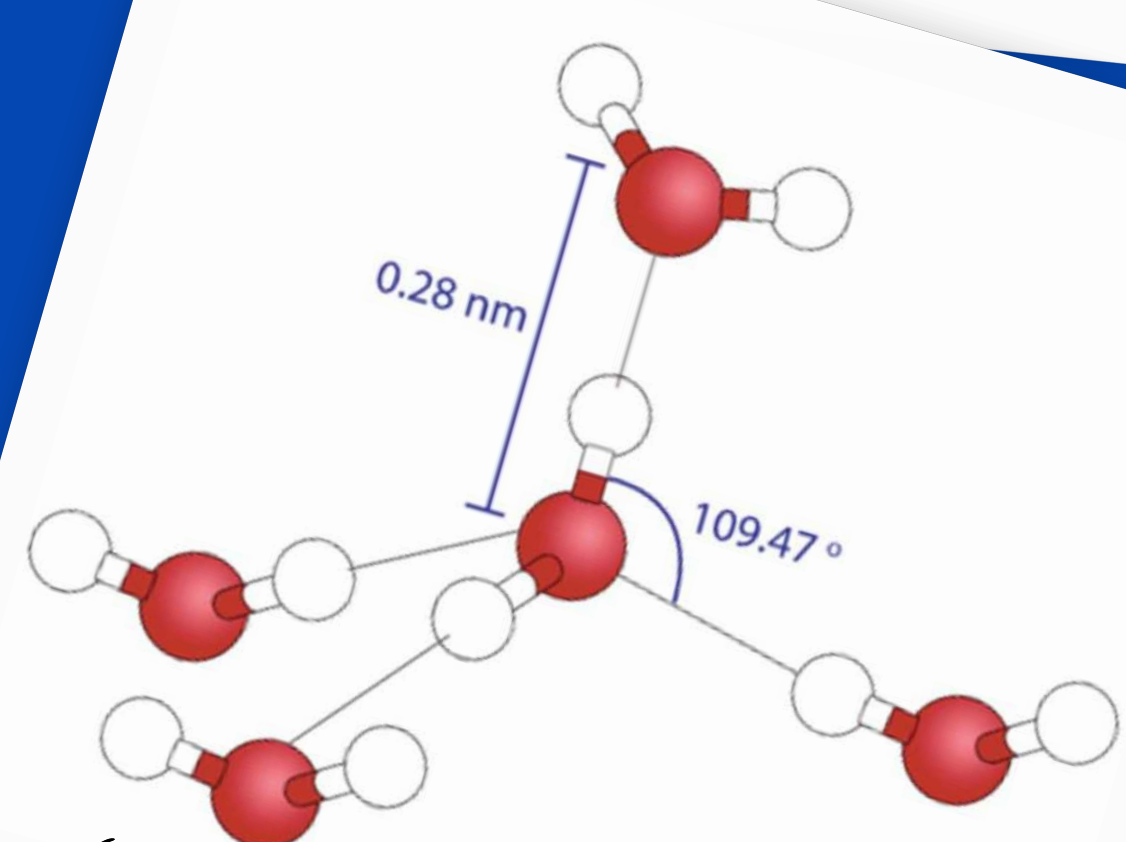
Fig. 3 (a)The water molecule,

b



(b) the para and ortho nuclear isomers, showing the vibrational energy levels, and

c



(c) schematic of the liquid structure, showing that each molecule forms two short, covalent bonds with hydrogen and two long hydrogen bonds. These bonds, and the positions of the water molecules fluctuate very rapidly [11].

So, what happens to the DOLLOPs when they encounter the magnetic field of the water treatment device [13]? All the protons of the HCO_3^- ions along the polymer backbone as well as those of the H_2O molecules bound at the surface of the dollop start to precess in response to the local magnetic field in a seething shakeup occurring during their brief stay in the field. The dollops will have random Brownian motion at a speed of order 38 ms^{-1} in addition to the flow velocity v of order 10 cm s^{-1} through a typical device that is $L = 5$ cm long. Their encounter with the magnetic field gradient $\nabla \boldsymbol{B}$ causes two protons on the same or adjacent molecules separated by a distance a to precess at slightly different frequencies, which will scramble the phase relations of the two protons and alter the *ortho:para* ratio to 1:1. The condition for the device to be able to scramble the spin orientations completely, which requires a relative dephasing of the protons in a molecule by π, is

$$C = 2(L/v) f_{\mathrm{p}}\, a\, \nabla \boldsymbol{B} > 1. \qquad (3)$$

The condition $C > 1$ requires a magnetic field gradient $\nabla \boldsymbol{B} > 152$ T m^{-1} for water and less for bicarbonate ion pairs. Nd-Fe-B devices come close to meeting this criterion, but the ferrite devices fall short.

We assume that the prenucleation cluster controls the nucleation of the calcium carbonate and determines whether calcite or aragonite will grow. The two have quite distinct morphologies, and acicular aragonite nucleates homogeneously and does not form hard limescale. Exactly how this works is unknown and must await detailed study of the structure, surface energy, and polarity of separated DOLLOPS, before and after surface treatment. Nevertheless, we now have a plausible hypothesis to tackle the central mystery of magnetic water treatment, namely, how it is possible to imprint a lasting memory on hard water of a fleeting encounter with an inhomogeneous magnetic field.

Two other effects of a magnetic field on water are explained in terms of nuclear magnetism. One is its influence on the evaporation rate of water in a confined space. The other is its influence on the growth of ionic crystals from supersaturated aqueous solution. Explanations of both effects involve proton dimers.

There are numerous reports in the literature of an influence of a magnetic field on the evaporation rate of water [13]. Since evaporation in air is sensitive to temperature, relative humidity, airflow, and confinement, it is important to conduct simultaneous experiments on two setups where the only difference is the presence or absence of a magnetic field.

Recent repeated experiments where pure water was confined in half-filled beakers [14], or in microfluidic channels [14], found an increase in the evaporation rate in a magnetic field of 12% ± 7% in beakers and 61% ± 42% in microchannels. The zero-field rate was several times slower in beakers, where convection is controlled by gravity. as compared to than it was in microchannels, where the flow dynamics are determined by surface tension.

Normal water vapour consists of a mixture of *ortho* and *para* water vapour in the equilibrium ratio of 3:1. However, there is no reason to expect that the isomers of H_2O freshly escaped from the water surface are in this ratio, and it takes months to establish equilibrium in the gas phase [16]. In the meantime, the two behave as independent gasses, each with its own vapour pressure. The effect of the magnetic field gradient is again to scramble the orientation of the two proton spins by differential Larmor precession, leading to a 1:1 ratio. Analysis based on the magnitude of the field effect leads to the conclusion that the ratio in freshly escaped water vapour is 39:61 [11].

Hans Lundager Madsen investigated the effect of a magnetic field on the crystallization from aqueous solution of carbonates and other salts of sparingly soluble cations, as well as the divalent magnetic ions Mn, Fe, or Co [16]. When crystallized from solution in a magnetic field of 270 mT, the rates of nucleation and crystal growth are enhanced in the diamagnetic salts but there is no effect at high pH, or when the cations are magnetic.

A key observation was that there is no effect when heavy water is used as the solvent. In D_2O, hydrogen is replaced by deuterium, where the nucleus is composed of a proton and a neutron. Each one has spin ½, and they couple to give I = 0, making the heavy hydrogen a boson rather than a fermion. The growth of nuclei in solution was assumed to involve the creation of doubly protonated anions on the growing surface, which is possible with no energy penalty for D_2 or H_2 in an I = 0 singlet *para* state, but the triply degenerate I = 1 *ortho* state has a ground state with orbital angular momentum and corresponding vibrational energy that reduces the rate of the process. Nuclear spin relaxation for H_2 in the field tends to equalize the *ortho* and *para* populations and thereby increase the growth rate [16]. There is no such effect for D_2.

In conclusion, water is a terribly complex liquid. The focus here was on a persistent, well-formulated claim for which there is a substantial body of experimental evidence (as well as reports to the contrary [5]) showing that exposure of flowing hard water to a magnetic field gradient influences the form of calcium carbonate that later precipitates when the water is heated to supersaturation. The evidence for involvement of the nuclear isomers of *ortho* and *para* water, has been summarised here to encourage investigation. Other amazing anecdotal claims for magnetic water treatment, such as the gradual release of chunks of encrusted limescale from a hot water system a week or two after installing a magnet device on the inlet pipe, are more challenging to study systematically but could throw light on the problem from a different viewpoint. Magnetoscience, like any other field of science, advances whenever there is a conflict between experimental evidence and consensus-based theoretical expectation. Science is not dogma, nor is rational investigation of natural phenomena, as opposed to ill-informed speculation, 'unscientific'.

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Navigating the Blue: Sea turtle's Magnetic Odyssey

by Ana Isabel Jiménez Ramírez
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Have you ever had the chance to dive alongside a sea turtle and marvel at their graceful movements and stunning beauty? Even if you haven't, one cannot help but admire these magnificent creatures. For more than 110 million years, sea turtles have been navigating the vast oceans, following migratory paths that stretch across thousands of kilometers. Impressive, isn't it? From the shallow waters where they feed to their nesting sites located on distant shores, their life journey depends on a remarkable ability to navigate accurately, using Earth's magnetic field as their guide.

The ability of animals to travel vast distances using Earth's magnetic field is one of nature's most intriguing mysteries. Species as varied as migratory birds, monarch butterflies, homing pigeons, and even some amphibians and crustaceans are believed to use the geomagnetic field to orient and navigate, particularly during long-distance migrations. Among these remarkable navigators, sea turtles stand out due to their astonishingly precise migration patterns, such as the loggerhead turtle (Caretta caretta) that journeys across the North Atlantic only to return to the very beach where it hatched years earlier [1].

The story of sea turtle navigation begins on sandy shores, where newly hatched turtles scramble towards the surf, guided by natural instincts and environmental cues. This frantic dash to the sea marks the beginning of an odyssey that can last decades and span thousands of kilometers. After leaving the beach, hatchlings are thrust into the open ocean, where they join ocean currents and drift towards safer waters. However, currents alone are insufficient for navigation. In 1991, researcher Kenneth J. Lohmann demonstrated that sea turtles have an amazing ability to find their way using an internal “magnetic compass” sense [2]. Subsequent studies revealed that these incredible creatures can also determine their geographic position by constructing a mental magnetic map. They do this by recognizing the unique magnetic field characteristics of different locations on Earth [3]–[6].

While the physical principles underlying magnetoreception are well understood, with each location on Earth having its own distinct geomagnetic field direction, the mechanisms by which individuals interpret and harness this information for navigation remain largely a mystery, especially for species like sea turtles, where the sensory organ or molecular basis for magnetoreception has yet to be identified.

There are currently three main mechanisms theorized, each offering potential insights into how these turtles navigate:

Magnetic-Particle-Based Magnetoreception

One theory suggests that animals detect magnetic fields through magnetite particles, which are tiny magnetic crystals within cells that align with the geomagnetic field, potentially providing a directional cue to the nervous system [7]. Magnetite-based sensing is well documented in bacteria and hypothesized in birds, where it may help them navigate by functioning as an internal compass [8]. Although magnetite has been identified in various species, it has not been consistently found in sea turtles, leading researchers to question its role in turtle magnetoreception. Natan and Vortman [9] recently proposed that sea turtles might instead rely on symbiotic magnetotactic bacteria, housed within their bodies, to act as magnetic sensors by aligning with the geomagnetic field [10]. This hypothesis suggests that these bacteria could reside in specific regions like the lacrimal glands and send navigational signals to the turtle's nervous system.

Electromagnetic Induction

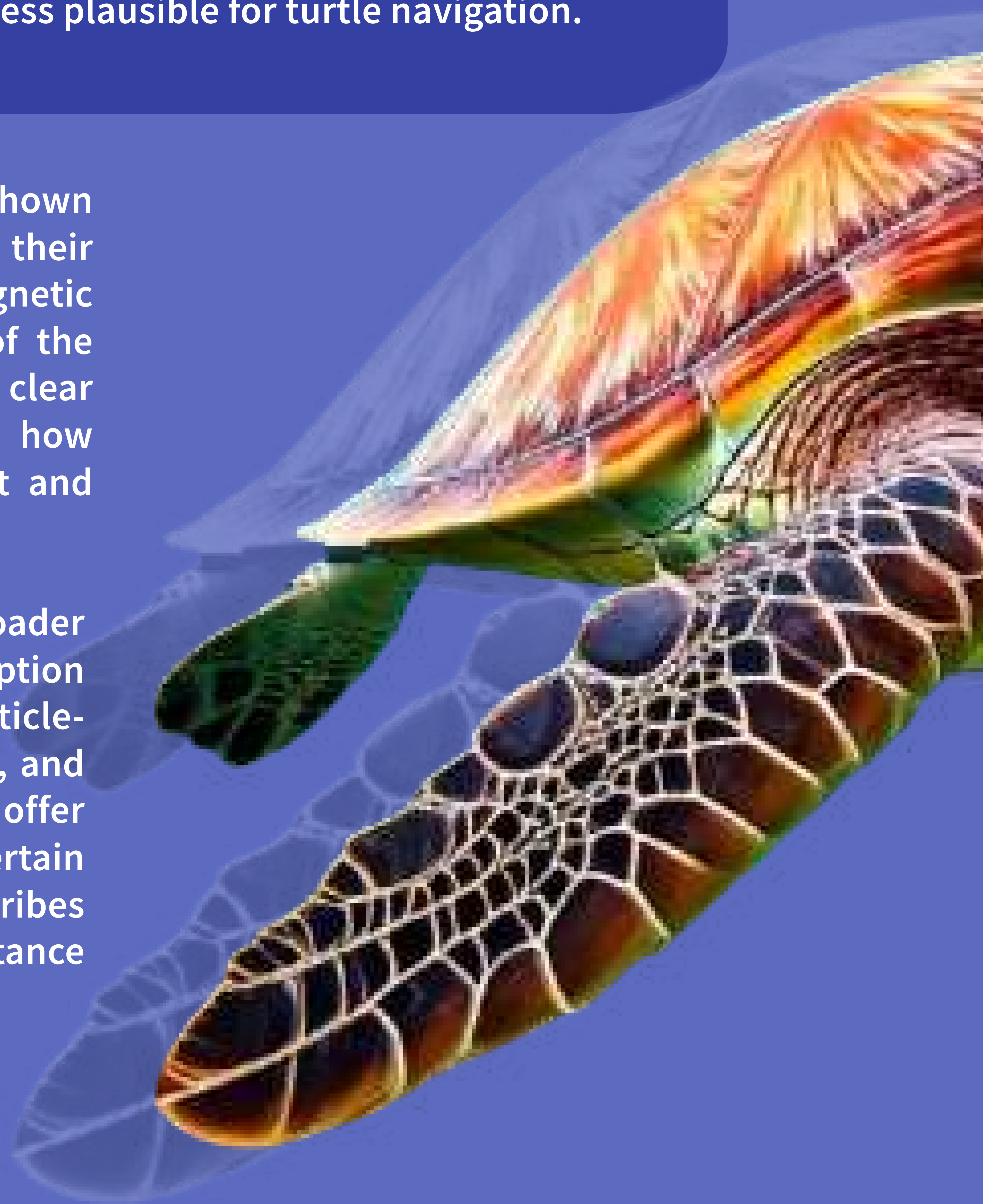
Another hypothesis involves electromagnetic induction, where conductive tissues moving through a magnetic field generate weak electric currents that could be detected by electroreceptors sensitive to small electric potentials [8], [11]. Sharks, for example, use this mechanism via specialized organs called ampullae of Lorenzini to detect magnetic fields in their marine environments [12]. This theory, while viable for certain species, does not appear to apply to sea turtles, as no electroreceptors necessary for this mechanism have been found in them [2].

Radical Pair

The radical pair hypothesis, gaining support in recent years, proposes that certain photopigments sensitive to light form radical pairs wherein the electron spins are influenced by magnetic fields [13]. When activated by light, these photopigments, such as cryptochrome, produce unpaired electrons with spins that fluctuate in response to the magnetic field, theoretically allowing animals to perceive the direction of the magnetic field [14]. Cryptochromes in birds' eyes are known to be sensitive to magnetic fields and may enable birds to perceive the geomagnetic field superimposed over their normal vision [15]. However, since sea turtles can orient themselves even in complete darkness [2], [3], the light-dependent aspect of this theory makes it less plausible for turtle navigation.

While extensive research has shown that sea turtles can adjust their movements based on magnetic inclination and intensity, none of the known mechanisms provides a clear explanation that fully explains how they achieve this on such a vast and precise scale.

Sea turtles highlight the broader challenges in magnetoreception research. While magnetic-particle-based, electromagnetic induction, and radical pair hypotheses each offer compelling explanations for certain species, none adequately describes how turtles achieve their long-distance navigation with such precision.



The symbiotic magnetotactic hypothesis could offer new insights, suggesting that turtles may partner with bacteria to detect magnetic fields, thus opening new possibilities for studying navigation. As research continues, sea turtles may one day unveil the secrets of one of nature's most extraordinary senses, deepening our understanding of how animals interact with Earth's magnetic field.

We should also keep in mind that the lives and migratory patterns of sea turtles are intricately tied to the delicate equilibrium of Earth's systems. As these remarkable animals navigate their ancient routes, they face significant threats from habitat loss, climate change, and human activities. Anomalies in Earth's magnetic field, particularly those due to anthropogenic magnetic fields, can disrupt the navigational cues on which sea turtles rely. To ensure their survival, we must protect their habitats by safeguarding nesting sites, reducing light pollution, and minimizing human-induced magnetic disruptions. By understanding the importance of their protection, we can help to ensure these ancient navigators continue to thrive for generations to come.

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Artistic visualization of academic research and work in the semiconductor industry. Image created by ChatGPT.

Martin's Reads

From Academia to the Semiconductor Industry: Key Insights from My Personal Transition

by Martin Lonsky
Associate Editor, IEEE Magnetics Society Newsletter

Last month marked my one-year anniversary working in the semiconductor industry with Nexperia, a leading power semiconductor device company. Before that, I spent 15 years in academia as a student, researcher, and educator. In this article, I would like to share some reflections on my journey from academia to industry, hoping to offer useful insights for readers considering a similar path.

In brief, my academic background spans five years of B.Sc. and M.Sc. studies in physics, followed by a Ph.D. degree in experimental condensed matter physics in Frankfurt, Germany. I then completed several postdoctoral roles in the United States and Germany before making the transition to industry.

Although personal factors influenced my decision to enter the private sector, my professional interests had also shifted from fundamental research to applied physics and engineering. This natural progression led me from studying fundamental physics to working on magnetic memory and power semiconductor devices, the latter being central to my current industry role.

How Academia Prepared Me for Industry

My academic training as a physicist provided a solid foundation for my current role. Knowledge of materials physics and hands-on experience in electronics, cleanroom technology, and data analysis proved to be invaluable as I transitioned. The problem-solving skills I developed during my time in academia also prepared me well for tackling the complex challenges I now encounter.

While a Ph.D. is helpful for certain roles, it is not a strict requirement for joining the semiconductor industry. This is even more true for postdoctoral experience. However, in my case, my postdoctoral training in magnetron sputtering—a technique essential for my current role in silicon carbide metallization—was a pivotal asset and, in fact, the reason why I applied for my current job in the first place. Consequently, I highly recommend that students aim to develop a broad range of skills that may be relevant for future industry roles.

Furthermore, my time working with other students and colleagues on research projects, homework, and papers was highly beneficial, as my position in industry involves even more teamwork and interaction with stakeholders. As my company is quite international, my experience abroad has been an asset in many ways, particularly in terms of English proficiency and intercultural competence. Additionally, technical communication skills acquired by writing papers and presenting at conferences are also vital in industry, where clarity and brevity are essential to convey ideas effectively. Lastly, I believe that my teaching and mentoring experience in academia has already helped me provide guidance for more junior colleagues in my company.

What I Would Do Differently in Hindsight

Reflecting on my academic journey, if I had known my career would lead to the semiconductor industry, I might have taken more courses in statistics (particularly Six Sigma, process capability indices, and statistical process control) as well as specialized courses in analog/digital electronics, energy systems, and semiconductor technology.

Additionally, an internship would have been incredibly valuable for gaining industry insight and building a professional network early on. Skills like project management and an understanding of semiconductor basics—front-end vs. back-end processes, global manufacturing chains, and the implications of policies like the U.S. and European Union Chips Acts—would have also been beneficial. However, these skills can also be learned on the job, and companies often provide several months for new hires to onboard and connect within the organization.

In retrospect, familiarity with outcome-driven research and decision-making under constraints would have better prepared me for industry. Unlike academia's pursuit of fundamental knowledge expansion, industry often focuses on targeted results that impact products or improvements. Decisions are frequently influenced by business considerations, resource limitations, and timelines, which required a mindset shift on my part as I adjusted to the private sector.

Comparison between Academia and Industry

In academia, I enjoyed the freedom to explore my own research interests, the chance to present at international conferences, and the independence of managing my own projects. I even found writing papers and proposals enjoyable, and teaching was especially rewarding.

In industry, I have found the satisfaction of working on practical applications with real-world impact. I appreciate the collaborative environment and that funding for research is less of a concern. The financial benefits of an industry role are also appealing.

Interestingly, I expected less flexibility in terms of working hours, remote work, and paid time off in industry, but in my case, the opposite has been true. This, however, varies significantly among countries, companies, and departments, so flexibility is not universal.

Conclusion

Ultimately, the choice between academia and industry is a personal one, with both paths offering unique advantages and challenges. The job market in both sectors is evolving: academic roles are increasingly competitive, while the semiconductor industry can be cyclical, with periods of growth followed by hiring freezes and budget cuts.

My experiences may not apply universally, as circumstances vary by country and individual situations. Nonetheless, I hope that sharing my journey provides some useful guidance, especially for younger readers contemplating their own career transitions.

Ultimately, whether in academia or industry, the goal is to find a fulfilling path that aligns with both your expertise and your vision for the future.

The Write Stuff:

How to Be a Bad Reviewer

by Ron Goldfarb
President Elect, IEEE Magnetics Society

Authors of research papers are used to being on the receiving end of constructive, or sometimes destructive, criticism from anonymous reviewers. These same authors are often given the opportunity for payback when editors ask them to review the work of others. Best reviewer practices are described abundantly on publishers' websites. Here I describe some worst practices.

Historial Notes

Regular peer review for quality began in 1752 when the Royal Society of London established a "Committee on Papers" to oversee the review and selection of articles for *Philosophical Transactions*. The process was rather strict, it seems, because Edward Jenner's initial attempt to publish his findings on smallpox in 1797 was rejected by *Philosophical Transactions* for lack of sufficient data. (Jenner subsequently self-published three monographs in each of the following three years, along with the names of his subjects—which would be unethical, of course, by modern standards.)

Review by peers, even informal review by friends, carries the risk of inducing competitors to publish sooner than they would have otherwise. For example, naturalist Alfred Russel Wallace lost some first-to-publish bragging rights for the theory of natural selection after he sent Darwin his draft manuscript in 1858.

By the 20th century, peer review was accepted as standard practice, although Einstein vigorously rejected the notion of anonymous peer review when it was applied to his 1936 manuscript that (mistakenly) questioned the existence of gravity waves.

Types of Peer Review

Most authors are familiar with confidential, anonymous, single-blind review in which the authors do not know the identities of the reviewers, but the reviewers know the identities of the authors. In the interest of perceived fairness or efficiency, other variations exist: double-blind reviews, unblinded reviews, reviewers known to the authors at the reviewers' option, select crowd reviewing, public disclosure of reviewers' names, publication of reviewers' reports along with accepted articles, post-publication blog of online commentary. The superiority of any one method of review over another remains to be demonstrated.

One way for authors to invite private comments prior to formal submission to a journal is by posting on a preprint server. The servers' versioning capabilities allow authors to establish precedence. Some preprints are never submitted for formal publication, or they are but are never accepted by a journal. Those articles persist in citable, self-published limbo. Physicists are well acquainted with arXiv, established in 1991 and currently hosted by Cornell University. With the coronavirus disease 2019 pandemic, preprints in bioRxiv and medRxiv became widely cited in the popular press. Posting on a preprint server is considered public dissemination.

Bad Reviewers

The worst that can happen if you perform poorly as a reviewer is that you will not be invited to review again. To avoid that fate, mind this list of "thou shalt nots":

- Do not agree to review if you do not have time to review.
- Do not agree to review if you are not qualified in the subject. (If you discover you are unqualified after seeing the full manuscript, promptly ask the editor to send it to an alternative reviewer.)
- Do not agree to review if you have a possible conflict of interest without disclosing it to the editor. (Examples include cases where an author is a competitor, a former student, a recent collaborator, or a close friend.)
- Do not contact the authors directly without the editor's agreement.
- Do not write harsh, sarcastic, or demeaning comments. (Authors early in their careers often take such remarks personally.)
- Do not insist that the authors cite your own papers. (You may ask the editor to pass along your suggestion to the authors at the editor's discretion.)
- Do not recommend acceptance just because a manuscript cites your own papers.
- Do not breach confidentiality. (The use of an artificial-intelligence chatbot to help write a review constitutes a violation and is prohibited by most journals.)
- Do not neglect to advise the editor if you suspect plagiarism or fraud.
- Do not insist that the authors write in the passive voice. (See *The Write Stuff: Weak Writing*.)

Fake Reviewers

Reviewers serve as journals' gatekeepers. Some authors attuned to "publish and prosper" figured out how to handpick their reviewers. *Science magazine reported* on article retractions by *Tumor Biology*: "… Like many journals, Tumor Biology allows authors to suggest reviewers; in this case, the reviewers were either made up, or had the names of real scientists but false email addresses. Manuscripts sent to these fake reviewers invariably received positive reviews that helped get the paper[s] accepted." In Whac-A-Mole fashion, most publishers now have defenses against fake reviewers.

Motivation

Fake reviewing aside, what motivates reviewers to spend hours scrutinizing someone else's manuscript? Maybe they relish the chance to learn something new about a subject of interest. Maybe they want to "pay back" the scientific community because others have reviewed their papers. Maybe they want to collect credit for reviewing (e.g., via Publons). Maybe they want to boost their immigration applications (editors often receive requests for letters of support). All are probably valid reasons.

An Editor’s Perspective

Although the term “referee” is sometimes used, I prefer “reviewer”: Referees *decide*; reviewers *recommend*. When I was a journal editor, a presumptuous reviewer once wrote, “My decision is that the paper in the current form cannot be accepted for publication.”

***Your* decision? Um, excuse me?**

A presumptuous reviewer “deciding” that a paper should be rejected.

Some reviewers reliably find grievous fault with every article presented to them. I occasionally made use of such predictable reviewers when I was an editor for a publisher that required all submitted articles to be sent for review; editorial rejections ("desk rejects") of obviously deficient papers were not allowed.

For other publishers, editors can decline to send submitted papers for full peer review. Although some authors think this unfair, it makes a lot of sense because the pool of qualified reviewers, who tend to be overburdened, is much smaller than the number of articles submitted for publication.

Also, the barrier is very low for electronic resubmission (and re-resubmission) of rejected articles to alternative journals. Drummond Rennie, deputy editor of the *Journal of the American Medical Association*, wrote in 1986, "There are scarcely any bars to eventual publication. There seems to be no study too fragmented, no hypothesis too trivial, no literature citation too biased or too egotistical, no design too warped, no methodology too bungled, no presentation of results too inaccurate, too obscure, and too contradictory, no analysis too self-serving, no argument too circular, no conclusions too trifling or too unjustified, and no grammar and syntax too offensive for a paper to end up in print."

Adapted from The Write Stuff: How to Be a Bad Reviewer, *originally published in August 2022 in* For Good Measure, *the internal newsletter of the National Institute of Standards and Technology's Physical Measurement Laboratory*.

Resounding Success at the IEEE Magnetic Frontiers Conference 2024:

Magnetic Materials for Green Energy Applications

by
Oliver Gutfleisch,
Alex Aubert, Semih Ener &
Amritesh Kumar
General co-chair, and local organizing team of IEEE Magnetic Frontiers 2024 Conference


Prof. Oliver Gutfleisch
TU Darmstadt

The IEEE-sponsored Magnetic Frontiers: Magnetic Materials for Green Energy Applications took place from September 15 to 19 in Darmstadt, Germany. The event was co-chaired by Prof. Oliver Gutfleisch (TU Darmstadt/Germany, IEEE Fellow) and Prof. Johan Paulides (Advanced Electromagnetic Group/Netherlands, IEEE Senior Member), and it brought together leading experts from academia and industry to explore the latest advances in magnetic materials and their critical role in the green energy transition.

The conference addressed the development and implementation of high-performance magnetic materials for energy applications, focusing on permanent magnets, soft magnets, and magnetocaloric materials. Both fundamental research and industrial advances were discussed, covering applications in transformers, motors, generators, and magnetic cooling systems. Special attention was also given to rare earth mining, resource efficiency, and magnet recycling, with an emphasis on life cycle sustainability and closing-the-loop approaches.

Plenary lectures were given by Dr. Masato Sagawa (Nd-Fe-B sintered magnet: Aiming to realize the perfect magnet for green energy applications),

Dr. Masato Sagawa
NdFeB, Japan

Prof. Franca Albertini (Heusler compounds for magnetocaloric applications), Prof. Kiyonori Suzuki (State of the art in soft magnets), and Dr. Alain Rollet (The Rare Earths Industry—The radioactivity issue and the separation challenges).

Dr. Alian Rollet
Carester, France

Prof. Franca Albertini
IMEM-CNR

Prof. Jun Cui
Ames National Lab

We were also honored to have Atsufumi Hirohata, the President of the IEEE Magnetics Society, at the conference. His participation added a great value to the discussions and further emphasized the importance of promoting research and collaboration in the field of Magnetic Materials for Green Energy.

Six sessions covered topics such as synthesis, advanced characterization, recyclability, and the use of artificial intelligence and machine learning to develop efficient, sustainable magnets. With the increasing use of magnets in motors, one session focused on the industrial perspective, addressing sustainability from rare earth mining to motor applications, paving the way for green energy production.

Dr. Katharina Ollefs
University of Duisburg-Essen

Dr. Alex Aubert
TU Darmstadt

Active participation during Q&A sessions

Engaging Q&A sessions

Checking out the posters

Discussions ongoing

Let's network

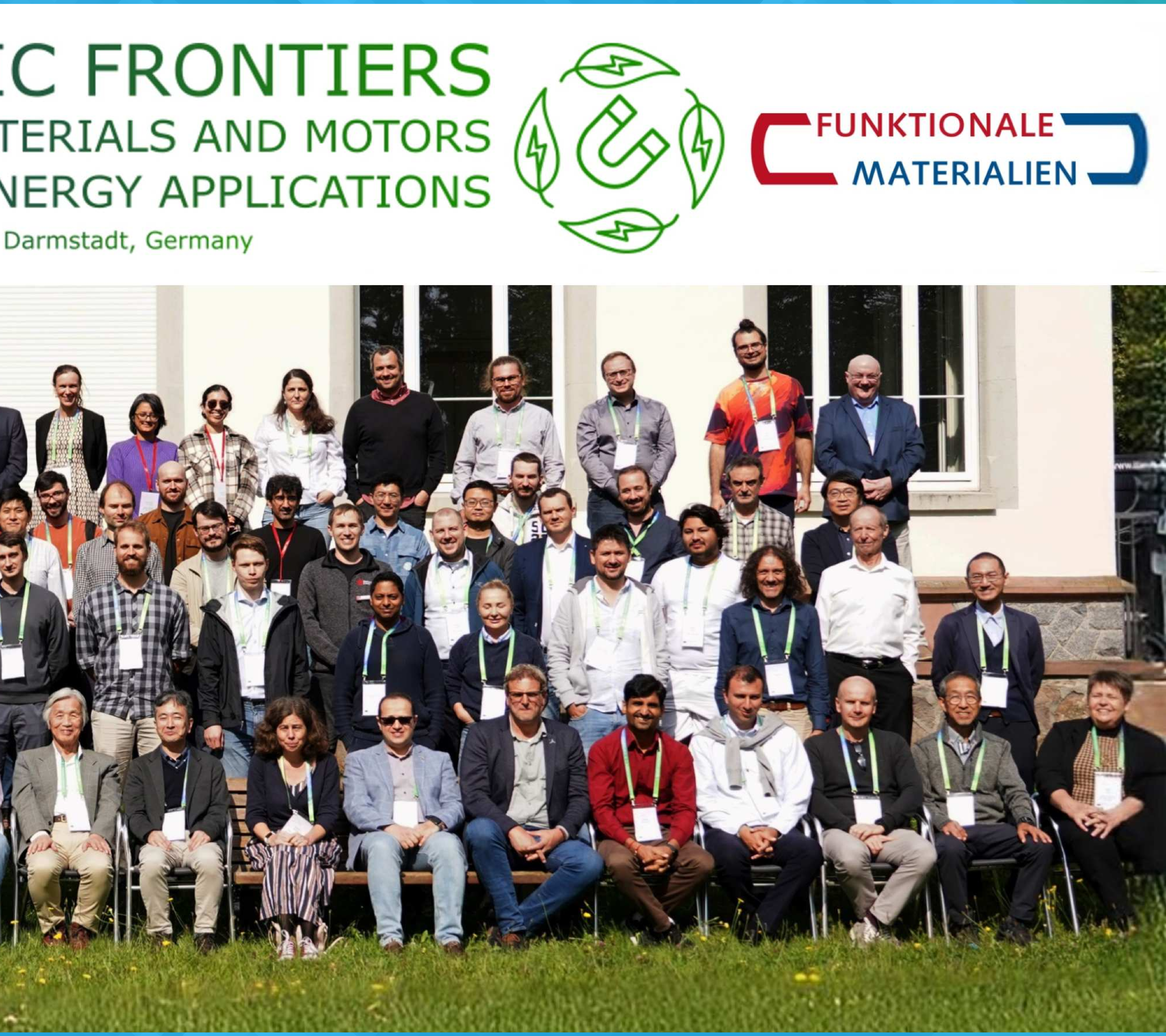
Poster presentations

Hear my exciting results :)

Check out this interesting part of my work ;)

The conference featured three dedicated poster sessions and over 50 flash talks, providing an excellent platform for both young and senior researchers to present their work and explore collaboration opportunities.

IEEE Magnetic Frontiers Conference 2024 group photo


IC FRONTIERS
TERIALS AND MOTORS
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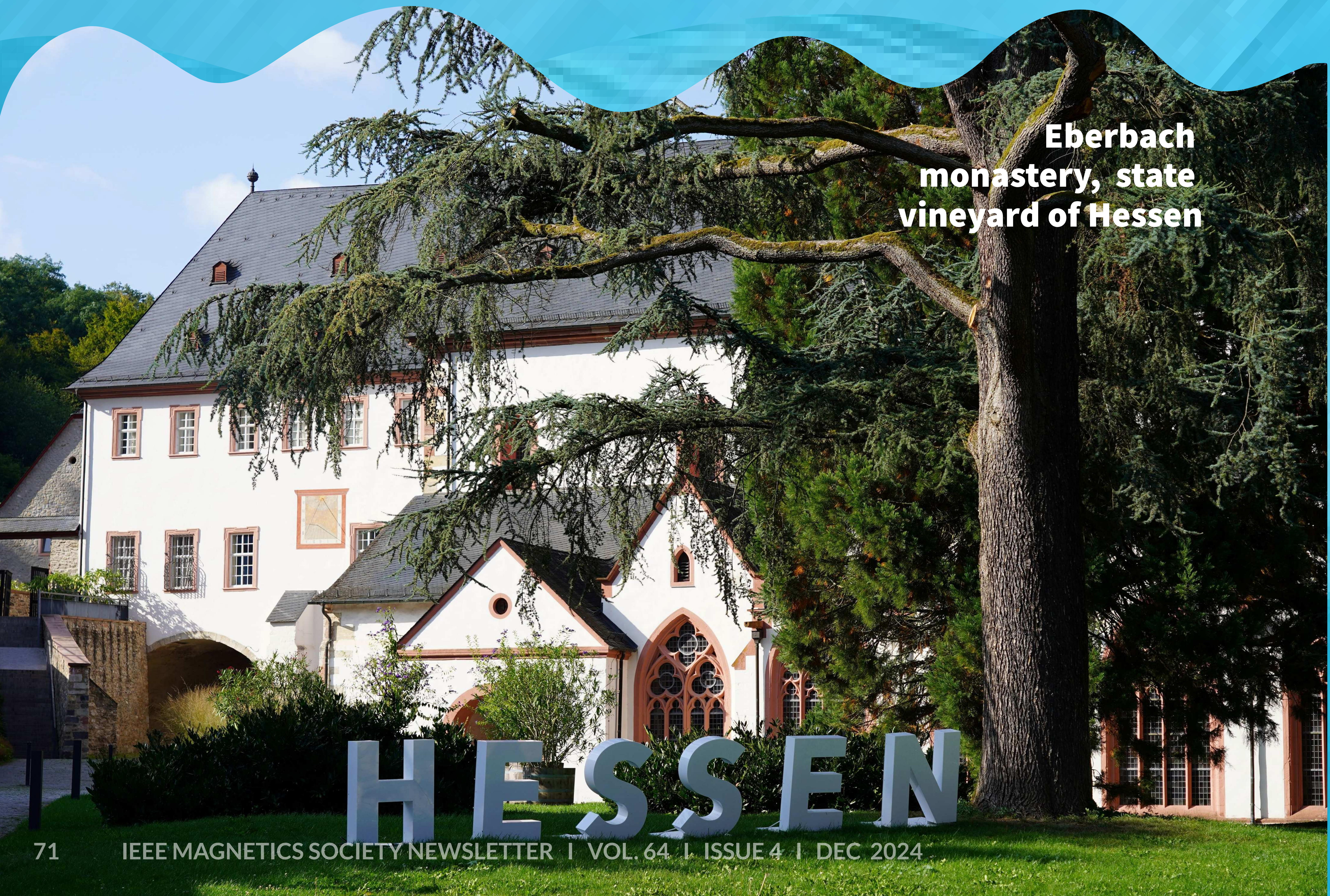
Darmstadt, Germany
FUNKTIONALE
MATERIALIEN

A highlight of the conference was the roundtable discussion, where a panel of leading industry and academic experts discussed global perspectives on manufacturing, recyclability, laws and regulations, economic feasibility, and challenges in the use of magnets.

Dr Rollat commenting on radioactive contamination in rare earth mineral tailings

In addition to the insightful presentations and intense scientific discussions, several activities were organized that triggered further interaction among the participants, including a winery tour and tasting at Eberbach Monastery, a group dinner at the iconic Orangerie Darmstadt, and a lab tour of the Department of Functional Materials lead by Prof. Oliver Gutfleisch at TU Darmstadt. The host group showcased its capabilities in the design, synthesis, and



Eberbach monastery, state vineyard of Hessen characterization of permanent and soft magnets, magnetocaloric materials, additive manufacturing, magnetic soft robotics, and hydrogen processing of rare earth intermetallics.

This year's Magnetic Frontiers event showed a dynamic and diverse international presence, with 117 participants from countries on five different continents. Of the participants, 78% were male and 22% were female. The ratio between industry professionals and academic institutions was more than one third, underlining the importance of collaboration between these sectors. The event provided a platform for cutting-edge discussions and innovations in magnetic materials for the green energy sector, offering insights into the latest technological advances and fostering valuable global connections.

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FUNKTIONALE MATERIALIEN

Funktionale Materialien

The TMRC 2024 Conference Was a Great Triumph!

By Yiming Huai
IEEE Fellow, and TMRC 2024 Conference Chair

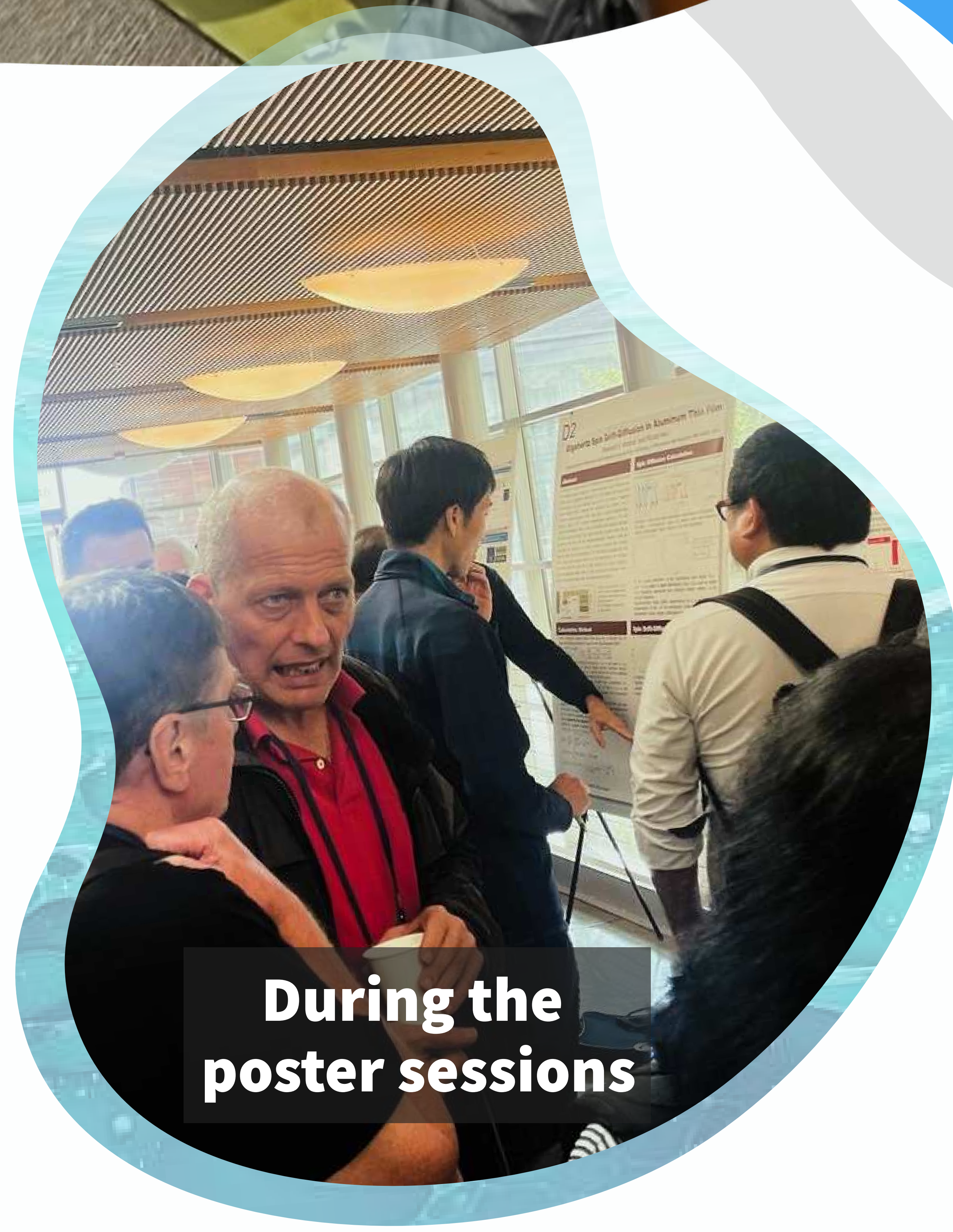
The 35th Magnetic Recording Conference (TMRC 2024) took place successfully from August 5–7 at the University of California (UC), Berkeley, spotlighting cutting-edge advances in Solid State Magnetic Memory and Recording Technologies exceeding 3 Tbits/in². This year's TMRC attracted 199 attendees globally—75% from industry and 25% from academia—highlighting the conference's international reach, with participation from Europe, Asia, and beyond.

The program featured 42 high-caliber invited papers, which will be published in IEEE Transactions on Magnetics, and poster sessions by invited speakers and contributors.

Our "say cheese" group photo at TMRC 2024

Attentatively listening during TMRC2024

The comprehensive agenda covered high-density hard disk drive (HDD) technologies, including heat-assisted magnetic recording (HAMR), microwave-assisted magnetic recording (MAMR), next-gen media, advanced read heads, and channel architectures, along with advances in MRAM and emerging magnetic memory applications. This year's new session on Magnetic Devices for AI Applications showcased promising intersections between magnetic storage and AI research. We were honored to welcome John Morris, CTO of Seagate Technology, as keynote speaker, who provided critical insights into future data storage technologies.



During the poster sessions

TMRC 2024 received enthusiastic praise from numerous high-profile attendees, with many calling it the best TMRC in decades.

Building on this momentum, a dedicated Industry Day session,

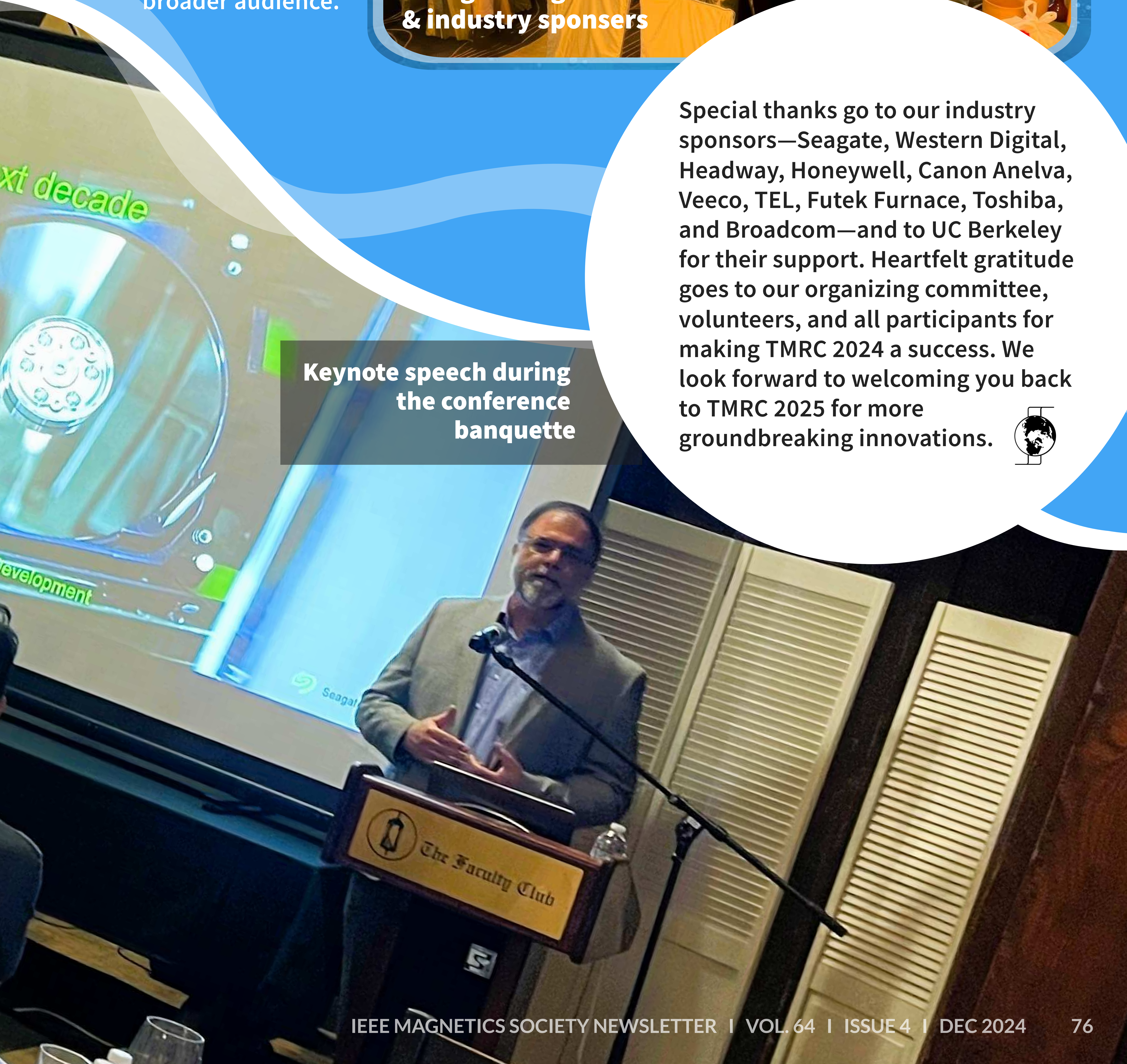
Let's pose before we finish up our drinks

More discussions over the conference banquette

“Magnetic Recording and Hard Disk Drives: Status, Challenges, and Future Directions,” will be hosted at the 16th Joint Conference on Magnetism and Magnetic Materials and Intermag in New Orleans, January 13–17, 2025, to engage a broader audience.

TMRC appreciation dinner to organizing committee & industry sponsers

Special thanks go to our industry sponsors—Seagate, Western Digital, Headway, Honeywell, Canon Anelva, Veeco, TEL, Futek Furnace, Toshiba, and Broadcom—and to UC Berkeley for their support. Heartfelt gratitude goes to our organizing committee, volunteers, and all participants for making TMRC 2024 a success. We look forward to welcoming you back to TMRC 2025 for more groundbreaking innovations.



Keynote speech during the conference banquette

10th Front Range Advanced Magnetics Symposium

By Ezio Iacocca and Dmytro Bozhko
FRAM Symposium Co-Chairs

Participants of the 10th FRAMS held in Colorado springs, Colorado.

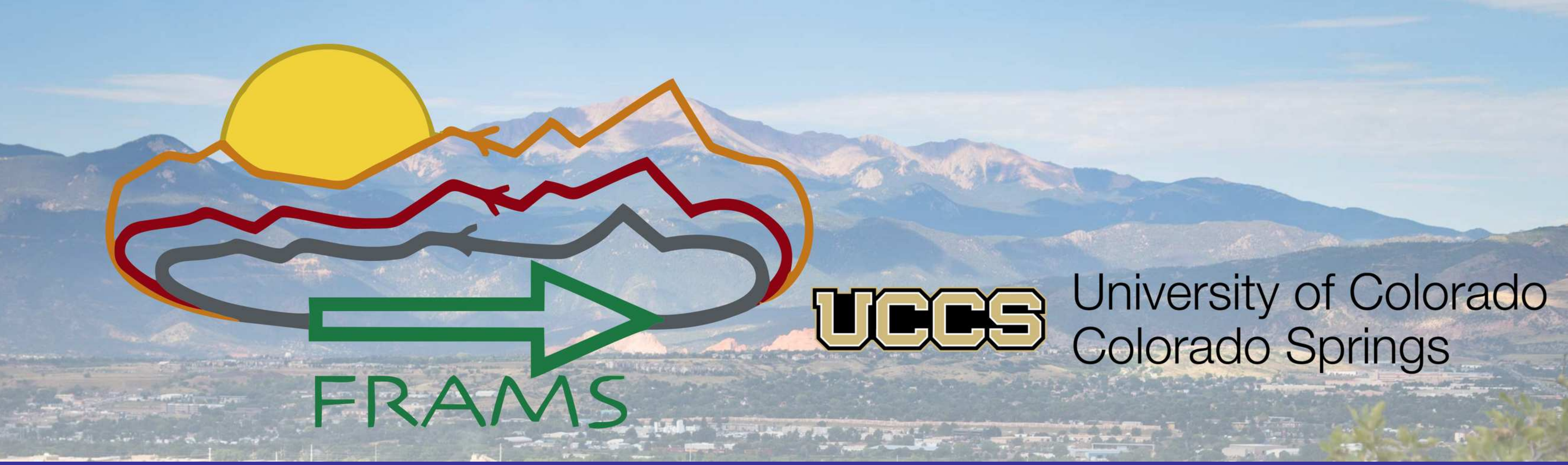
The University of Colorado at Colorado Springs (UCCS) hosted the 10th anniversary edition of the Front Range Advanced Magnetics Symposium (FRAMS 2024) on August 17, 2024.

This event started in 2015 at Colorado State University (CSU) in Fort Collins and has been held on a yearly basis since then, allowing local magnetism experts and students in the Front Range region (Colorado and Wyoming) to interact in a professional setting. The symposium was co-chaired by Ezio Iacocca and Dmytro Bozhko.

We congratulate the winners: Omolara Bakare (Virginia Tech), Kaitlin McAllister (UCCS), Yu Hao (UCCS), Ryan Greening (University of Denver), and Sam Saiter (Colorado School of Mines).

One of the goals of FRAMS is to help students to meet the magnetism experts in the region. In this edition of FRAMS, there were 63 attendees, including principal investigators, postdoctoral scholars, students, and industry sponsors. A total of 30 students attended the symposium, composing 47% of the total attendance. Twelve talks were delivered by principal investigators and industrial sponsors from the participating institutions in four oral sessions, including a plenary talk by Prof. Burkhard Hillebrands from RPTU Kaiserslautern as a special guest. Five poster awards were awarded from the 25 poster presentations.

Students had also the opportunity to further interact with field experts in the “Lunch with Experts” event, sponsored by the IEEE Rocky Mountain section. Our experts were Prof. Burkhard Hillebrands (RPTU Kaiserslautern), Carl Patton (CSU), Jinke Tang (University of Wyoming), and Randy Dumas (Quantum Design).



A special dinner and networking event was held with the support from the IEEE Magnetics Society. The event also recognized Prof. Zbigniew Celinski for his many years of service as the chair of the IEEE Pikes Peak section and numerous valuable contributions to the field of magnetism.

The poster awards, free registration, and student travel support were possible due to support from our industrial sponsors: Tabor Electronics, Quantum Design, Lake Shore Cryotronics, Danaher Cryogenics, Zurich Instruments, GMW Associates, and Thorlabs.

More information can be found in the FRAMS 2024 website.

The 11th FRAMS symposium will be held at the University of Colorado at Boulder in summer 2025.

Fourth Lebanese Electromagnetics Day in the ancient city of Byblos

by Ernst Huijer
Lebanon Chapter Chair

Lebanese Electromagnetics Day 14 june 2024

In the ancient city of Byblos—birthplace of the alphabet—the Lebanese electromagnetics community gathered on June 14 for the Fourth Lebanese Electromagnetics Day.

Hosted at the scenic Byblos sur Mer, the event was organized by the AP03/MTT17/MAG33 Chapter and featured presentations and discussions by both established and emerging professionals in the fields of magnetics and electromagnetics.

Keynote Presentations

The first keynote speaker, **Dr. Ali Harmoush**, Associate Professor at Ahlia University in Bahrain, presented on the **biological effects of electromagnetic radiation** from base transceiver station (BTS) cellular links, exploring its potential impacts on human health and student performance. As 5G and advanced cellular networks become widespread, understanding these effects is increasingly crucial.

Following this, **Dr. Mohammad Haidarh**, from the American University of Beirut, discussed **"Spin-Torque Oscillators: The Future of Electronics."** His talk highlighted the potential of spin waves as a low-power alternative to CMOS-based technology, focusing on the efficiency benefits of spin-torque oscillators and their relevance in future electronics design.

Student Competition

An exciting segment of the day was the student competition, where undergraduate, M.S., and Ph.D. candidates presented innovative projects, including:

- Wireless Mobile Charger
- Wearable Antennas for Telemedicine Applications
- Spin Pumping in YIG/C60/Pt Multilayers
- Indoor Localization with Digitally Modulated Signals

Concluding Lebanese Electromagnetics Day with Seaside Lunch

The event concluded with a seaside lunch, where student competitors were awarded prizes, followed by an inspiring talk by **Dr. Jean Yasmine**, archeologist and restoration architect, on the ancient history of Byblos, rounding out a day that celebrated both technological advancement and cultural heritage.

Brand New Swiss Magnetics Society Chapter

We are excited to announce the establishment of the IEEE Magnetics Society Swiss Chapter, which was created earlier in 2024.

NEW

Aleš Hrabec, Swiss Chapter Chair

The chapter's mission is to unite and strengthen magnetism-related activities across Switzerland, and to foster collaboration between academia and industry. The chapter aims to promote advancements in magnetic technologies as well as the exchange of knowledge among the chapter members. We look forward to building a vibrant magnetism community in Switzerland and beyond, working together with the international IEEE Magnetics Society chapters. The current chapter chair is Aleš Hrabec (ETH Zurich – Paul Scherrer Institute). Feel free to contact him with ideas and questions!

Lessons from IEEE Region 8 Action for Industry Event

José Miguel García-Martín
AdCom member of IEEE Magnetics Society, and
Industry Ambassador of IEEE Spain

In the twenty-first century, IEEE has lost half of its members in the industry. In fact, it is becoming increasingly difficult to find professionals in the industry who want to participate in any position in our organization. Although I am a researcher in a public institution, I have some experience in industry because I have co-founded a spin-off company, so I volunteered for the vacant position of Industry Ambassador in the Spain section. That's why I participated at the IEEE Region 8 Action for Industry (AI) meeting that took place in Grenoble last July 17th and 18th, together with a dozen Industry Ambassadors from various sections. I want to share with you what I learned there, where actions to increase the number of association members working in the industry were discussed.

The presentation prepared by the main organizer and head of AI, Toni Mattila, was finally delivered by Marios Antoniou, and it focused on the added value that can be offered to those working in companies. It can be summarized in these six points:

1) **Access an international talent pool, particularly in these times, when it is difficult to find good candidates to fill vacancies.**

2) **Participate in an online mentoring program through the Collabratec tool: IEEE members at any stage of their career, but especially those starting their professional journey, can receive guidance from recognized professionals with shared interests.**

3) **Influence the creation and development of standards that are essential to their business.**

4) **Gain knowledge through IEEE publications, both those at a more technical level and those focused on broader dissemination.**

6) Keep up with the latest advancements by attending IEEE conferences and technical events, where members can also establish valuable new connections.

Next, Jacopo Celè from CEA-Leti (Atomic Energy Commission, Electronics and Information Technology Laboratory) explained how his institution has a program that acts as a bridge from academic discoveries, typically at the TRL2 level, to a pre-industrial TRL4 or 5 level (in case any reader doesn't know them, TRL = Technology Readiness Level, which form a scale from 1 to 9 indicating the maturity of a technology).

It's important to note that CEA is an organization with more than 21,000 employees, divided into 9 research centers in France, primarily working in energy (initially nuclear, but now also renewables). In recent years, they have also developed digital transformation, medical advances, and work in the defense and security sectors. At CEA-Leti, they have a portfolio of 3,200 patents and have created over 70 startups. They have two funding streams: specific R&D funded by industry, and collaborative R&D funded by public money through competitive calls.

Then, the former chair of the Industry Engagement Committee, Costas Stasopoulos, explained how the number of industry members has dropped by 49% since the year 2000. For this reason, he believes it is essential to add value to young professionals in the industry and make IEEE more attractive to large corporations. He suggests a couple of initiatives: organizing industry-oriented events and establishing awards and recognitions for industry members and companies. Regarding conferences, he believes there should be a discounted fee for industry members and that the program should always include a session where members from various companies can engage in discussions.

Finally, he also believes that IEEE's so-called Local Groups could be a good way to initiate collaborations with the industry, as nonmembers can participate. To create them, only two IEEE members are needed, together with the permission of the local section, which could provide them with funds, as they don't have any assigned by default. This could be a way to explore current hot topics and attract industries.

Group photos taken at the IEEE Region 8 Action for Industry meeting (July 17 and 18, 2024, Grenoble, France).

The event also included brief presentations from each of the Industry Ambassadors of the different sections and an open roundtable for young professionals (YP). Finally, we had a discussion, and in my opinion, the most relevant ideas were the following:

i) There is an initial problem because industry professionals are interested in many different things and tend to have multidisciplinary interests, whereas IEEE requires a specific subscription for each society.

ii) Some conferences are successful with a lot of industry participation: they are usually held in the same location, without social events or gala dinners, and with moderate fees. Companies attend because they are interested in the technical content but don't have time to socialize or, in many cases, aren't interested (perhaps to avoid giving away any hints to competitors).

iii) An example would be the International Solid-State Circuits conference, always held in San Francisco, with high participation from Silicon Valley companies.

iv) Topics of interest to the industry include: climate change, energy efficiency, connectivity and the internet of things, artificial intelligence, digital capabilities, and security. Perhaps specific events (focused events) on these topics could be organized between two or more chapters.

v) On a human level, industry professionals could be attracted to volunteering at IEEE by explaining that they can develop leadership skills without the risk of being fired from their company.

It is also important to highlight the value of the IEEE eLearning Library platform, which offers paid courses but provides certificates.

Lastly, it was emphasized that a large part of the problem is the loss of young members, students and young professionals, who move away from the association as they begin climbing the corporate ladder.

In summary, the problem is clear, and many lines of action to solve it were outlined. Now we need to implement them and find motivated volunteers to establish a bridge between basic research and industry within IEEE.

STEP INTO THE SiM Discord

by IEEE MAGNETICS

YOUR MAGNETISM COMMUNITY HUB!

Calling all students and enthusiasts in magnetism! The Students in Magnetism (SiM) has launched a dedicated Discord space, and it's more than just a chat room—it's a place to connect, learn, and grow together.

VIRTUAL COFFEE HOURS

New Space, Same Great Coffee!

Due to rising rent (we feel your pain!), we're moving to our very own SiM Discord space: the same community, with a new virtual hangout.

FORUMS

Connect and network to make plans with fellow conference attendees before the conference starts - roommates, commutes, tours, etc. Now available for Joint 2025!

Forum usage is open to all!

AND MUCH MORE!

Opportunities – Find internships, scholarships, and event announcements...
The Lounge – A welcoming space to socialize, relax, and get to know fellow members...
SiM Sci-Hub – A dedicated channel where we share and discuss the latest research papers, fostering scientific discussions and collaborations.

Don't miss out—come be a part of SiM's growing online community on Discord. Let's make connections that last beyond the screen!

SiM@ieeemagnetics.org

www.StudentsinMagnetism.org

2024 IEEE Around-the-Clock Around-the-Globe Magnetics Conference

by Hans Nembach and Matt Pufall
AtC–AtG Steering Committee

The 2024 IEEE Around-the-Clock Around-the-Globe (AtC-AtG) Magnetics Conference was held on October 2, 2024, and was another great success. We (the Steering Committee, the Technical Committee, the Advisory Committee, and especially the group of postdoctoral researchers and students who organized the conference) are very grateful for the financial sponsorship provided by the Conference Executive Committee (CEC) of the IEEE Magnetics Society. The organizers did a wonderful job putting together an excellent program of tutorials, invited talks, contributed talks, and a poster session. The members of the Advisory Committee, who themselves organized the conference in 2023 and who shared their time and experience with the 2024 organizers, were also critical to the conference's success. They were also able to leverage the expertise of the Technical Committee, which is composed of organizers from past years. For the first time, we have integrated past organizers into the Steering Committee. We are most excited about having an organizer from the first AtC-AtG conference involved. Moving forward, we hope that all future committee members will be drawn from past organizers, who can bring their unique expertise and experience to foster both the continuity and development of the conference.

The 2024 AtC-AtG attracted 607 registrations, with 25% from Europe, Middle East, and Africa (EMEA), 53% from Asia Pacific (APAC), and 22% from the Americas. The total number of participants is stabilizing on a very high level. We noticed a shift from participation from EMEA to APAC by about 10%.

For more stats: 34% of the participants were female. The largest group of participants comprised graduate students with 44%, followed by 14% postdoctoral researchers. 17% of the registered participants were IEEE members, which is a significant drop from last year. Hopefully, this is not a reflection of the general trend of the decrease in membership in the IEEE Magnetics Society. A goal of conferences like the AtC-AtG is to help reverse this trend.

One promising metric in this direction is that 77% of the attendees participated for the first time.

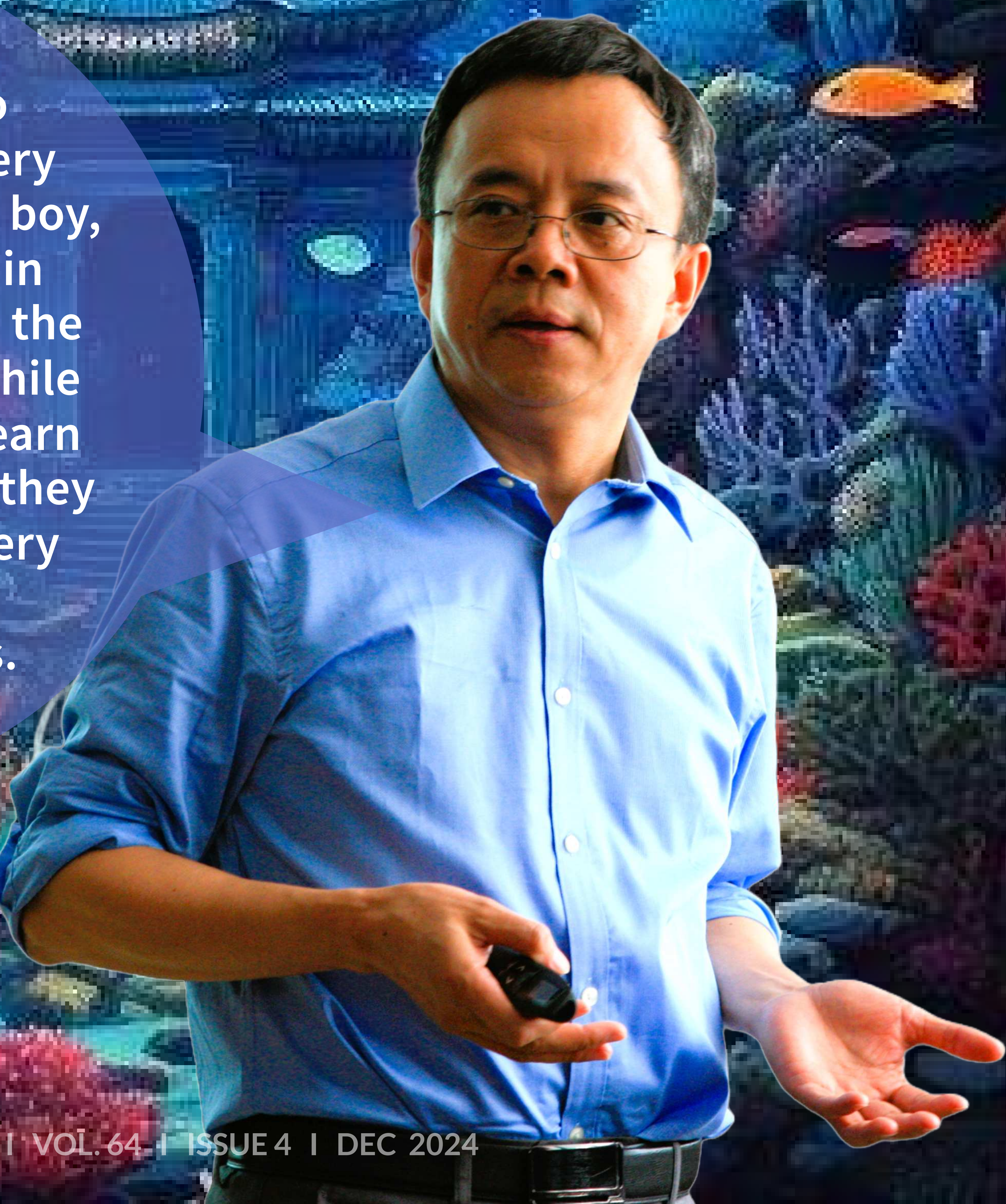
AtC-AtG draws participants from around the world, having participants from 51 countries. This shows that a virtual conference can attract a very broad audience, perhaps more so than an in-person conference. In total, 50 (86) contributed talks (posters) were given. The number of posters is very similar to last year. In addition, the conference featured 12 invited talks and tutorials by senior members of the magnetics community. The speakers were selected by the Organizing Committee based on their accomplishments, field of research, and regional and gender diversity. Special emphasis was put on identifying promising up-and-coming scientists and not to invite only well-established speakers, whose invited talks can be followed at many conferences. Therefore, 5 of the 12 invited speakers were women. The poster session was organized in Gathertown, which also served as a platform to enable networking and job advertising, which are important components of conferences.

Meet an AdCom Member

Life with Magnetic Hardening

by J. Ping Liu

I had the privilege to experience magnets very early. When I was a little boy, the education system in China was destroyed by the political movements. While kids had no chance to learn knowledge on sciences, they could easily obtain a very special toy for free: permanent magnets.



The political movements had high demands for powerful loudspeakers, so there were many cylinder magnets from used loudspeakers available. I still remember that I played with several magnets about 1 kg in weight. The special toys gave me much enjoyment in the dark and poor time, thanks to the hard magnetic ferrites!

The political vibration calmed down in the late 1970s. I then had my second privilege in life: being allowed to go to college (which was not possible for ten years). For some unknown reasons, I chose to major in materials engineering. I was going to do my master-degree study in the middle 1980s on the topic of tungsten carbide (WC). One day, I accidentally saw the news about NdFeB magnets. I was excited and immediately talked to my supervisors to request to change my topic to NdFeB. This was declined with the reason that the conditions for magnets research in our laboratory were not suitable. I knew this of course but I kept trying by talking to our university vice president, Prof. Huang Peiyun, who was an MIT PhD graduate and the father of powder metallurgy engineering in China. Surprisingly, he agreed with my request.

The research on NdFeB was not as easy as I expected though. I had no money to buy pure Nd, so I ended up using mischmetal as the raw material. It made me one of the earliest researchers in China studying the mixed rare-earth magnets. I used a hammer to crush the ingots. I even did not have a magnetic loop measurement device, so I had to take buses for three hours (one way) to measure the hysteresis loops. There were no new journals in our library. To get the updated research development, I wrote my first English letter to Dr. Sagawa. I am sure my letter contained many grammatical mistakes. Surprisingly, Dr. Sagawa replied to me with several reprints of his new publications.

My master-degree thesis was quite successful. I achieved the energy product of 27 MGOe using the mixed rare earths with Al addition. I realized the importance of rare earths, while China at that time was using the rare earths in large quantities as fertilizers. In 1989, I published an article titled "Rare-Earth Valley—The Hi-Tech in the 21st Century" in Science and Technology Daily (科技日报) to highlight the potential of the deposits, to appeal to government and industry to recognize their value, and to develop new materials, especially those using mischmetals. My article was highly noted by the Chief of the Science Commission in Inner Mongolia Province. He called a two-day high-level meeting to discuss my suggestions, which led to the establishment of the Baotou Rare-earth Hi-Tch Zone in 1990. My article was selected by the Chinese Rare-Earth Society as one of the eight most influential articles in three decades. Prof. Karl Gschneidner at Iowa State University and Ames Laboratory publicized my article and published my essay "I have a Dream" in the *Rare-earth Information Center News* [1].

I continued my research on rare-earth transition-metal compounds as a PhD student at the University of Amsterdam in the Netherlands, under the supervision of Profs. Frank de Boer, Peter de Chatel, and Jurgen Buschow. I found many interesting phenomena in numerous compounds, especially in the interstitial nitrides, carbides, and hydrides.

The five years in Europe were important for my career. I had the opportunities to meet, to know, and to collaborate with many life-time colleagues and friends, including Ekkes Brück, Mike Coey, Nora Dempsey, Dominic Givord, Oliver Gutfleish, Boping Hu, Olivier Isnard, Helmut Kronmüller, Xiaolei Rao, Tom Schrefl, Ralph Skomski, Paulo Wendhausen….

In 1995, I moved to USA for my postdoctoral research with Prof. David Sellmyer and then started my independent research, which has continued until today (for almost thirty years). I have been really lucky that I worked with many great colleagues, friends, collaborators, and students (the list is too long to put here). I have had the opportunity to organize and lead joint research activities in which we started the bottom-up approaches to produce nanostructured magnets. In the past two decades, I have focused on magnetic hardening in low-dimensional materials, including nanocomposites, thin films, and nanoparticles, especially nanowires. Although it is very challenging to carry out systematic research in the USA because the funding agencies change their appetite very quickly, I am glad that I did not withdraw from the field.

One of the reasons for me to persist with magnetic hardening is the perpetually intriguing Brown's coercivity paradox.

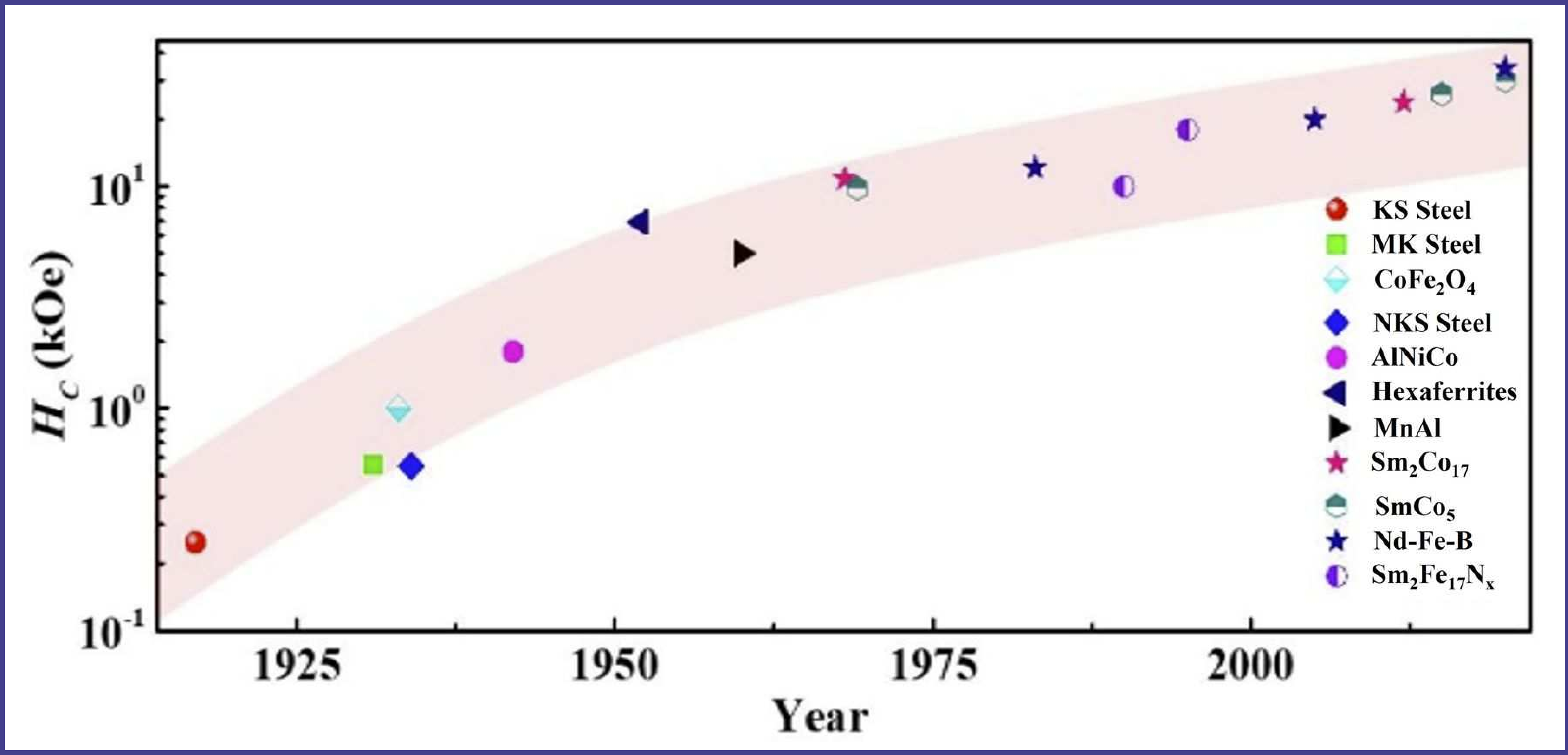


Fig. 1 Coercivity development in the past hundred years.

Coercivity is the most important property for permanent magnets. Figure 1 shows the remarkable progress in magnetic hardening in the past hundred years of our life. However, it is still not clear how far we can go with the coercivity and how to calculate and predict coercivity, which are like a mysterious black box. In 1945, Dr. Brown published his famous Brown's Theorem [2], which can be written in a simple formula:

$$H_c \geq H_a - N_d M_s$$

where H_c, H_a, and M_s are the coercivity, the magnetocrystalline anisotropy field, and the saturation magnetization, respectively. N_d is the demagnetization factor, which is dependent on the magnet shape [3]. Since no experimental data could meet the theorem for 70 years, the discrepancy is called as Brown's paradox.

Before I studied the original literature, I had several obvious misconceptions with Brown's theorem that should be corrected, for instance:

1. H_a is not the upper limit, but lower limit of H (assuming N is zero).
2. $H_a = (2K_1/\mu_0 M_s)$ (where K_1 is the magnetocrystalline anisotropy constant) must be larger than $N_d M_s$, because $H_c > 0$, so K_1 must be positive and large enough. Therefore, this theorem only applies to uniaxial systems.
3. H_a is not the overall anisotropy field ($H_a + H_c$) (where H_s is the shape of the anisotropy field); otherwise, the theorem derives $H_c \geq H_a + H_s$, which has no meaning in physics.

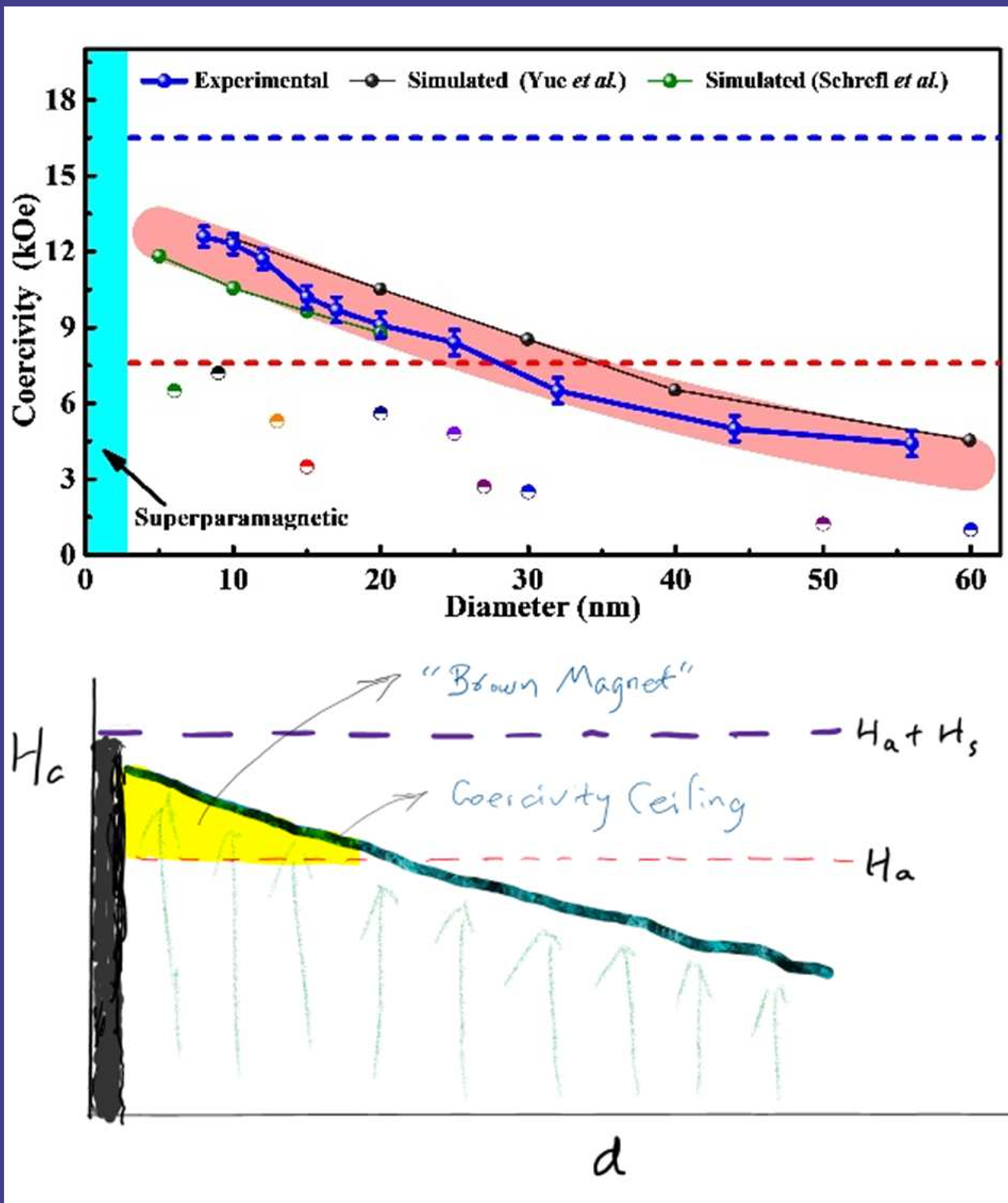


Fig. 2 Coercivity dependence on the diameter of Co nanowires [4].

I believe that nanowires are the key to open the black box between *H*$_a$ and *H*$_c$. After intense effort for nearly two decades, we realized the extraordinary magnetic hardening in Co nanowires.

Figure 2 shows the coercivity curves [4]. The hand-plotted phase diagram beneath the curves shows that Brown's Theorem holds in the yellow region, which I called the "Brown Magnet" region.

We are still in the dark room, but we have finally touched more regions of the "elephant" for the first time…

[1] J. Ping Liu, "I have a dream," Rare-earth Information Center News, no. 4, December 1990.
[2] W. F. Brown Jr., "Virtues and weaknesses of the domain concept," Rev. Mod. Phys. vol. 17, p. 15, 1945.
[3] J. M. Coey, Magnetism and Magnetic Materials. Cambridge, UK: Cambridge Univ. Press, 2010, pp. 244–251.
[4] J. Mohapatra, M. Xing, J. Elkins, J. Beatty, and J. Ping Liu, "Extraordinary magnetic hardening in nanowire assemblies: The geometry and proximity effects," Adv. Funct. Mater., vol. 31, no. 13, 2010157, 2021.

Awards & Nominations Calendar

2025 NOMINATIONS DUE

IEEE FELLOW
FEBRUARY 7

DISTINGUISHED LECTURER
JUNE 17

ACHIEVEMENT AWARD
JULY 31

MID-CAREER AWARD
JULY 31

EARLY CAREER AWARD
JULY 31

DISTINGUISHED SERVICE AWARD
JULY 31

Conference & School Calendar

To list your conference/events in the Newsletter in a future edition, please contact the Editor.

iSiM 2025

International Symposium on Integrated Magnetics

Jan 12-13, 2025
New Orleans, USA

Joint MMM-Intermag 2025

16th Joint MMM-Intermag Conference

Jan 13-17, 2025
New Orleans, USA

AIM 2025

2025 IEEE Advances in Magnetics

Feb 9-12, 2025
Bressanone, Italy

Magnetic Frontiers 2025

2025 Magnetic Frontiers: Altermagnetism - New Opportunities in Magnetism

May 12-16, 2025
Liblice, Czech Republic

COMPUMAG 2025

The 24th International Conference on the Computation of Electromagnetic Fields

Jun 22-26, 2025
Naples, Italy

MagSocSS 2025

2025 IEEE Magnetics Society Summer School

Jun 23-27, 2025
San Diego, USA

Sol-SkyMag 2025

9th International Conference on Magnetism and Spintronics

Jun 23-27, 2025
San Sebastian, Spain

ESM 2025

The European School on Magnetism 2025

Jun 30 - Jul 11, 2025,
Liège, Belgium

MML 2025

2025 12th International Symposium on Metallic Multilayers

Jul 13-18, 2025
Leeds, UK

REPM 2025

The 28th International Workshop on Rare Earth and Future Permanent Magnets and Their Applications

Jul 27-31, 2025
Tsukuba, Japan

Magnonics 2025

Magnonics 2025

Jul 28 - Aug 1, 2025
Mallorca, Spain

JEMS 2025

2025 14th Joint European Magnetic Symposia

Aug 24-29, 2025
Frankfurt am Main, Germany

Trends in Magnetism 2025

Trends in Magnetism 2025 - IV edition

Sep 1-5, 2025
Bari, Italy

Swiss Nanomagnetism Summit 2025

Swiss Nanomagnetism Summit 2025

Sep 8-9, 2025
Zurich, Switzerland

SMM 27

27th Soft Magnetic Material conference

Sep 8-11, 2025
Torino, Italy

MMM 2025

70th Annual Conference on Magnetism and Magnetic Materials

Oct 27-31, 2025
Florida, USA

PM'26

PHYSICS OF MAGNETISM 2026

Jun 22 -26, 2026
Poznań, Poland

Let's hear from experiences and interests of our outgoing President

Prof. Atsufumi Hirohata

About your Presidency

What do you consider to be your greatest achievements as president?

I am very proud of my team, officers and committee chairs, who actually carried out all the work. They are my greatest achievement! Personally, I am not good at singing my own praises,), making my team sing by themselves. Fortunately, their talents are readily apparent. I have been just distributing tasks like a conductor and feel I am very lucky to have such a talented team together with our Administrative Committee members.

What were the biggest challenges you faced during your presidency?

After the Covid-19 pandemic, the conference participation has become very difficult to predict (see my remarks). This led some conferences to record a loss or very little profit, which leads to a reduction in our financial support for the following conferences and initiatives. I feel very bad to hand our challenging finances to my successor, Ron Goldfarb. I trust he can revive our society's financial position again.

What important lessons have you learned from your time as president?

During my term, I tried my best to disclose as much information as possible to run the society and also to answer any questions raised by our members as much as possible. This may have generated the current atmosphere to widely discuss new ideas to make our society better.

How do you hope to be remembered as president of this society?

I am now quite relieved to be able to hand over (the management of) the society to Ron in one piece. I should just fade away ;-)

About the Society's Future

What do you see as the most pressing issues facing the society in the coming years?

Thanks to Ron's great idea, we now have 4,600+ members. In order to satisfy their needs, we need to make our conferences, especially Intermag and MMM, profitable. Over the past decades, our publications have been generating over a half of the income, followed by the conferences. After subtracting the corresponding expenses, the publications remain the only major income for the society, while the conference surplus has been invested into the following conferences.

To serve our members in various ways, including a planned support *for our members in hardship countries, we need to increase our income. The obvious target is our (flagship) conferences. We need more involvement / collaborations with industry for mutual benefits, which may in turn provide some financial benefits for us, for example. We may also need to encourage more "interactions" between conferences and publications, such as various types of conference-related publications. I would like to encourage our members and participants to propose new ideas to further improve our conferences.*

What are the greatest opportunities for the society to grow and evolve?

The MagSoc has been promoting and assisting our members in under-represented countries and regions in recent years. One example was to organise Intermag in Rio de Janeiro this May, which attracted over 100 new members from South America. We should continue to work with them and encourage more members from such countries and regions. Personally, I would assume the next target could be India, which could host Intermag in a decade or so.

What are the greatest opportunities for the society to grow and evolve?

As stated above, Ron's initiative to waive membership fees for student participants to Intermag and provide a discount on the IEEE Day worked very well to increase our members by almost 75%. We need to retain them and maintain our membership to be on the level of 4,500. Especially to show clear benefits to young professionals to keep their memberships after their graduation would be the highest priority. One possibility could be to encourage them to participate in the organisation of their local conferences and events more.

How can the society promote diversity and inclusion among its members?

The MagSoc has been working hard on diversity, equality, and inclusion over the past years. For example, we have been organising leadership training for our female members and providing guidance about refereeing / writing a scientific article for young professionals. We are always open for any more suggestions to be more diverse, equal, and inclusive!

About the Scientific Field

What are the major trends and developments in your field of science?

The advancement of tools available and the improvement of measurement sensitivity have been allowing us to redesign our research. One of the latest examples is the use of machine learning for the prediction of new magnetic materials. Such a technique can save time for experimentalists to make systematic surveys. To date, the technique requires additional consideration on phase diagrams and precise control of atomic positions in a lattice. These requirements will leave us to study magnetism and magnetic materials for at least another 10 years or so ;-)

How has technology changed the way scientists work and collaborate?

Our research environment has been becoming more and more collaborative. This is partially because of the limitation in budgets and the availability of tools needed. We always wish to secure a large budget, but we can be creative and collaborative with small funding. Some surveys show that countries without many international *collaborations have not grown their research outcomes. Science should be a driving force to encourage more international collaborations.*

What ethical challenges do scientists face today?

Traditionally ethical considerations involve some studies on humans, including patients. Such a study typically relates to our interests as a human being, contributing to our society in an apparent way. On the other hand, magnetism used to be independent from such ethical considerations. However, recent developments in nanoparticles for medical applications, for instance, led us to consider ethics. In addition, recent progress in artificial intelligence and associated technologies raises additional ethical concerns. The MagSoc may need to take a leading role to establish ethical guidelines.

How can scientists better communicate the importance of their work to the public?

The development of science and technology has relied on financial support provided by national governments, companies, and (in the past) private citizens with means. This means we are always obliged to make some return to our sponsors. It is hence critical to explain our achievements to the public and to improve their quality of life. Open access is one of the solutions set by the governments, but we as researchers need to be open for any questions and discussion raised by the public.

How can scientists from different countries collaborate more effectively?

Most international collaborations have been based on unwritten agreements, typically through *friendships. In my view, we should keep such a style without tying us up with too many detailed agreements and contracts. Of course, we need to consider the balance between our home country/region and the collaborators' situation to make the collaborations fair and sustainable.*

Personal Reflections

What are the most significant moments in your scientific career?

Anything has both good and bad sides. When I was entering a master's degree, I was advised by my supervisor to propose a research topic. I spent almost two weeks to plan a study on granular giant magnetoresistance, but then I was told such a study could not be carried out in our group. This motivated me to apply for PhD study abroad. In the end, late Tony Bland was the only one who replied to my application and accepted me. This was clearly one of the best moments in my career. As the Greek myths tells us, we can meet the God of Fortune only three times in our life. I believe this was the first encounter, and I managed to catch the God's regard. I try not to think if I met the God afterwards to save my fortune (but I may have met the God when I got married with my wife)...

How important has mentorship been to your career?

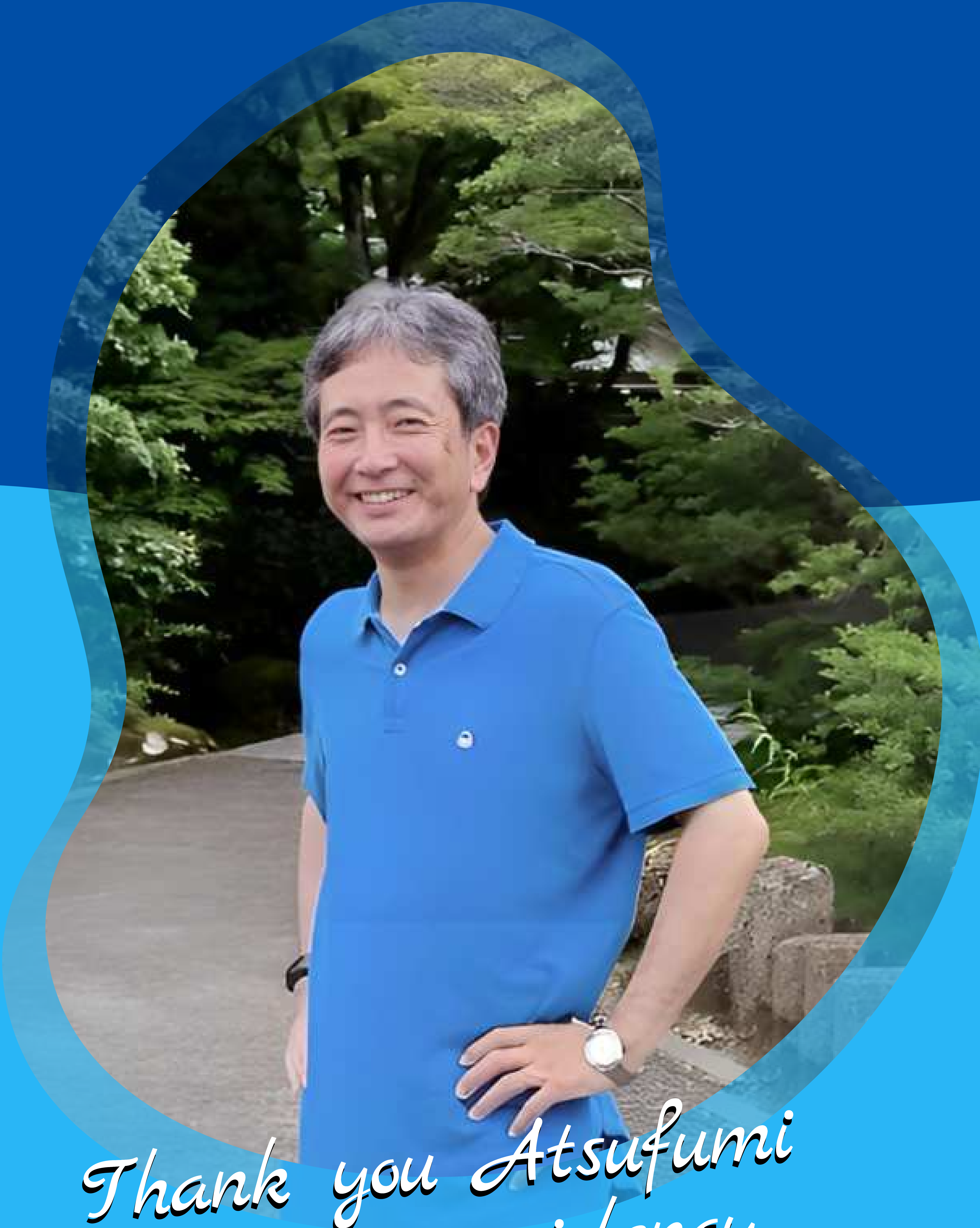
I have been very lucky to be mentored by many great researchers, including my former supervisors and colleagues. They taught me many lessons from the research strategy to lifestyle. I try to enjoy every opportunity to learn these lessons by attending networking events, dinner meetings, etc.

How have you balanced your work and personal life?

My wife was a secretary to a vice-president of a research institute in Japan and has good understanding on a researcher's life. Thanks to her, I am lucky enough to be able to focus on my research! Each researcher has a different situation and understanding on their work-life balance. It is important to find the balance that fits you at different stages of your life.

What are your plans for the future?

It has been a very dense two years for me with my move from the UK to Japan and a new cross-appointment in Germany in addition to my role as the MagSoc President. I should now spend more time on my research to deliver what I promised in my grant applications ;-) As an academic, I should also foster more students and early career researchers in the field of magnetism, researchers who will lead our society in the coming years!



Thank you Atsufumi
for your presidency
in MagSoc !

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