

## From the President

By Manuel Vázquez, President of the Magnetics Society

Together with my best wishes for 2018, please allow me to summarize some recent news on the Magnetics Society.

Since the last issue of the Newsletter, the main event organized by the IEEE Magnetics Society was the 62nd Annual Conference on Magnetism and Magnetic Materials, held in Pittsburgh, Pennsylvania during November 6-10, 2017. The Conference, Chaired by Pallavi Dhagat, was a great success from both the scientific and organizational points of view. I would like here to acknowledge the great job undertaken by Pallavi in chairing the Steering Committee, as well as Program co-chairs Yayoi Takamura and Mingzhong Wu, Publication Chair Victorino Franco, Treasurer



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## 5th Introductory Course on MRAM (InMRAM)

By Bernard Dieny, Course Chair

Taking place at MINATEC/PHELMA, in Grenoble, France during 2-4 July 2018, this introductory course aims at helping students, researchers and engineers with little or no background in magnetism, to better understand the physics and working principles of Magnetic Random Access Memory (MRAM), based on magnetic tunnel junctions. MRAM is attracting increasing interest in the microelectronics industry. In the past two years, numerous announcements from major microelectronics companies have been made about the forthcoming volume production on MRAM-based products.

The course will cover various aspects of MRAM technology: the basic spintronics phenomena involved, the materials, the various categories of MRAM (pros/cons, performances, degree of maturity), comparison with other technologies of non-volatile memories (Phase Change RAM and Resistive RAM) in terms of working principle, performances, foreseen applications, the fabrication process, and the perspectives of

low-power electronic circuits based on this hybrid CMOS/magnetic technology. The course language will be English.

The first four editions of InMRAM were quite successful with an average of 80 attendees from all over the world, coming from academic laboratories and companies. In the morning of July 2, each attendee will have the choice of two introductory tutorials: one on magnetism (for attendees having little or no background in magnetism) and one on microelectronics (for those having little or no background in microelectronics). In the afternoon of July 4, attendees will have the opportunity to visit either SPINTEC or to attend training on tools for the design of hybrid CMOS/magnetic circuits. More details can be found on the InMRAM website at [www.InMRAM.com](http://www.InMRAM.com).

Registration will be open between April 3 - June 3 2018. For more details, contact Bernard Dieny via [bernard.dieny@cea.fr](mailto:bernard.dieny@cea.fr)

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Petru Andrei, and the whole team of chairs and conference managers. In particular, I would like to emphasize the special events, some of which are now considered as part of a series, such as the Women in Magnetism and the Young Professional networking events. In addition, there were new initiatives: the Magnetism as Art Showcase, the Meet the Experts Panel Session, an Exclusive Event for Students; and the inaugural meeting on Next Generation Magnetics. The meeting also included special evening sessions, such as “Spintronics – Present and Future” (with the participation of Chia-Ling Chien, Albert Fert and Hideo Ohno), “Secrets for Highly Effective Communications” (Daniel Agan and Joseph Schreiber), “Tutorial on Terahertz Magnetism”, and a number of topical Symposia.

Rudi Schafer has been very busy with activities relating to numerous conferences supported by the Magnetics Society. In 2018, two main conferences will take place: the flagship 2018 INTERMAG Conference in Singapore, during April 24-30 chaired by S.N. “Prem” Piramanayagam and Sara Majetich, and the International Conference on Magnetism (ICM) in San Francisco during July 15-20. ICM will be in the U.S. for the first time since 1985 (Conference Chair Allan MacDonald, Secretary General Liesl Folks). Olga Kazakova is in charge of arranging the details for a number of additional Small Conferences, sponsored either financially or technically by the Magnetics Society.

Bernard Dieny was responsible for organizing a special poster session dedicated to MRAM during the 63rd International Electron Devices Meeting (IEDM) held in San Francisco during December 2-6, 2017, and the 9th MRAM Global Innovation Forum, a one-day meeting just after the IEDM, with significant support from Samsung. Both events were very successful in participation and subsequent scientific discussions.

My congratulations to Hideo Ohno, new 2018 Magnetics Society IEEE Fellow, and to the Society’s other 2018 awardees: Roy Chantrell (Achievement Award), Kevin O’Grady (Distinguished Service Award), and Anjan Soumyanarayanan (Early Career Award). I would like to thank Burkard Hillebrand, Chair of the Honors and Awards Committee, for his deep involvement.

Beth Stadler was responsible for the final selection of the outstanding 2018 Distinguished Lecturers (DLs): Alison B. Flatau, Can-Ming Hu, Mitsuteru Inoue, and YoshiChika Otani.

My special congratulations go to Ron Goldfarb for his intense dedication to IEEE activities as member of the IEEE Publication Services and Products Board (PSPB). While his term as chair of the PSPB Publishing Conduct Committee ended in 2017, in 2018 he was elected as PSPB representative on the IEEE Conferences Committee, a TAB Committee. As part of the IEEE Conferences Committee, he has been asked to be on the Technical Program Integrity Committee, which approves new conferences that are technically co-sponsored by societies/councils for inclusion in Xplore. In addition, Ikenna Nlebedim has been appointed the Society’s representative to the Young Professional IEEE Program. David Jiles volunteered for and was later nominated to the IEEE Fellows Committee.

A warm welcome goes to the newly elected Administrative Committee (AdCom) members: Cindi Dennis, Peter Fischer, Simon Greaves, Matthias Kläui, June Lau, Hans Nembach, Terou Ono, and Thomas Thomson. I also give grateful acknowledgement to the outgoing AdCom members for their outstanding contribution to the Magnetics Society: Franca Albertini, Bernard Dieny, Ming Cheng, Dafiné Ravelosona, Alexander Stancu, Thomas Thomson, Jiang-Ping Wang and Roger Wood.

As Finance Chair, Mingzhong Wu informs me that the Society’s finances are in good shape, and new initiatives and projects are expected to be developed during 2018 even though there has been an effective reduction concerning the 3% rule, following indications given by the IEEE Finance department.

Petru Andrei, Chair of the Publications Committee, has been very much involved in the process to establish a new Society Conference Proceedings in IEEE Xplore Digital Library, which we expect will be successful in accommodating the Society’s publications to higher editorial and financial standards.

As announced by Atsufumi Hiroata, Education Committee Chair, the 2018 Summer School will be held in Quito, Ecuador organized by Dario Niebieskikwiat and his local team. We expect a very successful School.

Laura Lewis, Chair of the Technical Committee has launched a new initiative – Next-Generation Magnetics. This group is considered to be a new forum for senior PhD students and post-docs to create a junior advocacy/technical committee group. Laura also has reactivated the committee’s actions on the Magnetic Technology Road Map.

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Membership Committee Chair Dan Wei informs me that in 2017, membership has followed a nearly constant trend. Oksana Chubykalo-Fesenko informed us that four new Chapters joined the Society during 2017, for a total of 39 Chapters from different regions of the world. The Society is becoming quite a global association.

Visibility and publicity activities significantly increased during 2017, as a consequence of the strong involvement of Philip Pong, Publicity Chair, particularly revamping the website and integrating DL videos and lectures online, via the IEEE.tv Magnetics Society Channel.

I would like to express very sincere thanks for the support of officers Pallavi Dhagat, President-elect, Masahiro Yamaguchi, Secretary/Treasurer, and Bruce Terris, Past-President.

And finally, I wanted to especially express my personal gratitude to Diane Melton, Director of Operations, who with her outstanding experience and invaluable professionalism, helped me so much with all organizational details, together with operations staff Molly Bartkowsky and Regina Mohr.

As in previous messages in this Newsletter, I want to add a final reminder to encourage all of you to advertise the general activities of the Magnetics Society; and to volunteer in the various activities promoted by our committees. Please feel free to contact the corresponding chair or directly me.

*Manuel Vázquez can be reached via [manuel.v.vazquez@ieee.org](mailto:manuel.v.vazquez@ieee.org).*

### Book Ideas Wanted

Is your area of research lacking a good topical overview book? Perhaps you have had a recent workshop on a hot topic and you are thinking of a way to summarize the state-of-the-art?

Consider publishing your book and e-book through IEEE, because when you do, a small

portion of the proceeds is returned to your community through the Magnetics Society. Need help getting setup or have more questions?

Contact June Lau via [june.lau@nist.gov](mailto:june.lau@nist.gov) for assistance.

## New discovery could improve brain-like memory and computing

Submitted by Jian-Ping Wang

***University of Minnesota researchers demonstrate the existence of a new kind of magnetoresistance involving topological insulators.***

From various magnetic tapes, floppy disks and computer hard disk drives, magnetic materials have been storing our electronic information along with our valuable knowledge and memories for well over half of a century.

In more recent years, a new type of phenomenon known as magnetoresistance, which is the tendency of a material to change its electrical resistance when an externally-applied magnetic field or when its own magnetization is changed, has found its success in hard disk drive read heads, magnetic field sensors, and in magnetoresistive random access memories.

A new discovery, led by researchers at the University of Minnesota, demonstrates the existence of a new kind of magnetoresistance involving topological insulators that could result in improvements in future computer storage. The details of their research are published in the most recent issue of the scientific journal Nature Communications.

“Our discovery is one missing piece of the puzzle to improve the future of low-power computing and memory for the semiconductor industry, including brain-like computing and chips for robots and 3D magnetic memory,” said University of Minnesota Robert F. Hartmann Professor of Electrical and Computer Engineering Jian-Ping Wang, director of the Center for Spintronic Materials, Interfaces, and Novel Structures (C-SPIN) based at the University of Minnesota and co-author of the study.

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# Kevin O'Grady Receives 2018 Distinguished Service Award

Submitted by Burkard Hillebrands, Honors and Awards Chair, and Ron Goldfarb, Distinguished Service Award Chair

In 2016 the IEEE Magnetics Society Distinguished Service Award was established to honor outstanding service to the Magnetics Society. Recipients are characterized by sustained voluntary service significantly beyond the typical. The award is presented at the INTERMAG Conference each year and consists of a certificate and cash prize.

The recipient for 2018 is Kevin O'Grady of the University of York in the UK. He receives the 2018 Distinguished Service Award for advancing international participation and inclusive representation in the IEEE Magnetics Society. His leadership roles began in 1995, when he was appointed chair of the Technical Committee. He was subsequently elected Society Secretary/Treasurer for 2001-2002, becoming Vice President in 2003-2004, and President in 2005-2006.

Kevin received his bachelor's and doctoral degrees in physics from the University College of North Wales, part of the collegiate University of Wales in the UK. He held positions at the University College of North Wales, Bangor, and Loughborough University of Technology, Leicestershire. Subsequently he held a chair in electronic engineering at University College of North Wales. Since 2000 he has been a professor of experimental physics at the University of York.

In 1991, Kevin founded a small company, Liquids Research Ltd., which manufactures ferrofluids and other dispersions of magnetic nanoparticles. In his university work he studied magnetization reversal, remanent magnetization curves, and thermal activation in a wide range of materials, particularly magnetic recording media. From 2000, he worked on the phenomenon of exchange bias in polycrystalline sputtered thin films primarily for read heads in hard disk drives. Kevin was a Magnetics Society Distinguished Lecturer in 2010, speaking on

"A New Paradigm for Exchange Bias in Polycrystalline Films."

During Kevin's tenure as Vice President of the Magnetics Society, he proposed the institution of an international summer school for graduate students. The Magnetics Society Summer School became a reality in 2008, and has been held annually

around the world since then, under the auspices of the Education Committee.

As President of the Society, Kevin initiated reforms to make its Administrative Committee and other committees more representative of society membership. He promoted participation by women and members from Asian countries. He established the Chapters Committee and, largely due to his efforts, the number of Magnetics Society chapters increased from 19 in 2004 to 39 today. Kevin involved the Chapters and Technical Committees in the selection of Distinguished Lecturers. Local chapters now arrange for Distinguished Lecturers to undertake lecture tours, rather than give single lectures.

Kevin served as program co-chair for the Intermag Conference on three occasions and as general chair of the Magnetism and Magnetic Materials-Intermag Conference in Washington, D.C., in 2010.



## New Senior Members

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

November 2017: Kheong Sann Chan, Wieslaw Jazdzynski, Mark Kief, Liyi Li, Gengchiao Liang, Wojciech Pluta and Gennadi Sizov.

February 2018: Christophe Dolabdjian, Nicola Donato, Krzysztof Komez, Chris Leighton and Ugo Reggiani.

For further information, visit the IEEE Web site at:

[www.ieee.org/membership\\_services/membership/grade\\_elevation.html](http://www.ieee.org/membership_services/membership/grade_elevation.html)



# Conference on Nanomaterials Applied to Life Sciences

By Montserrat Rivas, Conference Co-Chair

The first conference on Nanomaterials Applied to Life Sciences (NALS2017) was held during December 12-15, 2017 in Gijón, Spain. It was organized by the Nanoparticles for Bio-Applications (NanoBioAp) research cluster. The IEEE Magnetics Society was one of the conference's sponsors.

The conference centered on biological applications of nanomaterials for diagnosis and therapy in human and animal diseases, food safety, and environmental remediation. Participants with backgrounds in materials science, chemistry, physics, engineering, medicine and biology addressed the translation of research advances into clinical practice and industrial applications, which is often a challenge for the research community.

Magnetism was widely represented, with the participation of researchers working on magnetic nanomaterials and magnetic devices for applications in the life sciences.

NALS2017 had 127 attendees from 14 countries. The conference attracted many early-career researchers (25% of the participants were graduate students and postdoctoral associates) who were motivated to become involved in multidisciplinary investigations.

The success of NALS2017 generated great enthusiasm for the next conference, NALS2019, which will be held in Madrid in December 2019, and will be hosted by the Madrid Institute of Advanced Studies in Nanoscience (iMdea).



**Young researchers at their networking event with Manuel Vázquez, President of the IEEE Magnetics Society.**



**Eugenia Fortes receives the best student poster/oral presentation prize from Carmen Blanco, Conference Co-Chair.**



**David Cabrera receives the Best Student Oral Presentation Prize from Manuel Vázquez.**

# Two Successful MRAM Sessions During IEDM 2017

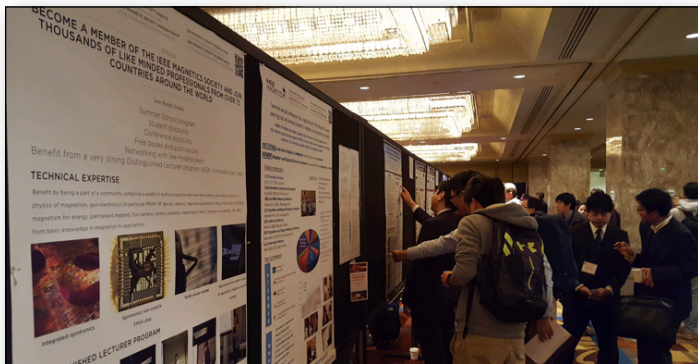
By Bruce Dieny, Chair of 9th MRAM Global Innovation Forum

IEDM is the main annual conference of the IEEE Electron Devices Society (EDS). It took place in San Francisco, during December 4-6, 2017. Since 2016, the EDS and the Magnetics Society have been collaborating on the organization of joint events, gathering experts in microelectronics and magnetism.

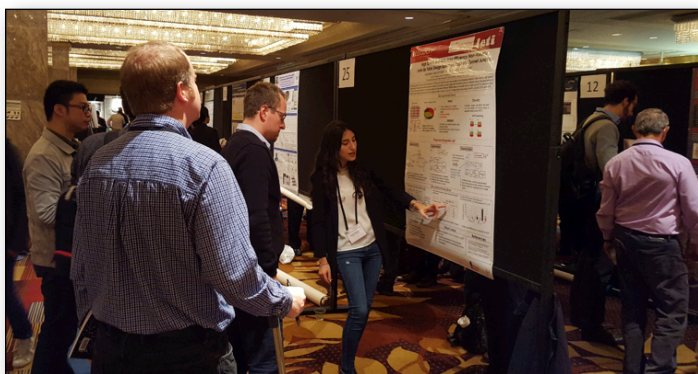
With the rising interest of the microelectronics industry for the emerging MRAM technology, it is important to strengthen the links between these two societies. Indeed, MRAM technology emerged from major breakthroughs discoveries realized within the spin-electronic community. Spin electronics is a marriage between magnetism and electronics. Nowadays, the development of MRAM really requires joint concerted efforts from both microelectronics and magnetism experts. This is why two MRAM-related special events were organized by the IEEE Magnetics Society within the framework of IEDM 2017.



The second event was the 9th MRAM Global Innovation Forum. This Forum was the ninth in a series initiated by Samsung Semiconductor, some four years ago, and these events are sponsored by Samsung. This edition saw 285 attendees gather, among whom 230 came from industry. This demonstrates the very strong industrial interest for MRAM.



The first was an MRAM poster session where 35 posters were presented covering various topics such as MRAM materials, spintronics phenomena involved in MRAM technology, MRAM fabrication and testing, low power circuits architecture benefiting from the non-volatility of MRAM, spin-logic, and so on. The poster session was highly visible since it took place in the exhibit area of IEDM (which was also the coffee-break area). Some 300 IEDM attendees came and interacted with the poster presenters, with a number of lively discussions.



The Forum consisted of 10 invited talks, mostly from industry personnel, and a panel discussion on “PCRAM, ReRAM, MRAM, competing or complementary technologies”. Three major foundries (Samsung, TSMC and Global Foundries) all announced the ramp up towards volume production of eMRAM in 2018. Among the various technologies of embedded nonvolatile memory, eMRAM clearly appears to be the preferred choice.

Some reports showed that satisfying solder reflow compliance and automotive specifications is now possible with eMRAM. This memory is mainly envisioned as the first alternative for eFLASH replacement. Indeed, eMRAM fabrication only requires three levels of masks, as compared to 16 to 20 for eFLASH. In addition, a much improved write endurance (>1010 cycles for eMRAM vs 105 cycles for eFLASH) is observed. In a second stage, some moderately fast SRAM (Cache L3 for instance) may also be replaced by MRAM.

The launch of MRAM volume production after more than 20 years of research and development is extremely rewarding for all those who have been working in this area for so many years. I am convinced however that this is only the beginning of spintronics in microelectronics. Lots of other breakthrough discoveries have been made in the past ten years, such as spin-orbit torques, voltage control of magnetic properties or interconversion between charge and spin currents by taking advantage of spin-orbit effects. They all open new perspectives

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## MRAM Sessions During IEDM 2017 *continued from page 6*

of applications for ultra-low power circuits. These phenomena enable the conception of devices and circuits which can be extremely useful in the rapidly expanding field of the Internet of Things, but also for all wearable applications as well as to reduce power consumption in server farms, or for power management in high performance computing.

These two events will be again organized at IEDM 2018. I am very thankful to the invited speakers: Luc Thomas (TDK/Headway), G. Hu (IBM), C. M. Lin (TSMC), S. Kang (Qualcomm), D. Eggleston (Global Foundries), Y. K. Lee

(Samsung Foundry), S. Fukami (Tohoku University), H. Yoda (Toshiba), T. Endoh (Tohoku University), and T. Jew (NXP); and to the panelists: G. Navarro (CEA/LETI), S. Kang (Qualcomm), T. Jew (NXP), T. Endoh (Tohoku University) and C. Petti (Sandisk/WD). My thanks also go to the program committee members: D. Worledge (IBM), H. Ohno (Tohoku University), K. J. Lee (Korea University), B. Terris (Western Digital); and to Sandra Ingrassia (SPINTEC) and Phyllis Mahoney (Widerkehr and Associates) for logistical help with the organization. Many thanks to Samsung Semiconductor for sponsorship.

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## Brain-like memory and computing *continued from page 3*

While magnetic recording still dominates data storage applications, magnetoresistive random access memory is gradually finding its place in the field of computing memory. From the outside, they are unlike the hard disk drives which have mechanically spinning disks and swinging heads—they are more like any other type of memory. They are chips (solid state) which one would find being soldered on circuit boards in a computer or mobile device.

Recently, a group of materials called topological insulators has been found to further improve the writing energy efficiency of magnetoresistive random access memory cells in electronics. However, the new device geometry demands a new magnetoresistance phenomenon to accomplish the read function of the memory cell in 3D system and network.

Following the recent discovery of unidirectional spin Hall magnetoresistance in conventional metal bilayer material systems, researchers from the University of Minnesota worked with colleagues from Pennsylvania State University to demonstrate for the first time the existence of such magnetoresistance in topological insulator-ferromagnet bilayers.

The study confirms the existence of the unidirectional magnetoresistance and reveals that the adoption of topological insulators, compared to heavy metals, doubles the magnetoresistance performance at 150 kelvin. From an application perspective, this work provides the missing piece of the puzzle to create a proposed 3D and cross-bar type computing and memory device involving topological insulators by adding the previously missing or very inconvenient read functionality.

In addition to Wang, researchers involved in this study include Yang Lv, Delin Zhang and Mahdi Jamali from the University of Minnesota Department of Electrical and Computer Engineering and James Kally, Joon Sue Lee and Nitin Samarth from Pennsylvania State University Department of Physics.

This research was funded by the Center for Spintronic Materials, Interfaces and Novel Architectures (C-SPIN) at the University of Minnesota, a Semiconductor Research Corporation program sponsored by the Microelectronics Advanced Research Corp. (MARCO) and the Defense Advanced Research Projects Agency (DARPA).

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## International Conference on Magnetism (ICM2018)

Submitted by Liesl Folks, ICM2018 Secretary General

ICM2018 takes place in San Francisco, USA during July 15-20, 2018. It is a major international conference series with more than 2000 attendees expected from all over the world. It continues a series of meetings held every three years, most recently in Barcelona, Busan, Karlsruhe, and Kyoto. You should attend ICM2018 if you are interested in fundamental or

applied research related to magnetism. ICM2018 is your opportunity to share your research with the largest and broadest collection of magnetism researchers assembled in one place, and to learn about their latest results.

For more details please visit [www.icm2018sf.org](http://www.icm2018sf.org).



# The 29th Magnetic Recording Conference (TMRC 2018)

Submitted by Tiffany Santos, TMRC 2018 Publicity Chair

The 29th Magnetic Recording Conference (TMRC 2018) will be held during August 8-10, 2018, at the Western Digital Milpitas Campus, in Milpitas, California. The focus of TMRC 2018 will be novel materials, devices and technologies for magnetic data storage and advanced applications.

Approximately 36 invited papers of the highest quality will be presented orally at the conference, and will later be published in the *IEEE Transactions on Magnetics*. Poster sessions will also be held following the oral sessions and will feature posters from the invited speakers and accepted contributed posters. Both invited and contributed papers are encouraged for publication.

Topics of interest include:

- Advanced Magnetic Recording for  $> 2$  Tbits/in<sup>2</sup> (Readers, Writers, Servo, Tribology, HDI, Signal Processing)
- Heat Assisted Magnetic Recording (HAMR System, Head/Media and HDI)
- Microwave-Assisted Magnetic Recording (MAMR)

- Alternative Magnetic Recording Technologies (SMR, TDMR, HIMR, Heated-dot, Tape, All Optical Switching)
- Spin Transfer Torque-Magnetic Random Access Memory (MTJ cell, MRAM chip, manufacturing and roadmap)
- MRAM & Magnetic Logic – New Physics & Materials (MRAM architecture, VCMRAM, SOT-MRAM, TI & 2D materials)
- Fundamentals (Metrology, Tooling, Materials, Recording Physics)

The Web site for TMRC 2018 can be found at: <http://tmrc2018.ucsd.edu>

Nominations for invited speakers should be submitted to the Program Chairs, Dr. Ganping Ju, Dr. Christian Kaiser, Dr. Goran Mihajlovic and Dr. Yuchen Zhou, via the form available from the conference Web site.

The deadline to submit nominations is March 23, 2018.

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## Claire Donnelly Awarded 2018 Richard L. Greene Dissertation Award in Experimental Condensed Matter or Materials Physics from the APS

Submitted by Laura Heyderman, IEEE Fellow

Claire Donnelly has been awarded the 2018 Richard L. Greene Dissertation Award in Experimental Condensed Matter or Materials Physics from the American Physical Society, recognizing doctoral thesis research of exceptional quality and importance.

This prize is for her dissertation on “Hard X-ray Tomography of Three Dimensional Magnetic Structures”, which she carried out under the



supervision of Laura Heyderman (IEEE Fellow).

For her dissertation, Claire and her collaborators at the Paul Scherrer Institute and the ETH Zurich developed techniques for the fabrication and characterisation of three dimensional magnetic structures.



## Conference Calendar

April 9-10, 2018 Magnetism 2018  
Manchester, UK  
<http://magnetism2018.iopconfs.org>

April 23-27, 2018 2018 International Magnetics Conference (INTERMAG 2018)  
Singapore, Singapore  
<http://www.intermag2018.com>

June 3-8, 2018 2018 IEEE Magnetics Society Summer School  
Quito, Ecuador  
[http://ieeemagnetics.org/index.php?option=com\\_content&view=article&id=135&Itemid=140](http://ieeemagnetics.org/index.php?option=com_content&view=article&id=135&Itemid=140)

July 1-4, 2018 12th European Magnetic Sensors and Actuators Conference  
Athens, Greece  
<http://www.emsa2018.com>

July 15-20, 2018 21st International Conference on Magnetism (ICM 2018)  
San Francisco, California, USA  
<http://www.icm2018sf.org>

August 8-10, 2018 The 29th Magnetic Recording Conference (TMRC)  
Milpitas, California, USA  
<http://tmrc2018.ucsd.edu>

August 26-30, 2018 25th Int. Workshop on Rare-Earth Permanent Magnets (REPM 2018)  
Beijing, China  
<http://www.repm2018.org>

3-7 September, 2018 Joint European Magnetic Symposia (JEMS2018)  
Mainz, Germany  
<http://jems2018.org>

To list your conference in the Newsletter Conference Calendar, please contact the Editor

## About the Newsletter

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

Contributions are solicited from Magnetics Society members, conference organizers, Society Officers & other volunteers, local chapters, and other individuals with relevant material. The Newsletter is published quarterly on the Magnetics Society webpage at

<http://www.ieeemagnetics.org>.

Please send articles, letters & other contributions via email to the Newsletter Editor, Gareth Hatch, at [g.p.hatch@ieee.org](mailto:g.p.hatch@ieee.org).

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