MAX-PLANCK-GESELLSCHAFT
TAGUNGSSTÄTTE SCHLOSS RINGBERG

BEYOND! CMOS

WORKSHOP

Materials and Devices Beyond! CMOS

October 07-10th 2015

Schloss Ringberg, Germany

Max Planck Institute of Microstructure Physics
Weinberg 2 * 06120 Halle (Saale) * Germany
Organizers Prof. Dr. Hardy Gross & Prof. Dr. Stuart Parkin
www.mpi-halle.mpg.de
office.parkin@mpi-halle.mpg.de

MARTIN-LUTHER-UNIVERSITÄT
HALLE-WITTENBERG

Unterstützt von / Supported by
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Stiftung/Foundation

AIM of the workshop

Discuss novel materials, methods of generating devices - especially for innately three dimensional systems - and means to combine such materials and devices to build nano-systems that go far beyond conventional computing systems especially with regard to energy consumption.

Start & end time?

We invite you to arrive on Oct. 07 at Ringberg between 3-6 p.m. At that time rooms will be available and the registration will be open. The official part of the program **starts** on Oct. 07, 2015 at 6 p.m. with a guided tour of the Castle by the manager Mr. Essl. He will show us around and provide us with some historical background information on the Castle and its secrets.

We **end** our Workshop on Oct. 09, at around 8 p.m. Accommodation is foreseen till Oct. 10th with your departure after breakfast.

Address & info on accommodation

Schloss Ringberg - Schlossstraße 20 - 83708 Kreuth - Phone:+49 (0)8022 27 90 (reception)
http://www.schloss-ringberg.de/contact
All rooms do have wireless access.
Breakfast is served from 7:45 a.m. on the workshop day and from 8 a.m. on Oct. 10th which is the day of departure.

Munich airport ←→ Tegernsee Bahnhof (by train & taxi)

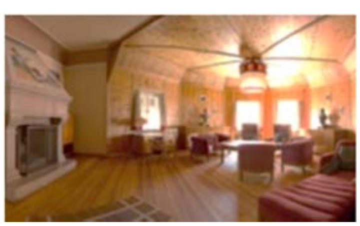
For information on your journey to Schloss Ringberg see: http://www.schloss-ringberg.de/travel

For your arrival/departure by public transportation please check the time table of “Deutsche Bahn” at http://www.bahn.de/p_en/view/index.shtml and see attached time table to/from Tegernsee. We recommend to choose the combination of S-Bahn /BOB (local train) instead of using the combination of bus/BOB; you have to change the train once at “München Donnersbergbrücke”.
You can buy your ticket online, upon arrival at the vending machines or at the ticket counter before entering the S-Bahn area at the airport. Your destination is “Tegernsee Bahnhof” and the train ride takes approx. 2 hours.

Please use a taxi from the train station “Tegernsee” towards the castle. Taxi Kaufmann has a guest list and is informed about all arrival times that you have sent beforehand. You can reach the **Taxi company by phone +49 (0)8022/ 5555** (code: MPI- Halle).

For any questions related to our workshop feel free to contact Simone Jäger at +49 (0) 172/ 76.79.965.
We look forward to welcoming you at Ringberg.
Have a save trip and see you soon.

Stuart & Hardy

Program

Materials and Devices Beyond CMOS

Oct. 07, 2015		
15:00-18:00		Arrival at Castle Ringberg (coffee, tea, fruit, cake for your welcome)
18:00-19:00	Essl	Guided tour of the Castle Ringberg
19:00-20:00		Welcome DINNER
20:00-21:00	Parkin	Opening - Concept of the *"BEYOND!"* Workshop series
Oct. 08, 2015		
07:45-08:45		BREAKFAST
		Chair: PARKIN
08:45-09:00	Parkin	Welcome to "BEYOND! CMOS" workshop
09:00-09:40	Poon	Integrated photonics for “more than Moore”, “more Moore”, and neural technologies
09:40-10:20	Peterson	3-D Additive Processing of Multi-layer Transistor Systems
10:20-10:40		Refreshing your brain (coffee, tea & more)
		Chair: GROSS
10:40-11:20	Williams	Electronic analogs of synapses and neurons
11:20-12:00	Di Ventra	Memcomputing: computing with collective states of interacting memory processors
12:00-13:00		LUNCH
		Chair: MERTIG
13:00-13:40	Cha	2D Electronic Chalcogenide Nanomaterials
13:40-14:20	Mak	Valley pseudospin transport in transition metal dichalcogenide atomic layers
14:20-15:00	Yan	From the bulk to the surface in a new topological matter, the Weyl Semimetal
15:00-15:20		Move & talk (coffe, tea & more)
		Chair: HANEIN / DATTA
15:20-16:00	Liu	Active 3D DNA plasmonics
16:00-16:40	Kadic	3D Microstructured Metamaterials
16:40-17:20	Cavalleri	Coherent ultrafast control of solids through optical phononics
17:20-18:00	Ropers	Ultrafast electron microscopy and diffraction using nanoscale photoemitters
18:15-19:45		DINNER
		Chair: FELSER
20:00-20:40	Salahuddin	Controlled Phase Transition for Next Generation Computing
20:40-21:20	Apsel	Communicating on a Shoestring: How Fireflies and Flexible Hardware Can Enable IoT

Oct. 09, 2015		
07:45-09:00		BREAKFAST
		Chair: DI VENTRA
09:00-09:40	Helmstaedter	Connectomics
09:40-10:20	Levi	Biomimetic Neural Network for the new neuromorphic roadmap
10:20-10:40		Refreshing your brain (coffee, tea & more)
		Chair: APSEL
10:40-11:20	Lemay	All-electrical (bio)sensing with CMOS nanocapacitor arrays: from nanoparticles to living cells
11:20-12:00	Hanein	Nano Materials for Neuro Technology
12:00-12:40	Yaksi	Sensory processing in zebrafish brain
13:00-14:00		LUNCH
		Chair: CAVALLERI
14:00-14:40	Delbruck	Silicon Retina Technology
14:40-15:20	Datta	Revisiting Spin Transistors
15:20-16:00		Networking time (coffee, tea & more)
		Chair: LIU
16:00-16:40	Wakamura	Quasiparticle-mediated spin Hall effect in a superconductor
16:40-17:20	Cao	Magnon-Polaritons in Microwave Cavities
17:20-18:00	Bazylak	Fuel cells for clean energy: designing new materials for higher efficiencies
18:00-19:30		Bavarian night - BUFFET at Castle Ringberg
19:30-20:00	Parkin	Closing remarks - future directions
Oct. 10, 2015		
08:00-9:00		BREAKFAST
		Departure - Taxi transfer to Tegernsee station

Abstract booklet

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Short biographical sketches

Integrated photonics for "more than Moore", "more Moore", and neural technologies

Joyce Poon

Department of Electrical and Computer Engineering; Toronto, Canada

"Beyond CMOS" inspires many different interpretations and opportunities, spanning from the physical layer (e.g., new materials, devices, circuits, and packaging) to the system level (e.g., new computing architectures and paradigms). In this talk, I will present examples from my research in integrated photonics that can lead to new microsystems for the beyond CMOS era. I will begin by describing my group's work in foundry-based silicon photonics, a "more than Moore" technology, for communications and computing. Then, I will describe our studies on the insulator-metal phase transition material, vanadium dioxide (VO_2), for highly miniaturized optoelectronics and novel electronic devices ("more Moore"). Time permitting, I will show how densely integrated photonic circuits can be applied to brain activity mapping. This may also lead to new types of brain-light interfaces for neuromorphic computing.

Biographical sketch

Joyce Poon is an Associate Professor of Electrical and Computer Engineering at University of Toronto, where she holds the Canada Research Chair in Integrated Photonic Devices. She and her team conduct theoretical and experimental research in micro- and nano-scale integrated photonics.

Dr. Poon obtained the Ph.D. and M.S. in Electrical Engineering from Caltech in 2007 and 2003 respectively, and the B.A.Sc. in Engineering Science (physics option) from the University of Toronto in 2002. She is the recipient of a McCharles Prize for Early Research Career Distinction, a MIT TR35 award in 2012, IBM Faculty Award in 2010 and 2011, Ontario Ministry of Research and Innovation Early Researcher Award in 2009, NSERC University Faculty Award in 2008, and the Clauser Doctoral Thesis Prize from Caltech in 2007.

3-D Additive Processing of Multi-layer Transistor Systems

Becky (R. L.) Peterson

PhD, Assistant Professor

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Printed electronics have been held up as the future for inexpensive roll-to-roll processing of large area circuits, but that vision has not yet been achieved. The real power of solution-based device fabrication may be in its ability to form complex, three-dimensional (3-D) microsystems with multiple functional layers with heterogeneous, vertical integration by exploiting additive processes, whether on flexible or rigid substrates. Such systems are desirable for high-density, high-performance circuits, for stealth military or civilian security devices, and for inexpensive, “disposable” biomedical or environmental sensing and monitoring systems. Multi-layer transistors structures have long been sought in the CMOS IC industry. Pad-level integration of memory chips has been achieved using various types of peripheral vertical interconnects. More recently, repeated bond and split processes have been used to integrate three layers of SOI silicon CMOSFETs as well as CMOS to III-V technologies for focal plan detectors [1]. Here, we describe a new method for heterogeneous integration via direct additive fabrication of oxide thin film transistors on top of functional CMOS silicon die.

Oxide-based electronic materials have seen a resurgence of interest based on the recent exploration of amorphous oxide semiconductors, topological insulators, ternary high-k dielectrics, and new transparent conducting oxides (Fig. 1). Amorphous oxide semiconductors, such as indium gallium zinc oxide or zinc tin oxide, can be facilely made via solution processes, with performance equivalent to that of vacuum processed (sputtered) films [2]–[5] (Fig. 2). We have shown that *n*-type zinc tin oxide thin film transistors exhibit electron mobility of approximately 8 $cm^2V^{-1}s^{-1}$, ON/OFF ratio of > 10^6 (limited by gate leakage), and sharp turn-on near zero volts. The films are smooth and amorphous, and exhibit band-like electron transparent at room temperature [3] (Fig. 3). Sputtered molybdenum makes an excellent ohmic contact with width-normalized contact resistance of < 9 Ω-cm [6], making sub-micron transistors for radio frequency (RF) circuits a future possibility. We have directly fabricated these devices on top of functional CMOS die, with no adverse effects on the silicon device performance. Following TFT fabrication, both the silicon and oxide transistors are fully functional. This process could be repeated to form additional transistors layers or other electronic, photonic, or sensing devices.

This new approach to additive heterogeneous integration using solution-processed inorganic films, offers great promise for realization of new 3-D structures and multi-functional systems.

Acknowledgment

The author would like to thank M. M. Hussain of KAUST for providing CMOS die. She also thanks students W. Hu, C.-L. Li, Y. Son, B. Frost, M. Kravchenko, J. Li, J. Miller, and Y. Zhao for their work, and Prof. K. Najafi and Mr. R. Gordenker for test lab access and support. This work was supported NSF ECCS BRIGE Award #1032538, a Samsung GRO 2012 Award, DARPA 2014 Young Faculty Award # N66001-14-1-4046 and by University of Michigan internal funding. Portions of this work were performed in U-M's Lurie Nanofabrication Facility, a site of the NNIN, which is supported by the NSF.

References

[1] C. K. Chen, D. R. W. Yost, B. F. Aull, C. L. Chen, P. M. Gouker, J. M. Knecht, B. M. Tyrrell, K. Warner, B. Wheeler, P. W. Wyatt, C. L. Keast, and V. Suntharalingam, "3D-enabled heterogeneous integrated circuits," presented at the IEEE SOI-3D-Subthreshold Microelectronics Technology Unified Conference (S3S), Monterey, CA, 2013, pp. 1–29.

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[4] K. K. Banger, Y. Yamashita, K. Mori, R. L. Peterson, T. Leedham, J. Rickard, and H. Sirringhaus, "Low-temperature, high-performance solution-processed metal oxide thin-film transistors formed by a 'sol–gel on chip' process," *Nat. Mater.*, vol. 10, no. 1, pp. 45–50, Dec. 2010.

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[6] W. Hu and R. L. Peterson, "Molybdenum as a contact material in zinc tin oxide thin film transistors," Appl. Phys. Lett., vol. 104, no. 19, p. 192105, May 2014.

[7] R. L. Peterson, "Unpublished work," 2014.

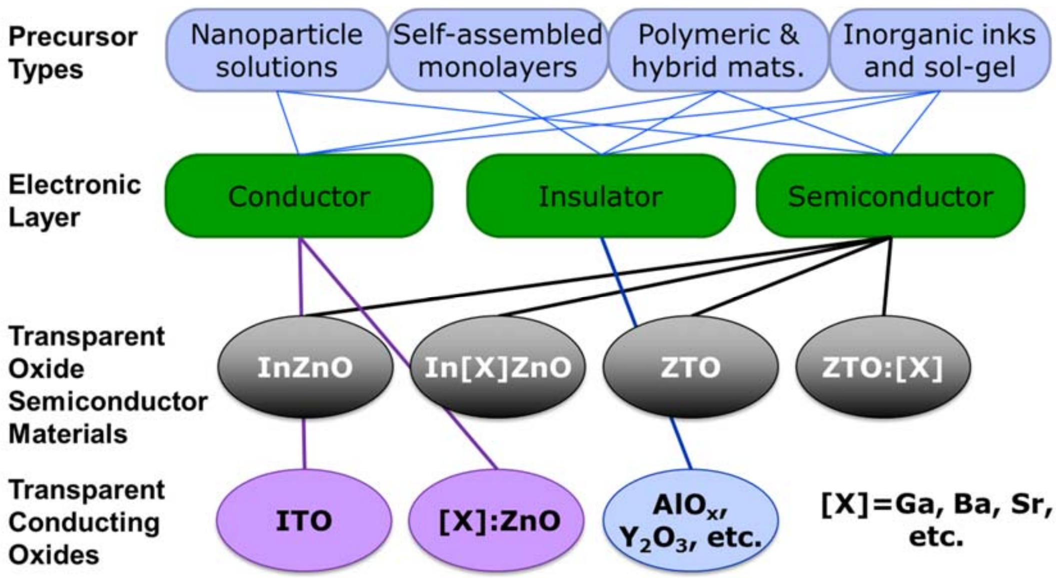

Figure 1. *Options for solution-processed electronic materials. In this work, we focus on printable inorganic amorphous and nanocrystalline oxide thin films.*

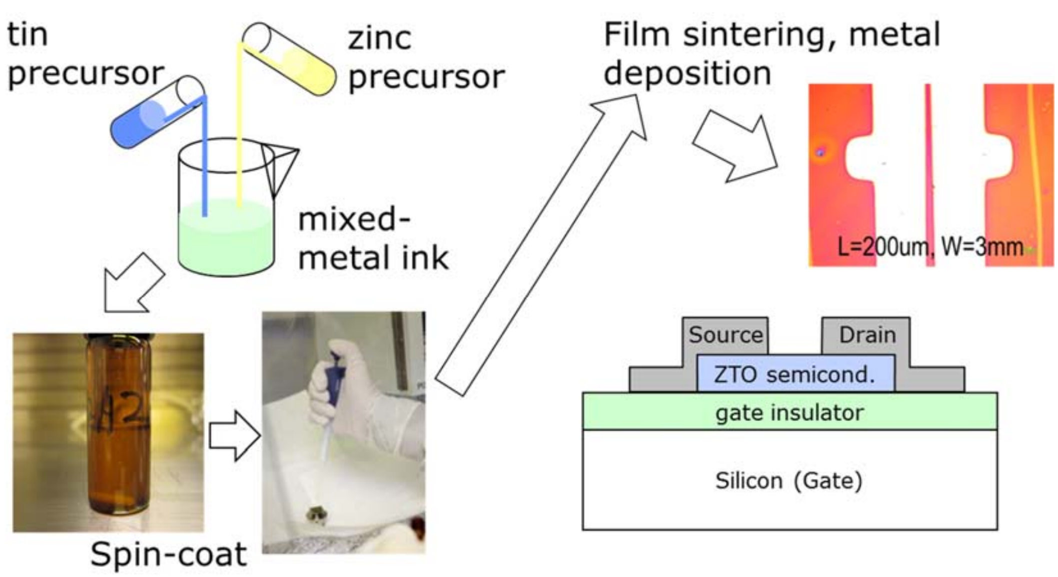

Figure 2. *Schematic of molecular precursor method of sol-gel ink formation followed by thin film multi-layer deposition, sintering, and device processing*

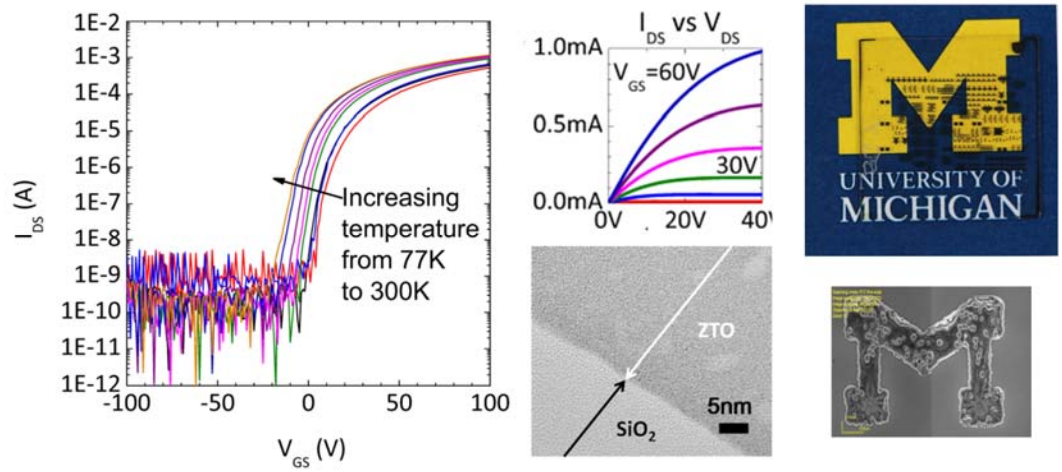

Figure 3. *(clockwise from left): Electrical performance of solution-processed oxide thin film transistors, transfer curves and output curves* [3]*; optical image of transistors on glass, on top of U-M logo; SEM of ink-jet printed oxide film in "M" shape; HRTEM showing amorphous ZTO layer and clean interface to SiO_2* [3]*.*

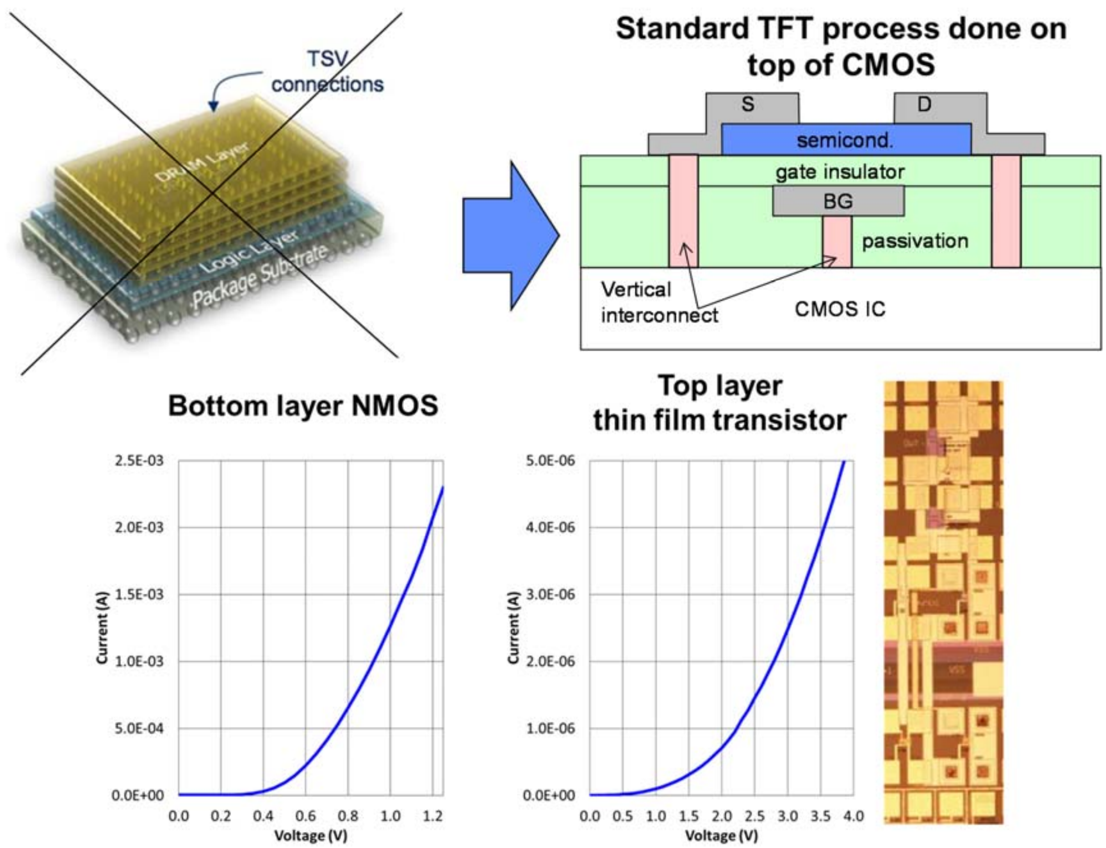

Figure 4. *Preliminary results of direct additive integration of oxide thin film transistors on top of CMOS die. Both transistor layers are functional after thin film transistor fabrication* [7]*.*

Biographical sketch

Becky (R. L.) Peterson received her B.S., M.S. and Ph.D. degrees from University of Rochester, NY, University of Minnesota – Twin Cities, and Princeton University, NJ, respectively, all in electrical engineering.

She was a post-doctoral research at the Cavendish Laboratory Department of Physics and as an Associate Lecturer at Newnham College at Cambridge University, UK, before coming to University of Michigan as an assistant research scientist in 2009. Since 2013 she has been a tenure-track Assistant Professor at the University of Michigan, Ann Arbor in the Electrical Engineering and Computer Science Department. Her research interests include solution-processed inorganic electronic and optoelectronic materials and devices, including thin film power electronics and sensors, and hetero-integration of these devices with CMOS and MEMS microsystems.

Dr. Peterson was the recipient of a DARPA Young Faculty Award in 2014 and an Elizabeth C. Crosby Research Award from the University of Michigan in 2013. She was a co-author of a PowerMEMS Conference Best Student Paper Award and an IMECE MEMS Division Best Paper Award, both in 2012. She was previously the recipient of an NSF Graduate Research Fellowship, an Association of Princeton Graduate Alumni Teaching Award, an American Association of University Women Engineering Fellowship, and an Automatic RF Techniques Group Microwave Measurement Student Fellowship. She has more than 50 publications in peer-reviewed archival conferences and journals, and her work has been supported by the DARPA, the U.S. National Science Foundation, Panasonic Corp. and Samsung. For more information, please visit: http://www.eecs.umich.edu/~blpeters

Electronic analogs of synapses and neurons

Stanley Williams

Abstract tba

Biographical sketch

Stan Williams is a HP Senior Fellow and the Director of the Information & Quantum Systems Lab at HP. He is also currently focused on developing technology that supports the concept of CeNSE: The Central Nervous System for the Earth. The idea is that nanotechnology has the potential to revolutionize human interaction with the Earth as profoundly as the Internet has revolutionized personal and business interaction.

Prompted by his exploration of the fundamental limits of information and computing, Williams recently completed extensive research in nano-electronics and nano-photonics. For the past 30 years, his primary scientific research has been in the areas of solid-state chemistry and physics, and their applications to technology. This has evolved into the areas of nanostructures and chemically-assembled materials, with an emphasis on the thermodynamics of size and shape.

Williams has been awarded more than 60 U.S. patents, published more than 300 papers in reviewed scientific journals and presented hundreds of invited plenary, keynote and named lectures at international scientific, technical and business events.

He has received numerous awards for business, scientific and academic achievement. Most recently he received the prestigious 2007 Glenn T. Seaborg Medal awarded by the UCLA Department of Chemistry and Biochemistry.

He was named to the inaugural Scientific American 50 Top Technology leaders in 2002 and then again in 2005 (the first to be so named twice). In 2005, Small Times magazine named the U.S. patent collection Williams has assembled at HP as the worlds top nanotechnology intellectual property portfolio and in 2000, MIT's Technology Review placed one of his patents among the top 5 that "will transform business and technology."

Williams received a bachelor of arts in chemical physics in 1974 from Rice University and a Ph.D. in physical chemistry from the University of California, Berkeley in 1978. He was a member of technical staff at AT&T Bell Labs from 1978 to 1980 and a faculty member of the Chemistry Department at UCLA from 1980 to 1995.

Memcomputing: computing with collective states of interacting memory processors

Massimiliano Di Ventra

Department of Physics, University of California San Diego, La Jolla, CA 92093-0319 USA

I will discuss a novel computing paradigm we named *memcomputing* [1] inspired by the operation of our own brain which uses memory circuit elements or memelements [2] as the main tools of operation. I will first introduce the notion of *universal memcomputing machines* (UMMs) as a class of general-purpose computing machines based on systems with memory. We have shown [3] that the memory properties of UMMs endow them with *universal computing power* [4]--they are Turing-complete--, *intrinsic parallelism*, *functional polymorphism*, and *information overhead*, namely their collective states can support exponential data compression directly in memory. It is the presence of collective states in UMMs that allows them to solve NP-complete problems in polynomial time using polynomial resources [3]. As an example, I will show the polynomial-time solution of the subset-sum problem implemented in a simple hardware architecture that uses standard microelectronic components [5], and the solution of prime factorization and the subset-sum problem using self-organizable logic gates [6]. This latter architecture is a scalable digital memcomputing machine that can be easily realized with available technology.

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Biographical sketch

Massimiliano Di Ventra obtained his undergraduate degree in Physics *summa cum laude* from the University of Trieste (Italy) in 1991 and did his PhD studies at the Ecole Polytechnique Federale de Lausanne (Switzerland) in 1993-1997.
He has been Visiting Scientist at IBM T.J. Watson Research Center and Research Assistant Professor at Vanderbilt University before joining the Physics Department of Virginia Tech in 2000 as Assistant Professor. He was promoted to Associate Professor in 2003 and moved to the Physics Department of the University of California, San Diego, in 2004 where he was promoted to Full Professor in 2006.

Di Ventra's **research interests** are in the theory of electronic and transport properties of nanoscale systems, non-equilibrium statistical mechanics, DNA sequencing/polymer dynamics in nanopores, and memory effects in nanostructures for applications in unconventional computing and biophysics.
He has been invited to deliver more than 240 talks worldwide on these topics (including 7 plenary/keynote presentations, 7 talks at the March Meeting of the American Physical Society, 5 at the Materials Research Society, 2 at the American Chemical Society, and 1 at the SPIE).
He has been Visiting Professor at the Technical University of Dresden (2015), University Paris-Sud (2015), Technical University of Denmark (2014), Ben-Gurion University (2013), Scuola Normale Superiore di Pisa (2012, 2011), and SISSA, Trieste (2012). He serves on the editorial board of several scientific journals and has won numerous awards and honors, including the NSF Early CAREER Award, the Ralph E. Powe Junior Faculty Enhancement Award, fellowship in the Institute of Physics and the American Physical Society.

Di Ventra has published more than 170 papers in refereed journals (13 of these are listed as ISI Essential Science Indicators highly-cited papers of the period 2003-2013), co-edited the textbook *Introduction to Nanoscale Science and Technology* (Springer, 2004) for undergraduate students, and he is single author of the graduate-level textbook *Electrical Transport in Nanoscale Systems* (Cambridge University Press, 2008).

2D Electronic Chalcogenide Nanomaterials

Judy J. Cha

Mechanical Engineering & Materials Science, Yale University

Two-dimensional (2D) chalcogenides have gained renewed interest due to their interesting electrical properties such as topological surface states in Bi_2Se_3 and hydrogen evolution catalytic activities in MoS_2. Our ability to thin them down to a single layer and their anisotropic bonding nature opens up possibilities for novel heterostructures where we can tailor their electronic properties. I will present one-step heterostructure synthesis method to synthesize these chalcogenide nanostructures and examine their electronic transport properties. I will discuss ways to control the alignment of molecular layers in these 2D chalcogenides, which exploits stress and strain built in the film during the growth. Electron tomography will be used to reconstruct the 3D structure of vertically oriented molecular layers in MoS_2 thin films. Intercalation is an effective knob to tune the electrical and optical properties of the 2D layered chalcogenides by inserting guest species at the van der Waals gap. I will present effects of Cu intercalation into Bi_2Se_3 nanoplates on the optical properties.

In the second part of the talk, I will present synthesis and electronic properties of SnTe nanoplates. SnTe is a topological crystalline insulator whose surface states are spin-polarized and Dirac-dispersive, protected by the crystal symmetry instead of the time reversal symmetry. Although, SnTe is cubic and not a layered material, large SnTe nanoplates expanding hundreds of microns in lateral dimension with ~ 100 nm in thickness are possible by carefully controlling the growth conditions. I will show that doping SnTe nanoplates with In induces superconductivity and the surface states remain intact at these In dopant concentrations via transport measurements. Our results support the hypothesis that In-doped SnTe may be a topological superconductor which can host Majorana fermions.

Lastly, I will discuss surface effects on the transport properties of chalcogenides nanostructures, which are often undesirable and should be avoided. I will use WTe_2 nanoflakes as an example to demonstrate the surface effects.

Biographical sketch

Judy J. Cha is an assistant professor in the Department of Mechanical Engineering and Materials Science at Yale University. Prior to Yale, she was a post-doctoral researcher at Stanford University in the department of Materials Science and Engineering. She received her Ph.D. in Applied Physics from Cornell University, Ithaca, NY in 2009. Notable awards she has received include the IBM Faculty Award (2014), the Presidential Student Award from Microscopy Society of America (2010), and the Graduate Student Silver Award at the Spring Materials Research Society meeting (2008).

Her research focuses on synthesis and transport measurements of two-dimensional chalcogenide nanostructures, in particular topological insulator and topological crystalline insulator nanoribbons and nanoplates. She uses analytical scanning transmission electron microscopy and electron energy-loss spectroscopy to characterize the synthesized nanomaterials in order to correlate the transport properties to their local atomic structures.

Valley pseudospin transport in transition metal dichalcogenide atomic layers

Kin Fai Mak

Department of Physics, Penn State University
University Park, PA 16802 USA; kzm11@psu.edu

Two-dimensional (2D) atomic layers of transition metal dichalcogenides (TMDs) have attracted much recent attention due to their unique electronic properties. In addition to charge and spin, electrons in 2D TMD possess a new valley degree of freedom (DOF) that has finite Berry curvatures. As a result, not only optical control of the valley DOF is allowed, but each valley is also predicted to exhibit an anomalous Hall effect (AHE) whose sign depends on the valley index. In this talk, we will discuss our recent observation of this new valley Hall effect (VHE) in monolayer and bilayer TMD transistors. In monolayer TMD a finite AHE is observed when circularly polarized light is used to preferentially excite electrons into a specific valley. The dependences of the photo-induced anomalous Hall conductivity on photon helicity, photon energy and doping levels agree well with theoretical predictions of VHE in these materials. We have also applied Kerr rotation microscopy to study the edge magnetizations induced by the transverse valley Hall currents in bilayer TMD transistors. A highly gate tunable VHE by inversion symmetry breaking is observed. Our studies open up new opportunities for electrical control of spin and valley pseudospin transport in 2D semiconductor materials.

Biographical sketch

Kin Fai Mak received his PhD in physics from Columbia University at 2010. He was a Kavli postdoctoral fellow at the Kavli Institute at Cornell for Nanoscale Science before joining Pennsylvania State University as an assistant professor in physics. His research focuses on experimental studies of the electronic properties of novel two-dimensional materials with atomic thickness.

From the bulk to the surface in a new topological matter, the Weyl Semimetal

Binghai Yan

Junior group leader, Max-Planck-Institute for Chemical Physics of Solids, Dresden, Germany

Weyl semimetals (WSMs) are topological quantum states wherein the electronic bands linearly disperse around pairs of nodes, the Weyl points, of fixed (left or right) chirality. The recent discovery of WSM materials in (Ta,Nb)(As,P) compounds has triggered an enormous amount of work to explore very exotic properties of those systems. In this talk, I will introduce our recent theoretical and experimental progress, which includes the band structures, the surface Fermi arcs (ARPES), and the magneto-transport that is due to the chiral anomaly effect. I will also present interesting perspectives of their applications in spintronics, valley-tronics and energy storage.

Biographical sketch

Binghai Yan got his PhD in Physics in Tsinghua University, China in 2008. Then he worked as a postdoc in Uni-Bremen with Prof. Thomas Frauenheim and Stanford University with Prof. Shou-Cheng Zhang. Since 2012, he is an independent theory group leader in MPI-CPfS and sometimes dares to organize exciting experiments. He is a materials theoretician who is actively interacting with condensed-matter physicists and solid-state chemists. His current interest focuses on topological quantum materials, e.g. topological insulators and topological semimetals. He is trying to build multi-junctions between different fields that cover condensed-matter physics, high-energy physics, chemistry and materials science, aiming for spintronics, valley-tronics and energy storage applications.

Active 3D DNA Plasmonics

Laura Na Liu

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We utilize structural DNA technology to achieve intelligent plasmonic nanomachines with engineerable optical response and active functionalities. Plasmonic metal particles are assembled at specific locations on an active 3D DNA origami template with nanometer scale accuracy. The plasmonic system constitutes a well-defined 3D configuration with unique optical response. Due to the intrinsic programmability and excellent functionalities of DNA, the plasmonic nanomachine can respond to external stimulus upon recognition of biochemical events or stimulated movements of the DNA template. Any conformational changes of the plasmonic nanomachine will lead to the near-field interaction changes of the metal particles in the 3D assembly and therefore give rise to immediate optical signal changes in the spectrum, providing an active optical response to external stimulus. Due to the native biocompatibility of DNA, this will enable a new generation of 3D plasmon rulers.

Biographical sketch

Laura Na Liu is Professor in the Kirchhoff Institute of Physics at the University of Heidelberg since 2015. She received her Ph. D in Physics from the group of Prof. Harald Giessen at the University of Stuttgart in 2009, working on 3D complex plasmonics at optical frequencies. In 2010, she joined the group of Prof. A. Paul Alivisatos as postdoctoral fellow at the University of California, Berkeley. From 2011 till 2012, she visited the group of Prof. Naomi Halas at Rice University as visiting professor. At the end of 2012, she obtained the Sofja Kovalevskaja Award from the Alexander von Humboldt Foundation and became an independent group leader at the Max-Planck Institute for Intelligent Systems.

The research of Laura Na Liu is multi-disciplinary. She works at the interface between nanoplasmonics, biology, and chemistry. Her group focuses on developing sophisticated and smart plasmonic nanostructures for answering structural biology questions as well as catalytic chemistry questions in local environments. She is an associate editor of Science Advances.

Laura Na Liu got several prestigious awards, including Hertha-Sponer Prize of the Deutsche Physikalische Gesellschaft (DPG) (2010), Nanowissenschaftspreis AGENT-D (2011), Sofja Kovalevskaja Award of the Alexander von Humboldt Foundation (2012), Elisabeth Schiemann-Kolleg of the Max Planck Society Fellowship (2013), Heinz Maier-Leibnitz Prize of the Deutschen Forschungsgemeinschaft Gesellschaft (DFG) (2014), European Research Council (ERC) Starting Grant Award (2014), and Light2015 Young Woman in Photonics Award of the European Optical Society (EOS) (2015).

3D Microstructured Metamaterials

Muamer Kadic[1], Tiemo Buckmann[1], Tobias Frenzel[1], Claudio Findeisen[2], Christian Kern[1], Robert Schittny[1], Peter Gumbsch[3,4] and Martin Wegener [1,4]

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[2] *Institute for Applied Materials, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany*
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[4] *Institute of Nanotechnology, Karlsruhe Institute of Technology (KIT), 76021 Karlsruhe, Germany*

Metamaterials are man-made structures that obtain their unusual (meta=beyond) effective properties from geometrical structure rather than chemistry. While the notion was first used for electromagnetism, mechanical, thermodynamic, and electrical metamaterials are playing an increasing role in current research [1]. Using 3D printing [2], metamaterials offer an opportunity to realize different properties and functionalities by micro-structuring a single material. Here, we will focus on three recent examples: controlling deformations [3], absorbing energy, and changing the sign of the Hall coefficient [4-5].

An elegant way to design functionalities in mechanics is called transformational elastodynamics [6]. It requires that one can design a metamaterial with extremal properties such as pentamode metamaterial (solids behaving as liquids). We have fabricated such metamaterials (see Figure 1a) using 3D Direct Laser Writing (DLW) and have shown that one can use them to build an elasto-mechanical unfeelability cloak [3]. This metamaterial-based cloak makes objects (here a stiff cylinder) different from their surrounding appear just like their surroundings.

Materials absorbing mechanical (shock) energy are all around us. There are usually based on viscoelasticity or plastic (irreversible) deformations. Here, we present a new class of metamaterials (see Figure 1b) which is based on buckling (instabilities) and that behaves as fully reversible (i.e., reusable) mechanical metamaterials. These metamaterials have successfully been fabricated and characterized, showing very good performance.

In 2007, using homogenization theory [4], Briane and Milton have proven the existence of three-dimensional, isotropic, periodic metamaterials with a Hall coefficient that is negative with respect to that of its constituents. We have simplified their design to a simple porous structure made of a single constituent material (see Figure 1c).

We have demonstrated that this sign-inversion can be controllable by a single structure parameter [5]. Corresponding experiments are in progress.

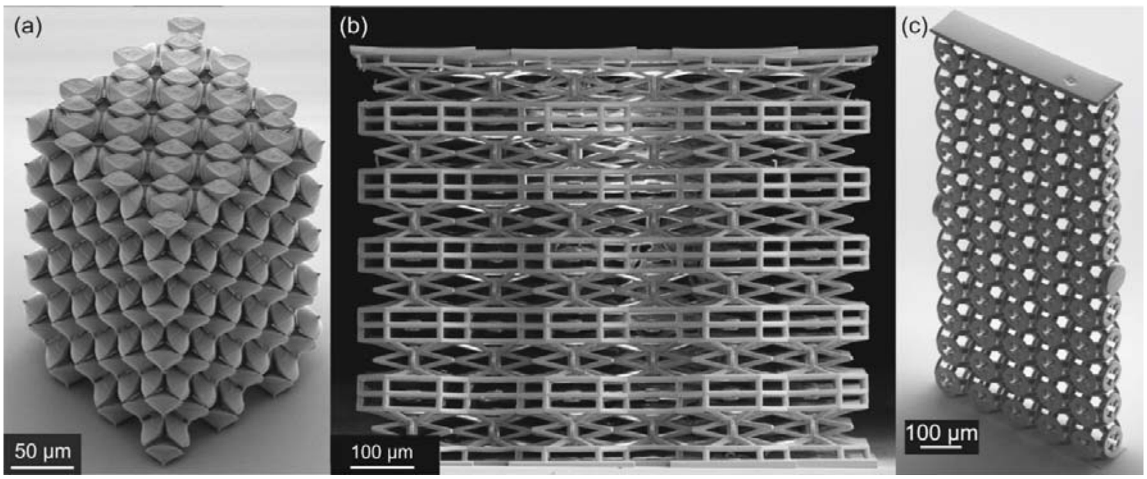

Figure 1: SEM micrographs of pentamode metamaterials (a), buckling metamaterials (b) and Hall-metamaterials(c).

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Biographical sketch

Work Experience

- Postdoctoral research, Applied Physics, Karlsruhe Institute of Technology group of Prof. Martin Wegener.
  Research area: Acoustics, Electromagnetism, Thermal and Mechanical Metamaterials, Finite Element Calculations, Transformational Physics, Magneto-transport.
- PhD (2008-2011), Institut Fresnel, University of Marseille, France
  Research area: Electromagnetism, Plasmonics, Scattering Matrix Calculations, Finite Elements, Cloaking, Lensing, Metamaterial Design.
- Researcher (2006-2008) Trinity College Dublin, Ireland
  Research area: General LASER optics and characterization of metallic nanostructures and quantum dots.
- Internship (2006) MINATECH, CEA
  Research area: Electromagnetic simulation and modeling of the evaluation of interconnect performances.

Education

- 2008-2011, PhD in Physics, Aix-Marseille University, “Metamaterials for surface plasmons”
- 2001-2006, Engineering degree, National Institute of Applied Sciences of Rennes, France
- 2005-2006, Business degree, ESC Rennes School of Business, Rennes, France

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Coherent ultrafast control of solids through optical phononics

Andrea Cavalleri

Condensed Matter Department, Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany

In this talk I will summarise recent work aimed at driving solids between different phases with light. I will focus primarily on experiments that control bond distances and angles at high speeds with mode selective nonlinear excitations of infrared active phonons. Control of superconductivity, TeraHerz Frequency Magnetoelastics and Quantum Plasmonic Phenomena are amongst the new developments I will address.

Biographical sketch

Andrea Cavalleri was trained in Electrical Engineering and in Laser Physics at the Universities of Pavia (Italy) and Essen (Germany). He received a Laurea Degree (Pavia) and his PhD (Pavia) in 1994 and 1998, respectively.

Between 1998 and 2001 he was a Postdoc at UC San Diego, working with the late K.R. Wilson. In the extraordinary setting of the Wilson group, Cavalleri and co-workers performed the first measurements of atomic-structural dynamics in solids with femtosecond x-rays, which they generated from Terawatt-laser produced plasmas. These experiments pioneered the field of ultrafast structural science, and lead to the first direct detection of coherent phonons and structural phase transitions in the solid state.

Between 2001 and 2005, he was at the Lawrence Berkeley National Laboratory, where he started combining nonlinear THz excitation techniques with ultrafast x-ray probes, especially in correlated electron systems. In this effort, he and Bob Schoenlein developed the first scientific applications of sliced pulses of synchrotron radiation. For his work on the photo-induced insulator-metal transitions, Cavalleri was awarded the David Shirley Award for Outstanding Scientific Achievement at LBNL.

In 2004, Cavalleri received the European Young Investigator Award and joined the faculty of the University of Oxford. He was promoted to Professor of Physics in 2006. As a faculty member at the University of Oxford, Cavalleri lead a small group of students and postdocs to investigate light control of quantum materials, culminating in the striking demonstration of light induced superconductivity in the striped cuprates.

In 2008 Andrea Cavalleri was appointed to be the first director of the Max Planck Research Department for Structural Dynamics, a pilot project that in 2013 lead to the foundation of the Max Planck Institute for the Structure and Dynamics of Matter, of which he is currently the managing director.

Amongst recent distinctions, Cavalleri was named a fellow of the American Physical Society in 2011, was the 2012 Angstroem Lecturer at Uppsala University, received a 2013 ERC Synergy grant and was awarded the 2015 Max Born Medal and Prize by the UK institute of Physics and the German Physical Society.

Ultrafast electron microscopy and diffraction using nanoscale photoemitters

Claus Ropers

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Novel methods in time-resolved electron microscopy, diffraction and spectroscopy promise unprecedented insight into the dynamics of structural, electronic and magnetic processes on the nanoscale. A key to the realization of such technologies is the generation of highly coherent ultrashort electron pulses. In this talk, our recent development of imaging and spectroscopy capabilities using localized electron sources [1-3] will be discussed. Specifically, ultrafast low-energy electron diffraction from atomically thin films and surfaces will described [4], and results from the first field-emitter based ultrafast transmission electron microscope (UTEM) will be presented. In particular, the enhanced electron beam properties of this instrument facilitate nanoscale local probing with femtosecond temporal resolution, as demonstrated in the study of quantum-coherent interactions between free electrons and light [5]. Further ongoing investigations with the UTEM involve spatio-temporal dynamics in nanostructured materials, the imaging of optically-induced magnetic structures and work towards radio-frequency electron microscopy and a femtosecond Lorentz microscope.

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Biographical sketch

Claus Ropers studied physics at the University of Göttingen and the University of California at Berkeley. Conducting his doctoral studies at the Max Born Institute (Berlin), he received a PhD from the Humboldt University in Berlin in 2007. At the University of Göttingen, he was appointed Assistant Professor at the Courant Research Centre “Nano-Spectroscopy and X-Ray Imaging” (2008), Associate Professor at the Institute of Materials Physics (2011), and Full Professor for Experimental Solid State Physics at the 4th Physical Institute (2013). Focusing on ultrafast processes in nanostructures and at surfaces, his group develops novel experimental tools for the study of ultrafast structural and electronic dynamics, including ultrafast electron microscopy and diffraction. He was awarded the Carl-Ramsauer Prize, Nanoscience Prize (AGeNT-D) and Walter-Schottky Prize, and received an ERC Starting Grant (2014).

Controlled Phase Transition for Next Generation Computing

Sayeef Salahuddin

Associate Professor, Electrical Engineering and Computer Sciences,
University of California, Berkeley

Phase transition materials have long been investigated for fundamental physics and also for potential application in electronics. In this presentation, I shall discuss how a controlled phase transition can lead to fundamentally new switching devices that has significantly less energy dissipation compared to the state of the art. In particular, I shall talk about the state of negative capacitance that can be achieved in certain material systems with stored energy of phase transition. Our recent experiments with ferroelectric materials have shown that such a state of negative capacitance can actually be achieved. I shall also describe our very recent results where such negative capacitance, when combined with conventional transistors, lead to effects that was long believed to be impossible. Finally, I shall discuss how these effects can usher in a new era of energy efficient electronics.

Biographical sketch

Sayeef Salahuddin is an associate professor of Electrical Engineering and Computer Sciences at the University of California, Berkeley. His research interests are in the interdisciplinary field of electronic transport in nanostructures currently focusing on novel electronic and spintronic devices for low power logic and memory applications. Salahuddin received a number of awards including the NSF CAREER award, the IEEE Nanotechnology Early Career Award, the Young Investigator Awards from the AFOSR and the ARO and best paper awards from IEEE Transactions on VLSI Systems and from the VLSI-TSA conference. He is on the editorial board of IEEE Electron Devices Letters and currently chairs the Electron Devices Society committee on Nanotechnology.

http://www.eecs.berkeley.edu/Faculty/Homepages/salahuddin.html

Communicating on a Shoestring: How Fireflies and Flexible Hardware Can Enable IoT

Alyssa Apsel

Associate Professor Department of Electrical and Computer Engineering
Cornell University Ithaca, NY

Over the past decades the world has become increasingly connected, with communications driving both markets and social movements. Low power electronics, efficient communications, and better battery technology have all contributed to this revolution, but the cost and power required for these systems must be pushed further to make cheap, ubiquitous, seamless communication accessible to a wider community. In this talk I will discuss two engineering approaches to this problem. I will look at various approaches to drive the power down in radio networks that span across circuits and systems. I will also look at creative biologically inspired approaches to enabling very low power networks and IoT.

Finally, I will discuss how by adding flexibility and building reconfigurable hardware, we can likewise build lower power and less costly consumer systems that can adapt across protocols and networks and work under changing device technologies.

Biographical sketch

Alyssa Apsel received the B.S. from Swarthmore College in 1995 and the Ph.D. from Johns Hopkins University, Baltimore, MD, in 2002. She joined Cornell University in 2002, where she is currently an Associate Professor of Electrical and Computer Engineering. The focus of her research is on power-aware mixed signal circuits and design for highly scaled CMOS and modern electronic systems. She has authored or coauthored over 90 refereed publications in related fields of RF mixed signal circuit design, ultra-low power radio, interconnect design and planning, photonic integration, and process invariant circuit design techniques resulting in eight patents and several pending patent applications. She received best paper awards at ASYNC 2006 and IEEE SiRF 2012, had a MICRO “Top Picks” paper in 2006, received a college teaching award in 2007, received the National Science Foundation CAREER Award in 2004, and was selected by Technology Review Magazine as one of the Top Young Innovators in 2004.

She has also served as an Associate Editor of various journals including IEEE Transactions on Circuits and Systems I and II, as the chair of the Analog and Signal Processing Technical committee of ISCAS 2011, as Deputy Editor in Chief of Circuits and Systems Magazine, and on the Board of Governors of IEEE CAS.

Connectomics

Moritz Helmstaedter

Director at the Max Planck Institute for Brain Research, Frankfurt, Germany

Brains are highly interconnected networks of millions to billions of neurons. For a century, we have not been able to map these connectivity networks. Only recently, using novel electron microscopy techniques and machine-learning based data analysis, the mapping of neuronal networks has become possible at a larger scale. This new field of connectomics is still limited by technology and requires next- generation human-machine interaction for data analysis, but it is already starting to provide exciting insights into how neuronal circuits operate in the brain. Our goal is to make connectomics a high- throughput screening technique for neuroscience, to use connectomes for discovering brain-implemented algorithms, which may inspire novel machine learning, to map the imprints of sensory experience onto neuronal networks in the brain, and to investigate connectome alterations in models of psychiatric disease.

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Biographical sketch

Moritz Helmstaedter is one of the pioneers of connectomics, a research field aiming at mapping communication maps of nerve cells at high throughput. His ambition is to unravel the brain's computational algorithms, measure the imprints of experience in neuronal circuits, and search for connectome alterations in models of psychiatric disease.

Biomimetic Neural Network for the new neuromorphic roadmap

Timothée Levi

University of Bordeaux, 33400 Talence, France

Millions of people worldwide are affected by neurological disorders which disrupt connections between brain and body causing paralysis or affect cognitive capabilities. Such a number is likely to increase in the next years and current assistive technology is still limited. Since last decades Brain-Machine Interfaces (BMIs) and generally neuroprosthesis have been object of extensive research and may represent a valid treatment for such disabilities. The realization of such prostheses implies that we know how to interact with neuronal cell assemblies, taking into account the intrinsic spontaneous activity of neuronal networks and understanding how to drive them into a desired state or to produce a specific behavior. The long-term goal of replacing damaged brain areas with artificial devices also requires the development of Spiking Neural Network (SNN) system. They will fit with the recorded electrophysiological patterns and will produce in their turn the correct stimulation patterns for the brain so as to recover the desired function. Our study describes the development of neuromorphic devices containing biomimetic neural networks.

Two designs are described, one using digital silicon neurons, and the other using microfluidic neurons, which is a new way to explore in neuromorphic engineering.

Firstly, the digital SNN, we will describe, implements biologically realistic neural network models, spanning from the electrophysiological properties of one single neuron up to network plasticity rules. This digital implementation computes in real-time biologically realistic cortical Izhikevich neurons and it requires few resources. The interneuron connections are composed of biomimetic synapses and synaptic plasticity. It is freely configurable from an independent-neuron configuration to different neural network configurations. This SNN will be used for the development of a neuromorphic chip for neuroprosthesis, which has to replace or mimic the functionality of a damaged part of the central nervous system.

Secondly, a new approach which is not yet in sthe state of the art is the design of biomimetic artificial neuron using microfluidic techniques. This microfluidic device is able to mimic the electrical activity of one biological neuron.

Usually these artificial neurons are made in Silicon but this device could replace the electronic one and solve most of the issues of biocompatibility.

This microfluidic device is composed of two chambers for intra and extra-cellular modelling, different PDMS channels, selective permeable membrane for positive ionic exchange, quake valves and electrodes for recording the membrane potential. We obtain an electrical membrane potential similar to the biological neuron.

Biographical sketch

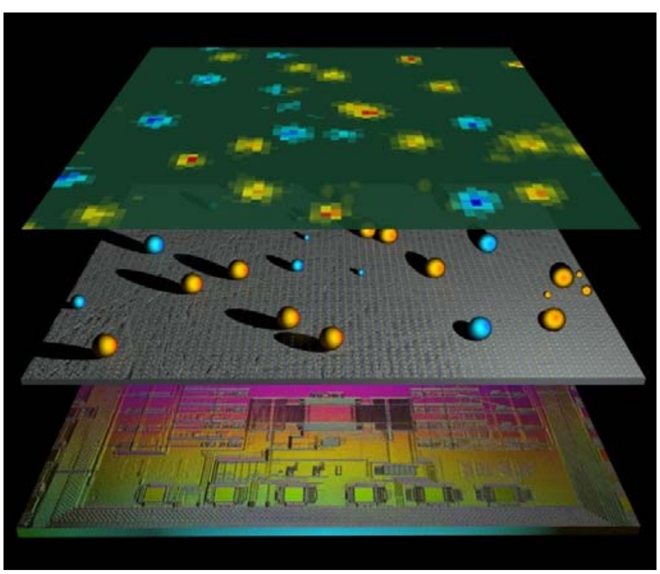
Timothée Levi received the Ph.D degree in Electronics at Univ. of Bordeaux in 2007. From January 2008 to October 2008, he was post-doc fellow at CEA-LETI in France. From October 2008 to October 2009, he was a JSPS Post-doc fellow at the University of Tokyo, Japan. From October 2009 to today, he his an Associate Professor at IMS lab., Univ. Of Bordeaux, France. During this period, from September 2013 to August 2015, he was a Visiting Research Fellow at University of Tokyo, Japan. He has published more than 12 papers in reputed journals, 5 book chapters, one patent and 42 international conferences and has been serving as an guest editors of Frontiers of Neuroscience, NOLTA and AROB Journal. He was PI of the European FET Project Brainbow.

All-electrical (bio)sensing with CMOS nanocapacitor arrays: from nanoparticles to living cells

Serge G. Lemay

MESA+ Institute for Nanotechnology, University of Twente, the Netherlands

Massively parallel sensing platforms for environmental monitoring and point-of-care medical diagnostics can in principle be realized by combining all-electrical signal transduction with low-cost integrated circuits. Despite notable successes, however, bioelectronics has so far failed to deliver a broadly applicable platform. This is in no small part because the mobile ions present in biologically relevant solutions largely suppress electrostatic interactions. Here we overcome this difficulty by performing high-frequency (50 MHz) impedance spectroscopy at a high-density array of nanoelectrodes, effectively outrunning ionic screening. As proofs of concept we detect in real time and at submicron resolution a wide range of synthetic and biological micro- and nanoscale entities including plant virus (CCMV) particles as well as BEAS, THP1 and MCF7 cancer cell lines. This is only possible by integrating the nanoelectrode array directly with CMOS electronics on a single chip so as to keep stray capacitance to a minimum. Our approach thus takes simultaneous advantage of three strengths of integrated circuits: miniaturization, high frequency operation and large-scale integration. This work is a close collaboration with NXP Semiconductors.



Bottom: Optical image of a CMOS chip incorporating an array of ~65,000 nanoelectrodes (pink rectangle in the center) as well as the accompanying readout, memory and communication circuitry.

Middle: AFM image of part of the nanoelectrode array. Each dot corresponds to an independently addressable electrode modulated at 50 MHz. The colored microspheres are an artist's rendition.

Top: Two-dimensional map of the capacitive response of the electrodes upon sedimentation of dielectric (blue) and conducting (yellow) microspheres. This demonstrates the ability to distinguish between analytes based on their electrical properties.

Ref.: *C. Laborde, F. Pittino, H. A. Verhoeven, S. G. Lemay, L. Selmi, M. A. Jongsma and F. P. Widdershoven, Nature Nanotechnology, published online 03 August 2015, doi:10.1038/nnano.2015.163*

Biographical sketch

Serge G. Lemay was born in Rimouski, Québec, Canada, in 1970. He received the Bachelor degree in Electrical Engineering with minor in physics from the University of Waterloo, Canada, in 1993, during which he specialized in semiconductor device physics, and the Ph.D. in Physics at Cornell University, USA, in 1999, where his research focused on low-temperature electronic transport and synchrotron measurements on quasi-one-dimensional metals. He then joined the section Quantum Transport at Delft University of Technology as a postdoc to study transport in single-walled carbon nanotubes using scanning tunneling microscopy (STM). In 2001 he became a faculty member in the section Molecular Biophysics at the Kavli Institute of Nanoscience at Delft, where he received a full chair in Nanotechnological Biophysics in 2008. During this time his research turned toward electrostatics in liquids, electrochemistry, biophysics and the signal transduction problem in bioelectronics. In 2010 he founded a new chair on Nanoionics at the MESA+ Institute for Nanotechnology, University of Twente; this three-PI group pursues research on, among others, electrochemical nanofluidics, fluidic-enabled scanning probes and high-frequency integrated biosensors. He has received several career awards including Vidi (2002) and Vici (2007) grants from the Netherlands Organization for Scientific Research (NWO) and a Consolidator Grant (2011) from the European Research Council (ERC). He is director of the program “Beyond Moore – Nano-Bio Interfaces and Devices,” part of the Dutch network NanoNextNL funding collaborative research between academia and industry.

Nano Materials for Neuro Technology

Yael Hanein

[1]*School of Electrical Engineering, Tel-Aviv University, Israel*
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Novel materials offer new opportunities in the realization of neural interfaces. Nano materials in particular can offer advantage in improve electrode impedance, in reducing device rigidity, in establishing photo sensitivity and more. The first such device we developed is a new flexible neuronal micro electrode array, based entirely on carbon nanotube technology, where both the conducting traces and the stimulating electrodes consist of conducting carbon nanotube films embedded in a polymeric support. The use of carbon nanotubes bestows the electrodes flexibility, and excellent electro-chemical properties. We also demonstrated that carbon nanotube electrodes can be further modified with quantum dots converting them to bio-mimetic, photo-sensitive pixels. Such photo-sensitive pixels are ideal for artificial retina applications. More recently, we have also explored the use of the carbon electrodes for skin applications, demonstrating unique performances allowing long term high fidelity recording.

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Biographical sketch

Yael Hanein is a Professor of Electrical Engineering at Tel Aviv University. In the past she conducted research at the Weizmann Institute (MSc and PhD in Physics), Princeton University (visiting student at the lab of Nobel Prize Laureate Prof. Dan Tsui), and at the University of

Washington (Postdoc in Electrical Engineering and Physics). Her research field is neuro-engineering and her main passions are developing wearable electronic technology and bionic vision.

Her research group has pioneered the use of nanomaterials for neuro applications and in 2012 she received a prestigious personal grant from the European Research Council (ERC) to study nanomaterials for neuro stimulation applications. Prof. Hanein has co-authored over 55 scientific publications, and delivered numerous scientific talks worldwide and many popular presentations at schools, bars, and kindergartens, as well as at high profile events such as Science Foo Camp, the World Economic Forum meetings, Falling Walls in Berlin, and Solve for X (organized by Google-X).

Her academic activity has received extensive media attention. In 2006 she was named in the list of the 40 most promising Israelis under 40 (The Marker), in 2012 she was included in the list of the 50 most influential women in Israel (Lady Globes), and in 2013 she was included in the list of the most innovative people in Israel (The Marker).

In 2009 she joined an international group of young researchers who founded the Global Young Academy and served on its first executive committee. In 2012 she was appointed to the Israel Young Academy by the Israel Academy and served for two years as the first head of its executive committee.

Prof. Hanein has extensive connections with the industry, conducting sponsored research and joint projects. In 2009 she joined Rainbow Medical to help establish NanoRetina, a startup company developing artificial vision (based on NR proprietary IP).

She is the co-founder of Tel Aviv University Micro and Nano Central Facilities (MNCF). In this capacity she led a ten-year effort, transforming MNCF into an industry-compatible prototyping fab with eight full-time highly trained employees, over 40 industrial users, and over 2.5 million NIS in annual revenue from academic and industrial users. Since 2012 she has been the head of Tel Aviv University Center for Nanoscience and Nanotechnology, steering Tel Aviv University activities in Nanoscience and Nanotechnlogy.

In 2013 she embarked on a new endeavor, co-directing XIN. XIN is a joint research center of Tel Aviv University and the elite Chinese university, Tsinghua, in Beijing. XIN focuses on young researchers and is supporting outstanding research projects geared towards innovation that benefits society. XIN's first effort is to develop Things for the Internet of Things.

For more see:

http://nano.tau.ac.il/hanein/index.php/group/people/8-projects/26-yael-hanein

Sensory processing in zebrafish brain

Emre Yaksi

Kavli Institute for systems neuroscience, Center for Neural Computation
The Faculty of Medicine, NTNU; Olav Kyrres gate 9; Postboks 8905;
7030 Trondheim, NORWAY

Our laboratory is mixture of enthusiastic life scientist, physicists and engineers, whose goal is to understand the fundamental principles underlying the function of brain circuits in health and disease. In order to achieve this aim, we use genetically tractable small model organisms, zebrafish and fruitfly. We monitor, dissect and perturb these tiny brains, through a combination of functional imaging, optogenetics, electrophysiological recordings, molecular genetics and quantitative behavioral assays.

Our primary goal is to understand how chemosensory world (smell and taste) is represented in the brain and how these computations regulate different behaviorals (e.g. fear, arousal, feeding). Moreover, we are interested in understanding how these representations are modulated by behavioral states of animals (e.g, stress and hunger) or other senses (e.g. vision). We achieve this by focusing on those brain areas that integrate information from multiple sensory modalities and closely relate to behavior. Small and accessible brain of zebrafish provides an exceptional framework for studying the neural circuit computations both locally and across multiple brain regions simultaneously.

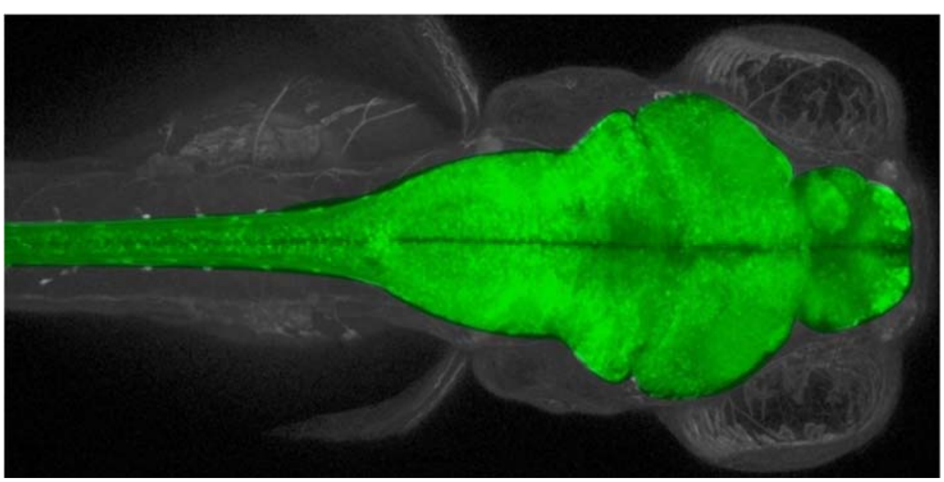
In my seminar, I will discuss about how internal states of brain networks can generate ongoing spontaneous neural activity and how this ongoing brain activity can influence the representations of sensory information in the brain. Our findings suggest that a small evolutionary conserved brain region, habenula, sits in the middle of this complex network, acting very much like a hub. We showed that habenula operates like a switchboard and can use ongoing brain activity to gate and relay information from multiple brain regions to downstream brainstem nuclei that regulate animal behavior.

5 selected publications from the Yaksi lab (our lab members are in bold):

- Christiaens JF† **Franco LM†**, Cools T, De Meester L, Michiels J, Wenseleers T, Hassan BA, **YaksiE*** and Verstrepen KJ,* (2014) The fungal aroma gene ATF1 promotes dispersal of yeast cells through insect vectors. *Accepted in Cell Reports*.† Equal Contributions,* co-last corresponding authors
- **Jetti SK, Llopis NV, Yaksi E**, (2014)Spontaneous activity governs olfactory representations in spatially organized habenular microcircuits, Current Biology, 24, 1–6, February 17
- **Dreosti E, Llopis NV, Yaksi E*** and Wilson S*, (2014) Left-right asymmetry is required for the habenulae to respond to both visual and olfactory stimuli, Current Biology, 24, 1–6, February 17. * co-last corresponding authors
- Yaksi, E. & Wilson, R.I. (2010) Electrical coupling between olfactory glomeruli. Neuron 67: 1034-47
- Yaksi, E., and Friedrich, R. (2006). Reconstruction of firing rate changes across neuronal populations by temporally deconvolved Ca2+ imaging. Nature Methods 3: 377-83.

Biographical sketch

Dr. Emre Yaksi is an associate professor at the Kavli Institute for Systems Neuroscience (NTNU) since January 2015. Dr. Yaksi was born on 1978, in Turkey. He received his B.Sc. (2001) in Molecular Biology at Middle East Technical University, Ankara-Turkey. He obtained his PhD (2007) at Max Planck Institute for Medical Research, Heidelberg-Germany. He worked as a post-doctoral fellow (2007-2010) at Harvard University, Boston-USA. From 2010-2014, he was an assistant professor at the Catholic University of Leuven and a group leader at Neuroelectronic Research Flanders, Belgium.



Silicon Retina Technology

Tobi Delbruck

Institut of Neuroinformatics, UZH-ETH Zurich, Switzerland
http://www.ini.uzh.ch/~tobi

This talk will be about the history and development of asynchronous “silicon retina” vision sensors that offer a spike event output like biological retinas. These neuromorphic sensors offer unique advantages for real-world vision problems in terms of latency, dynamic range, temporal resolution, and post-processing cost. The talk will include live demonstrations of a sensor.

URL: http://sensors.ini.uzh.ch.

Biographical sketch

Tobi Delbruck (IEEE M’99–SM’06–F’13) received a Ph.D. degree from Caltech in 1993. Currently, he is a Professor of Physics and Electrical Engineering at ETH Zurich in the Institute of Neuroinformatics, University of Zurich and ETH Zurich, Switzerland, where he has been since 1998. His group focuses on neuromorphic sensors and processing. He has co-organized the Telluride Neuromorphic Cognition Engineering summer workshop and the live demonstration sessions at ISCAS and NIPS. Delbruck is past Chair of the IEEE CAS Sensory Systems Technical Committee and current Secretary of the IEEE Swiss CAS/ED Society. He has been awarded 9 IEEE awards.

Revisiting Spin Transistors

Supriyo Datta

Purdue University

There has been enormous progress in the last two decades, effectively combining spintronics and magnetics into a powerful force that is shaping the field of memory devices, while new materials and phenomena continue to be discovered at an impressive rate, providing an ever-increasing toolbox. Our objective is to explore different ways to exploit this versatile toolbox to devices, not only for standard deterministic logic, but also for brain-inspired probabilistic logic.

I will first discuss the key properties of transistors, namely input-output isolation and gain that allow them to be interconnected in large numbers to construct large scale circuits. We will then look at examples of how diverse phenomena in modern spintronics and nanomagnetics can be integrated to design transistor-like devices to provide the building blocks for implementing both Boolean and non-Boolean logic functions, along with their relative merits and drawbacks compared to the semiconductor devices in use today.

Biographical sketch

Supriyo Datta started his career in the field of ultrasonics, but since 1985 he has focused on current flow in nanoscale electronic devices. The approach pioneered by his group for the description of quantum transport, combining the non-equilibrium Green function (NEGF) formalism of many-body physics with the Landauer formalism from mesoscopic physics, has been widely adopted in the field of nanoelectronics. This is described in his books Electronic Transport in Mesoscopic Systems (Cambridge 1995) and Quantum Transport: Atom to Transistor (Cambridge 2005) and he was elected to the US National Academy of Engineering (NAE) for this work. Datta is also well-known for his contributions to spin electronics and molecular electronics and was selected by Sigma Xi for the Procter Prize, https://www.sigmaxi.org/programs/prizes-awards/william-procter/

In his latest book

Lessons from Nanoelectronics: A New Perspective on Transport (World Scientific 2012)

Datta has argued that the insights gained from nanoelectronics provide a new approach to the problems of non-equilibrium statistical mechanics of broader relevance. This is the basis for the two-part online course he teaches on edX: see https://nanohub.org/groups/u

Quasiparticle-mediated spin Hall effect in a superconductor

T. Wakamura[1,7], H. Akaike[2], Y. Omori[1], Y. Niimi[1], S. Takahashi[3], A. Fujimaki[2], S. Maekawa[4,5] and Y. Otani[1,6]

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[2]*Department of Quantum Engineering, Nagoya University, 464-8603 Nagoya, Japan*
[3]*Institute for Materials Research, Tohoku University, 980-8577 Sendai, Japan*
[4]*CREST, Japan Science and Technology, 102-0075 Tokyo, Japan*
[5]*Advanced Science Research Center, Japan Atomic Energy Agency, 319-1195 Tokai, Japan*
[6]*RIKEN-CEMS, 2-1 Hirosawa, 351-0198 Wako, Japan*
[7]*Laboratoire de Physique des Solides, Université Paris-Sud, 91400 Orsay, France*

Superconductivity often brings novel phenomena to spintronics. According to theoretical predictions, superconductivity may enhance the spin Hall effect (SHE) due to the increase in the resistance of superconducting quasiparticles which mediate spin transport in superconductors. However, there have been no experimental reports of the SHE in superconductors so far.

In this work, we show a first experimental observation of quasiparticle-mediated SHE in a superconducting NbN, which exhibits an enormous enhancement below the superconducting critical temperature (T_C = 10 K). We fabricated a lateral device structure composed of Py (NiFe) and NbN wires bridged by a nonmagnetic Cu wire. A pure spin current is generated in the Cu bridge by a spin injection current (I) between the Py and the Cu, and absorbed into the NbN wire. The absorbed spin currents are converted into charge currents via the inverse SHE, thereby generating the inverse SH voltage (V_{ISHE}). When NbN is in the normal state at 20 K (>T_C), inverse SH signals ΔR_{ISHE} ($R_{ISHE} \equiv V_{ISHE}/I$) are independent of I. However, at 3 K (<T_C), as I decreases ΔR_{ISHE} dramatically increases, and when I = 0.01 mA, the signal becomes more than 2000 times greater than that in the normal state as shown in Fig. 1. Our experimental demonstration of large enhancement of the SHE in a superconductor shows a great potentiality of superconductors for spintronics and its future applications [1].

[1] T. Wakamura *et al*, Nature Materials **14**, 675 (2015).

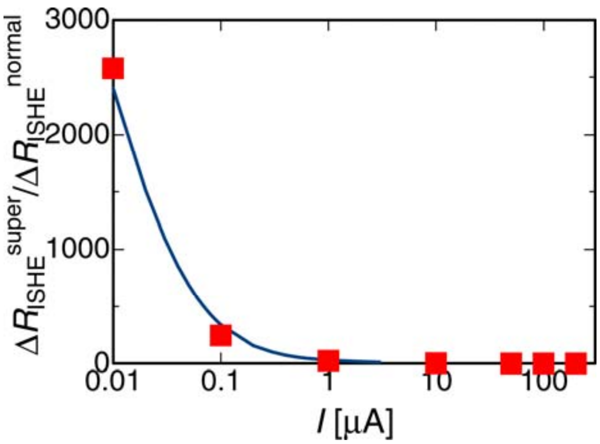

Fig. 1: DR_{ISHE} in the superconducting state (D$R_{\mathrm{ISHE}}^{\mathrm{super}}$) as a function of I.

Biographical sketch

Taro Wakamura is a Japanese experimental physicist now working at the University Paris-Sud as a Marie-Curie Fellow. Starting his research carrier at the University of Tokyo with Professor Harold. Y. Hwang in 2009, he proceeded to work on spintronics in Professor YoshiChika Otani's group in the University of Tokyo for his PhD study from 2010 to 2015. His studies are especially on spin transports in superconductors, and he has demonstrated distinctive properties of superconductors for spintronics including enhanced spin relaxation time and gigantic spin Hall effect. Moving to Orsay in June 2015, his current interests are not only in spintronics but also in spin-related mesoscopic phenomena such as spin-orbit interaction and magnetism in two-dimensional materials.

Magnon-Polaritons in Microwave cavities

Yunshan Cao[1]

[1] Kavli Institute of NanoScience, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands

Recent experiments report the strong coupling of microwaves to the magnetic insulator yttrium iron garnet (YIG) with weakly damped magnetization dynamics [1]. We developed a scattering approach to study the coupled magnetization and microwave cavities beyond the paramagnetic/macrospin and rotating wave approximations that are implicit in the so-called Tavis-Cummings model [2]. To this end we solve the coupled Landau-Lifshitz-Gilbert (LLG) and Maxwell's equations for a thin film magnet in a microwave cavity, leading to rich characteristic phenomena like strong coupling, Purcell effect and magnetically induced transparency (MIT) in spectra of the transmitted or absorbed microwaves. Our method is valid for the full parameter range spanning the weak to strong coupling limits. We demonstrate strong coupling achievement not only for the main FMR mode but also for standing spin waves, although the lowest excitation has a decisive leading role for coupling strength. Spin pumping in FI|N bilayers as detected by inverse spin Hall voltages provides additional access to study strong coupling electrically. We also apply the formalism for a sphere YIG in a spherical microwave cavity. Strong and ultra-strong coupling can be realized for an isolated YIG spheres with itself acting as an efficient microwave antenna.

[1] H. Huebl et al., Phys. Rev. Lett. 111, 127003 (2013); G. Stenning et al., Opt. Express 21, 1456 (2013);Y. Tabuchi et al., Phys. Rev. Lett. 113, 083603 (2014); X. Zhang et al., Phys. Rev. Lett. 113, 156401 (2014).

[2] J. M. Fink et al., Phys. Rev. Lett. 103, 083601 (2009).

Biographical sketch

Yunshan Cao received the Bachelor degree in physics from Beijing Normal University in 2007, and the Ph.D. degree in theoretical physics from Peking University in 2012. From November 2012 on, she works with Gerrit Bauer as a postdoc in the Kavli Institute of NanoScience at the Delft University of Technology, the Netherlands. Her current research interest mainly includes: spintronics, magnetization dynamics, and cavity-QED.

Fuel cells for clean energy: designing new materials for higher efficiencies

Aimy Bazylak

Thermofluids for Energy and Advanced Materials (TEAM) Laboratory, Department of Mechanical & Industrial Engineering, Faculty of Applied Science & Engineering, University of Toronto, Toronto, Canada

The hydrogen polymer electrolyte membrane (PEM) fuel cell provides enormous potential for a clean energy infrastructure. However, due to cost and inefficiency barriers, low temperature PEM fuel cells have not yet reached widespread commercial adoption. Mass transport limitations such as liquid water flooding and high oxygen diffusion resistance to the catalyst sites still lead to inefficiencies. If these issues become resolved, smaller and more reliable fuel cells could be produced at a lower cost. Fortunately, liquid water does not exist in high temperature PEM fuel cells, so the liquid water flooding issue that plagues low temperature PEM fuel cells is essentially eliminated. However, there are other mass transport limitations that inhibit high temperature PEM fuel cells, such as membrane leaching into the surrounding porous materials. In this talk, Prof. Bazylak will discuss her activities in studying transport phenomena and material design and characterization of PEM fuel cell porous materials. In particular, she will discuss her current activities in low temperature PEM fuel cells as well as her new collaborative work with Dr. Roswitha Zeis for advancing high temperature PEM fuel cell technologies.

Biographical sketch

Prof. Aimy Bazylak is an Associate Professor in Mechanical & Industrial Engineering at the University of Toronto. She is the Tier II Canada Research Chair in Thermofluidics for Clean Energy and the Director of the University of Toronto Institute for Sustainable Energy (ISE). In 2008, she received the inaugural Bullitt Environmental Fellowship for leadership in the environmental field. She was awarded the I.W. Smith Award for Outstanding achievement in creative mechanical engineering within 10 years of graduation (2011) and the Ontario Ministry of Research and Innovation Early Researcher Award (2012).

She is the Director of the Thermofluids for Energy and Advanced Materials (TEAM) Laboratory, where she leads a group of 14 graduate students and postdoctoral fellows working in PEM fuel cells, PEM electrolyzers, and subsurface geology. In 2014 she became a Fellow of the Canadian Society for Mechanical Engineering and was most recently awarded an Alexander von Humboldt Fellowship for Experienced Researchers (Germany).