A Magnetic Moment: Prospects for MRAM Technology, Markets and Applications

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About the Authors

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David holds a B.S. in Physics from Truman State University, B.S.E.E. from University of Missouri-Rolla, and M.B.A. in Technology Management from the University of Phoenix.

Hai (Helen) Li is Assistant Professor of the ECE Department at University of Pittsburgh. She received her B. S. and M. S. degrees from Tsinghua University, China and her Ph.D. degree in 2004 from Purdue University. Prior to joining Pitt, Helen worked for Qualcomm Inc., Intel Corp., and Seagate Technology and started her academia career with Polytechnic Institute of New York University. She has extensive industry experience in STT-MRAM circuit-level optimization and design. Her current research focuses on emerging memory technologies, architecture/circuit/device co-design, emerging memory design, neuromorphic hardware, and 3D integration technology and design.

Helen has published more than 80+ technical papers in refereed journals and conferences, filed 69 U.S. patents (54 granted) and one Seagate Trade Secret. Her new book "*Non-volatile Memory Design: Magnetic, Resistive, and Phase Change*" was published with CRC Press in 2011. She also authored five book chapters in the related area. Helen received two best paper awards and three best paper nominations from ISQED, ISLPED, DATE, and ASPDAC. She has served as technical program committee of more than 20 international conference series, been the reviewer for numerous journals and conferences and is the recipient of the NSF Career Award.

Thomas Mikolajick is Head of the Chair for Nanoelectronic Materials and Scientific Director at NaMLab GmbH. He is also Head of the VDE/VDI-Society Microelectronics, Microsystems and Precision Engineering (GMM) working group "materials for non-volatile memories" and coordinator of the Cool Silicon Cluster http://www.cool-silicon.de/. Previously, he was the Head of the Institute for Electronic- and Sensor Materials at TU Bergakademie Freiberg (2006-2009) and lead the new memory technologies (2000-2003) and flash memory pre-development (2003-2006) at Infineon .

Thomas is the author and co-author of about 100 scientific publications and he is inventor or co-inventor in about 170 patents. He received his Ph.D. in Electrical Engineering from the FAU Erlangen-Nuremberg, Germany in the year 1997 and his diploma I electrical engineering also from the FAU Erlangen-Nuremberg in the year 1990.

Stefan Slesazeck is a Senior Scientist at NaMLab GmbH responsible for concept evaluation, hardware development, electrical characterization and modelling of memories. Prior to NaMLab, he was a project leader for the pre-development of new memory concepts with Qimonda Dresden (Germany) focusing on concept evaluation for 1T – DRAM including floating body devices, cell concepts, access schemes for WL-driver and sense amplifier. As a device engineer at Infineon Technologies, Stefan focused on the module development of 3D DRAM access devices in 65nm and 46nm buried word line technology and pre-development of 3D DRAM access devices for FinFET and EUD.

Stefan received his Ph.D. in microelectronics from the Dresden University of Technology, Germany in the year 2004.

Gregory Wong is the Founder and Principal Analyst at Forward Insights, a market and technical intelligence company focusing on semiconductor memories, emerging memory technologies and solid state storage.

He has in-depth knowledge of the technology, cost, performance, competitive landscape, and markets and applications of multi-bit per cell NOR, NROM, NAND flash memories, emerging memories and solid state drives. Greg has authored numerous reports on flash and emerging memories and solid state storage and was a contributor to *Inside NAND Flash Memories* and *Inside Solid State Drives*.

Greg previously held a number of management positions in strategic planning, business development and engineering at Hitachi, Siemens, ProMOS and Qimonda/Infineon. At Qimonda/Infineon, Greg was responsible for competitive intelligence and reverse engineering for flash memories. This encompassed analyzing and evaluating flash memory vendors' strategies, technologies, design architectures, product performance, manufacturing capabilities and costs. Greg worked closely with senior management on strategy formulation and setting operational performance targets. Greg has worked in Canada, Japan, China, Taiwan and Germany.

Greg earned his B.A.Sc. degree in Electrical Engineering from the University of Toronto, and his M.B.A. degree from the Richard Ivey School of Business in London, Ontario.

About Forward Insights

Forward Insights provides independent, insightful market research, consulting and information services focusing on semiconductor memories and solid state storage. The company offers unparalleled depth and understanding of the strategic, market and technical complexities of the semiconductor memory landscape.

Services

Forward Insights offers a unique and comprehensive strategic, financial, market and technical perspective on the semiconductor memory industry. The professional services offered include:

- Strategy Consulting
- Financial & Cost Analysis
- Market Forecasts
- Technology Analysis
- Competitive Analysis
- Technology and Design Services
- Surveys
- Training
- Custom projects

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Forward Thinking

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Mission

"Unique and strategic perspectives on semiconductor memories, emerging memory technologies and solid state storage"

Forward Thinking

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About NamLab

NaMLab (**Na**no-electronic **M**aterials **Lab**oratory)

The research at NaMLab focuses on materials for electronic devices and new device concepts. Among these are high-k materials for capacitors, transistors and other applications, novel switching devices including memristors, nanowire based electronics as well as materials for energy harvesting devices such as solar cells.

Future nano-electronic products require the development of new materials that are not currently available. NaMLab consequently focuses its research activities on materials and applications that show the potential to offer significant advantages over materials and products used today. In addition to investigating and characterizing new materials, NaMLab is undertaking research on the integration of these materials into semiconductor products with nano-scale dimensions.

NaMLab, originally founded as a research joint venture between Qimonda AG and the TU Dresden in July 2006, has its roots in the Corporate Research Department of Infineon AG and is now owned completely by the Technical University of Dresden. NaMLab receives basic financing from the Saxon Ministry of Science and Arts (SMWK). The company benefits from excellent working conditions in its office and clean room building opened in October 2007 and located within the TU Dresden campus.

Characterization:

- physical characterization (conductive AFM, SSRM, SEM)
- electrical device characterization;
    - 200mm/300mm wafer probe stations
    - 5K – 500K temperature range
    - Analytical measurements of memory cells (lifetime, switch time , storage and deletion windows)
    - charge carrier mobility with Hall and split-C(U)
- optical characterization (FTIR ellipsometry, µRaman and photoluminescence)
- dielectric reliability (TDDB, BTI, SILC)
- high-k material development
    - oxides: AlO, TiO, ZrO, HfO and mixtures
    - metals: Al, Pt, Au, TiN, Ti, Ru
    - methods: ALD, MBE, PVD, evaporation

Development:

- materials for emerging memories
- high-k stacks for capacitors and transistors
- development of new memory concepts
- charge trap device development
- development of explorative devices based on silicon nano wires

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