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TECHNICAL BRIEFS

TUNNEL FIELD EFFECT TRANSISTORS: PAST, PRESENT AND FUTURE

MAYANK SHRIVASTAVA AND V. RAMGOPAL RAO

Why Tunnel FETs?

The answer to this question is linked with breakdown of Moore's law and Dennard's scaling theory. In the last two decades, MOS technology has seen a significant progress in terms of scaling down from sub-micron feature sizes to sub-10 nm dimensions. To give a quantitative feel, the gate length, gate dielectric thickness and junction depth have been reduced by about three orders of magnitude in the past 20 years, which has significantly improved the power-performance metrics. However, in recent times, the scaling pace has slowed down – for example, a 11 nm technology node doesn't have 11 nm gate length devices anymore. The minimum gate lengths are still around 20–24 nm. This is attributed to an increased S/D leakage, weak gate control and higher power consumption at very short gate lengths. To address this, power supply (V_{DD}) scaling is desired; however, to meet the ON current requirements, i.e. performance targets, the threshold voltage needs to be scaled along with VDD. However, leakage current increases exponentially as threshold voltage is reduced. Hence, threshold voltage has become a non-scalable parameter, as any decrease of threshold voltage exponentially increases the leakage current, which is mainly because of MOSFET's fundamental limit of subthreshold swing (60 mV/dec at room temperature). In reality, owing to the short channel effects, subthreshold swing (SS) is far worse than the ideal value of 60 mV/decade.

Around the same time when Dennard's scaling theory practically became difficult to implement (late 90's), a significant increase in requirement for low power technologies for wireless and handheld applications was seen. The surge in handheld consumer electronic devices like smart phones, smart watches and tablet PCs requires

(continued on page 3)

YOUR COMMENTS SOLICITED

Your comments are most welcome. Please write directly to the Editor-in-Chief of the Newsletter at radhakrishnan@ieee.org

10. It is my pleasure to welcome both of them to our team as New Editors.



Kyle Montgomery is a Research Engineer with the Air Force Research Laboratory (AFRL) in Albuquerque, New Mexico, USA. In addition, he holds

a Research Assistant Professor title at the University of New Mexico in the Electrical & Computer Engineering department, where he teaches a graduate course on solar cells. Dr. Montgomery's research

interests (PhD, Purdue University, 2012) focus on high efficiency solar cells and power systems for space applications. He serves on the EDS Young Professionals Committee and the planning committee of the IEEE Photovoltaic Specialists Conference (PVSC).

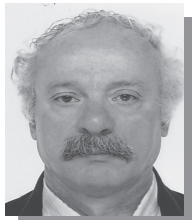


Ming Liu is a Professor at the Institute of Microelectronics, Chinese Academy of Sciences and Director of the Key Laboratory of Micro-

electronics Devices & Integrated Technology. She received her Ph.D. in Material Engineering from Beijing University of Aeronautics and Astronauts, China in 1998 and later joined the Institute of Microelectronics, Chinese Academy of Sciences and became professor in 2000. Her current research areas include micro/nanofabrication, new structure NVM device and circuit, modeling and simulation, reliability and organic electronic devices.

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EDS BOARD OF GOVERNORS MEETING HIGHLIGHTS



Simon Deleonibus
EDS Secretary

May 28–29, 2016: The EDS Mid-Year Governance Meeting returned to Region 8 this year in grand style, bringing together the Society's senior leadership and several

EDS Chapter Chairs from across Region 8 to beautiful Grenoble, France. The meeting was a phenomenal success, combining vital society business with some truly special social events to create an enriching and energizing event for all attendees. The weekend began on Saturday morning, with a series of important Standing Committees meetings.

The EDS BoG meetings started with the introduction of new EDS Operations Director, James Skowrenski, who joined the EDS team with extensive experience in association management. The first day's meetings included Fellows Evaluations, Publications and Newsletter Joint meeting, Technical Committees meeting and Education, Membership and Chapters meeting.

The Fellows Evaluation Committee began their work bright and early Saturday morning, with the



EDS Forum members during dinner at Restaurant du Teleferique in Grenoble (450m above sea level) – May 29, 2016

difficult task of reviewing and evaluating 42 IEEE Fellow nominations. Led by Paul Yu, the committee did the evaluations of all nominations and endorsements for many hours, proving once again that the work of this committee is among the most challenging and important to the Society and the IEEE.

As the EiC of Newsletter, M. K. Radhakrishnan presented the status and the improvements made in the

newsletter during the last 3 years. The increased emphasis on technical content, introduction of columns for YPs and introduction of Messages from Presidents in each issue were highlighted. The transition to web format and open access for Newsletter received positive reviews.

Hisayo Momose, EDS VP of Publications and Products, chaired the critical Publications committee meeting. The new editor for J-EDS was

announced as Mikael Ostling and the strategy for the management of the EDS publication portfolio was shared.

Led by EDS's VP of Technical Committees and Meetings, Ravi Todi reviewed our many technical meetings and conferences. The discussions also included the newly approved Electron Devices Technology and Manufacturing Conference, which will be held on February 28 to March 2, 2017 in Japan.

Combining the Membership, Chapters and Education meetings has proved very effective. Vice Presidents Tian-Ling Ren (Membership), M. K. Radhakrishnan (Regions and Chapters) and Mansun Chan (Education Chair), convened an outstanding forum to address these important areas of the society's life. In addition to providing an important strategic planning session, the highlight of the meeting was the open dialogue with all present. This meeting was followed by Region 8 Chapters meeting chaired by Region 8 SRC Chair Simon Deleonibus in which several EDS chapter chairs from across Region 8 participated. The meeting provided an excellent opportunity for staff and volunteer leadership to learn more about the chapters' perspectives, needs, and successes. This meeting continued with the Region 8 Chapters meeting

The EDS Forum and Board of Governors met on Sunday, May 30th for the Mid-Year Governance meeting chaired by the President Samar Saha. The meeting's discussions covered nearly every aspect of the society's operations, ending with an extended Open-Forum to provide a free exchange of ideas and debate over how we can continue to improve the Society to ensure its preeminence as the world's leading organization devoted to device engineering. Here are some of the highlights:

- EDS Treasurer, Subramanian Iyer, reviewed the financial state of EDS and the news is good! Publication page counts and prices for 2017 have been approved. Also, EDS membership dues will remain the same at \$18 for 2017.
- EDS has endorsed the collaboration with the CMPT society and SEMI in sponsoring the heterogeneous integration roadmap with the goal of collaboration with other IEEE societies and other organizations.
- An updated EDS field of interest has been approved and will be sent to IEEE for formal approval.
- It has been noted that EDS member strength is almost stagnant and the student member strength

is very low compared to the student Chapters.

- A good number of Chapters are found to be shy in communicating activities and reports. Regions and Chapters committee is empowered to revitalize weak Chapters. A concerted effort to improve and monitor student Chapters is planned.
- For the EDS Region 9 Outstanding Student Paper Award a minor modification to the eligibility requirements is made by allowing a nominee to be enrolled at a higher education institution located in Region 9 at the time of the paper publication date.
- A motion was made and passed to create an EDS Documents Review Ad Hoc Committee to review the inconsistencies of the EDS Constitution and Bylaws, along with other documents.

We offer our sincere thanks to Mireille Mouis and Marco Pala for their invaluable help in planning this meeting. Without their diligence, patience, and dedication, this meeting simply would not have happened.

Simon Deleonibus
EDS Secretary

EDS REGION 8 MEETING

The EDS Region 8 Meeting was held during the BoG/Forum meetings series in Grenoble on the afternoon of May 29th. The meeting gathered 30+ attendees from all regions and mainly Region 8 Chapters Chairs and Representatives (11). For the meeting preparation, all Region 8 Chapters Chairs were requested by Region 8 SRC Chair, Simon Deleonibus, to send 3 highlights from their Chapter's recent activities. After introductory remarks and data presentations by both M. K. Radhakrishnan, EDS Vice President of Regions and

Chapters and Simon Deleonibus, the Chapters Chairs and Representatives were invited to comment directly on their highlights tables.

An intensive debate occurred during the discussion on the following points:

- Region 8 is the widest region for IEEE and includes 1,619 members, 52 chapters, among which 13 are 100% EDS, 31 are Joint Chapters and 8 Students Chapters. It has the largest proportion of Joint Chapters among all re-

gions, mainly due to the fact that diversification is widely spread in the industry activities.

- The formal reporting of our Chapters to the IEEE EDS headquarters was analyzed and commented through the use of a common metrics. The available data include L31 forms, MQ and DL deliveries, and EDS Newsletter reporting. As a matter of fact, the number of L31 forms generated by the Chapters is not a direct measure of Chapters' activities because these forms are used for

different purposes by different Chapters. The number of these forms ranges from 0 to 132 in a year (2015) in different Chapters! For no reason, these forms have to be used for internal reporting! Region 8 has at least 6 «dormant/shy Chapters» (3 Chapters are 100% EDS), which for unknown reasons have not reported for the last 3 years. This number has to be corrected and we should know why.

- The activity of Region 8 SRC (Chair Simon Deleonibus; Vice-Chairs Tomislav Suligoj, Arokia Nathan and Andrzej Napieralski) was reported. Region 8 SRC has prioritized since 2015 to revitalize «dormant/ shy» chapters (2 were reactivated last year and 6 are in revitalization process in 2016), increase the number of chapters (2 were created in 2015 and 2 are in process), strengthen the network by visits to the Chapters (2 in 2015). New opportunities for chapters creation (at



Society officers and chapter chairs who attended the EDS Region 8 Meeting in Grenoble, France

least 3) are analyzed and being considered.

- A discussion was carried out on the opportunity to create new chapters from larger ones. This is not a simple question, because local conditions in each country need to be considered. For example, in some countries, maintaining or defining one/several chapters could be critical because members may be spread all over the country or concentrated in a specific area. Finally, do we need

more chapters or more members? Which is the optimal number to set up a Chapter? All these questions have to be addressed properly on a case-by-case basis.

- The detailed highlights tables of different chapters and their slides presented at the meeting have been disseminated to all Chapters Chairs.

*Simon Deleonibus
Region 8 SRC Chair
CEA/LETI, MINATEC
Grenoble, France*

AWARDS AND RECOGNITIONS

2016 WILLIAM R. CHERRY AWARD WINNER



Dr. Pierre Verlinden

Dr. Pierre Verlinden, Chief Scientist and Vice-President of Trina Solar, has received the IEEE William R. Cherry Award in recognition of his long and distinguished career

at the forefront of PV technology and commercialization, for leading technology advances including the interdigitated back contact (IBC) cell, mono- and multicrystalline PERC silicon solar cells and multijunction III-V dense array technology for CPV application, and for his overall leadership of key R&D organizations throughout his career. Dr. Verlinden is currently

Vice-Chair of the State Key Laboratory of PV Science and Technology, Changzhou, China, as well as adjunct Professor at Sun Yat-sen University, Guangzhou, China.

He has been involved with high-efficiency PV technologies for more than 35 years, first as an early developer of IBC silicon solar cells from 1979, at the University of Louvain, Belgium, and Stanford University, California. He continued his pioneer work on IBC solar cell development for CPV and one-sun applications as Director of R&D at SunPower until 2001. After a short stay at Origin Energy Solar, Australia, to build a pilot line for the Sliver cell, he founded AMROCK and helped many other companies and research centers

to develop advanced PV technologies, including multijunction III-V dense arrays for reflective CPV systems at Solar Systems, Australia. In early 2012, Dr. Verlinden joined Trina Solar in Changzhou, China, where, marrying western-style and Chinese-style R&D, he transformed the State Key Laboratory of PV Science and Technology into one of the most advanced research centers in photovoltaics. He has been associated with several efficiency world records during his long career dedicated to photovoltaics.

Dr. Verlinden delivered his Cherry Award acceptance speech on Monday, June 6th in the Oregon Ballroom, during the 2016 PVSC Opening Keynote Session.

in December, which is the brain child of all the Chapters in the region.

During the year, one ED Chapter and three ED Student Chapters were

formed in the region. Now there are plans for two more Chapters and one student Chapter in Bangladesh. The communication between Chapters

will be streamlined through a Google Group. The next Chapter Chairs meeting will be held in conjunction with ICEE in December 2016.

MQs, DLs AND CONFERENCE REPORTS

EDS MINI-COLLOQUIUM HELD IN GRENOBLE, FRANCE



Lecturers and attendees of EDS Mini-Colloquium on May 30, 2016

The French chapter of the Electron Devices Society organized a Mini-Colloquium held in Grenoble, France, at the Phelma Minatec Campus, May 30, 2016. The MQ gathered nine EDS Distinguished Lecturers from around the world presenting state of the art of various nano-electronics branches.

First, Dr. Simon Deleonibus gave an overview of the IEEE-Electron Devices Society and its benefits. Then the program continued with the oral presentations, each of about 25 minutes, on the following topics:

- *State of the art Power Switching Devices in SiC*, Mikael Ostling, KTH, Royal Institute of Technology, Sweden
- *Ultra-thin Chips – a New Paradigm in Silicon Technology*, Joachim Burghartz, Institute for Microelectronics Stuttgart, Germany
- *GaN-HEMT Compact Model for Future Hybrid III-V/CMOS Technology*, Xing Zhou, Nanyang Technological University, Singapore
- *Recent Advances of Si/SiGe Tunneling FET for Low Voltage/Power Applications*, Steve Chung, National Chiao Tung University, Taiwan
- *Silicon device technology for intelligent communications*, Shunri Oda, Tokyo Institute of Technology, Tokyo, Japan
- *Transparent Large Area Flexible Electronics*, Arokia Nathan, Cambridge University Centre for Advanced Photonics and Electronics, UK
- *Flexible, Bendable Self Packaged MEMS Sensors*, Zeynep Celik Butler, University of Texas at Arlington
- *Three Dimensional Integration Technology*, Mukta Farooq, IBM, Hopewell Junction, USA
- *SiGe Heterojunction Bipolar Transistor “HBT” Reliability Overview with a comparison to III-V HBT’s*, Fernando Guarin, Global Foundries, USA

The MQ was attended by about 60 participants.

Simon Deleonibus
Region 8 SRC Chair

Mireille Mouis
ED France Chapter Chair
IMEP-LaHC

Marco Pala
IEEE Member
IMEP-LaHC