Report on the 1st Workshop of
University of Tsukuba Forum on Power Electronics Tomorrow (UTOP)

"Aiming for SiC Power Devices with Greater Availability"

Time & Date: 1:00-5:35pm, June 27, 2014

Venue: Bunkyo School Building, Tokyo Campus, University of Tsukuba

Program:

Mediator: Yuji Yano, Associate Professor, Institute of Applied Physics, University of Tsukuba

13:00 Opening Remarks
Yasuo Miake, Vice President, University of Tsukuba

13:10 "Activities at Power Electronics Laboratory, University of Tsukuba"
Hiroshi Tadamo, Professor, Institute of Applied Physics, University of Tsukuba
Graduate School of Pure and Applied Sciences, University of Tsukuba

13:30 "Looking toward a Bright Future for the Next Generation Semiconductor Power Devices"
Ryuichi Shimada, Institute Professor, University of Tsukuba

13:50 "Technical Trends of Recent Power Devices"
Noriyuki Iwamuro, Professor, Institute of Applied Physics, University of Tsukuba

14:10 "Mounting Technologies Suitable for the Next Generation Semiconductor Power Devices"
Hiroshi Yamaguchi, Advanced Power Electronics Research Center,
National Institute of Advanced Industrial Science and Technology (AIST)

15:00 - 15:15 Coffee break

Mediator: Takonori Isobe, Associate Professor, Institute of Applied Physics, University of Tsukuba

15:15 "Challenges in Application of SiC Devices and Approaches by Toshiba"
Hiromichi Tai, Power and Industrial Systems R&D Center,
Toshiba Corporation Power Systems Co.

16:05 "Development of SiC Devices and Ultra-compact SiC Invertor Modules"
Takashi Nakamura, Power Electronics R&D Div.,
Research and Development Headquarters, Rohm Co. Ltd.

17:05 Panel Discussion "Aiming for SiC Power Devices with Greater Availability"
Mediator: Prof. Hiroshi Tadano, Institute of Applied Physics, University of Tsukuba
Panelists: Dr. Hiroshi Yamaguchi, AIST
Mr. Hiromichi Tai, Toshiba Power Systems Co.
Dr. Takashi Nakamura, Rohm Co. Ltd.

17:35 Closing Address

1. Opening Remarks by Yasuo Miake, Vice President, University of Tsukuba

Professor Miake could not attend the workshop, therefore, his opening remarks was screened via video.

[Abstract]

University of Tsukuba opened "Power Electronics Laboratory" in Graduate School of Pure and Applied Sciences in April, 2013. At this laboratory, we have been conducting researches and fostering human resources concerning the new materials and devices for power electronics. Our activities compose a part of Tsukuba Innovation Arena (TIA), which is an Academia-Industry-Government collaborative research platform in the field of nano-technology. In order to promote the activities, we recently started University of Tsukuba Forum on Power Electronics Tomorrow (UTOP) in collaboration with Technology Forum for the Future Asia (TeFFA), which is a non-profit organization aiming at contributing to development in Asia in the field of energy, environment, disaster defense and biotechnology with international cooperation.

This forum is planning to hold four (4) workshops a year. As the 1st workshop, we chose the topic of SiC devices, cutting-edge power electronics devices. We expect the forum can provide an effective collaboration platform for researchers, engineers, users, sales persons, educators, students, etc. in the field of power electronics.

2. "Activities at Power Electronics Laboratory, University of Tsukuba"

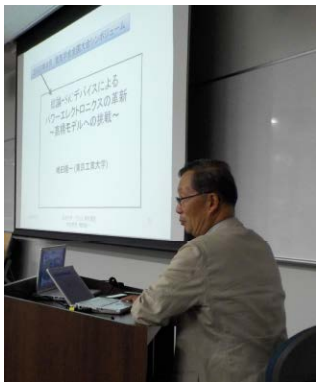
Hiroshi Tadano, Professor, Institute of Applied Physics, University of Tsukuba
Graduate School of Pure and Applied Sciences, University of Tsukuba

University of Tsukuba opened "TIA Collaboration Power Electronics Course" at its graduate school in April, 2014, which comprises two endow courses and a collaborative graduate school. Students can learn Power Electronics as an academic system and experience practical research activities through collaborative research with industry. The students are expected to contribute to further progress of Power Electronics in industry and/or academia.

Iwamuro-Yano laboratory at Fuji Electric Endow Course deals with new devices using advanced materials, mainly SiC; and Tadano-Isobe Laboratory at Yoyota/Denso Endow Course is making research on novel power conversion circuits. Professors Okumura and Yamaguchi belong to the 1st collaborative graduate school, Professor Shimada is

involved in management of laboratories and research guidance of ultra- high voltage power source systems.

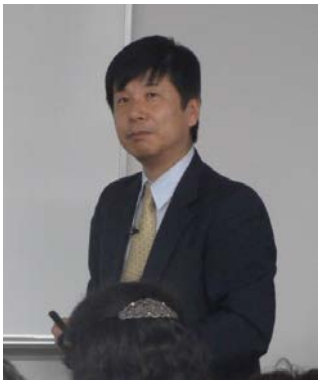
3. “Looking toward a Bright Future for the Next Generation Semiconductor Power Devices”
   Ryuichi Shimada, Professor, Institute Professor, University of Tsukuba



“Ultralow loss power device technology development” in the national project of New Sunshine Program was conducted a couple of decades ago. Crystal growth of 4-inch SiC wafer was accomplished, and MOS inter-facial control technology with high channel mobility was developed as outputs of the project. Those fruits lead to the power electronics technology today.

Power electronic devices could contribute to low-cost product supply to the society utilizing their tolerance to high-voltage and high-temperature. Their application will cover the power grid field (micro-grid, DC power distribution, etc.), induction heating, power source for medical particle accelerator, etc. In addition to those applications, they are expected to find their way into energy industry and also electric-mechanic integration.

4. “Technical Trends of Recent Power Devices”
   Noriyuki Iwamuro, Institute of Applied Physics, University of Tsukuba



Technologies on Si-IGBT and SiC-MOSFET were reviewed. Trench FS type is dominant for Si-IGBT using thin wafer technology, of which progress is recently slowing down. Development of RC-IGBT, integration of IGBT and FWD attracts much attention today, aiming at cost reduction and downsizing of products.

SiC-MOSFET has greatly improved in recent years by advanced production process and crystal quality, and is obtaining higher reliability. Planer type MOSFET will expand its product lineup, and development of trench-gate type and SJ-type MOSFET will be accelerated in the next few years.

5. “Mounting Technologies Suitable for the Next Generation Semiconductor Power Devices”

Hiroshi Yamaguchi, Advanced Power Electronics Research Center, National Institute of Advanced Industrial Science and Technology (AIST)

Power electronics manages power conversion/control by switching with power devices, of which R&D activities on SiC devices, GaN devices and diamond devices are in progress.

SiC devices are already in the market as 5kV class MOS, 10kV class IGBT, PND, etc., and on the way to mass production. Application research for GaN devices have started especially on integration technologies. Concerning diamond devices, crystal/device manufacturing technologies are still under study.

Practical use of SiC devices have just opened and been attracting much attention because of their high durability, however, they still have problems for modularization, such as heat resistance of module materials and/or peripheral parts.

Big market for power electronics in the future would be in the field of micro-grid and power control equipment. High efficiency, compactness, easy-maintenance, low-noise and high-durability of products are important in those fields.

6. “Challenges in Application of SiC Devices and Approaches by Toshiba”

Hiromichi Tai, Power and Industrial Systems R&D Center, Toshiba Corporation Power Systems Co.

SiC devices are characterized by high electric field intensity, high thermal conductivity, high heat resistance and high carrier mobility. Those characters can provide high resistance to voltage/temperature and high speed switching to the devices , however, we have problems to be solved in order to apply them to our products. The most important item in developing products is “cost” management. Under today’s information environment of globalization, it is necessary to supply products with a certain level of quality at low cost, which can hardly be imitated.

Engineers and researchers are actively working on devices of IEGT and IGBT, modules of IBBT/IEGT, NOSFET, etc. toward power conversion application. I hope they take a lesson from GaAs development, which once expected as a next-generation high-frequency device but occupies a limited market today.

7. "Development of SiC Devices and Ultra-compact SiC Invertor Modules"

Takashi Nakamura, Electronics R&D Div., Research and Development Head-quarters, Rohm Co. Ltd.

Rohm started basic researches on SiC-MOSFET in 2002, developed its prototype in 2004, and launched marketing in 2005. In 2010, an integrated production system was established, followed by production of SiC schottky diode (SBD) and SiC-MOSFET.

The SBD has a newly developed trench structure and enabled a large reduction of leak current. On the other hand, MOSFET has a double trench structure and has a product line of 400V-1200V, which has a low resistivity and a high tolerance to avalanche. Full SiC power modules are also on the market.

SiC devices can greatly reduce a switching loss, therefore, they would have opportunities to replace large current Si-IGBTs as much improved alternatives. Power modules are requested to have heat-tolerance, stress-relaxation, low-inductance, high thermal-conductance, high current-density, etc. And advanced materials are also required in order to support those performances. For instance, a novel molding compound is requested to have a high Tg, thermal expansion matching, flexibility, good filling and adhesive characteristic, etc.

We exhibited a ultra-small SiC invertor for EV and HEV, and awarded Division Grand Prix at CEATEC2012. This module could reduce the volume to 1/10 of existing one and cooled with air; no water cooling unit would be necessary.

7. Panel Discussion "Aiming for SiC Power Devices with Greater Availability"

Prof. Tadano had charge of moderator, and Dr. Yamaguchi of AIST, Mr. Tai of Toshiba, Dr. Nakamura of Rohm took part in the discussion as panelists.

Panelists and participants on the floor had a short but fruitful time for exchanging views on problems for SiC module application, analysis of failure cause, importance of peripheral technology, which is more easy-to-use device; IGBT or MOS?, to what extent

reliability on SiC devices is understood?, and so on.