My Journey as a Researcher in the Semiconductor Field

Hisayo S. Momose (IEEE Fellow)

I was engaged in research and development in the semiconductor field for more than 30 years. I am delighted by the opportunity to reflect on my life as a researcher. When I was a child, I liked reading, and I read many books from diverse areas, including fairy tales, history, adventure, and science fiction. In addition, I read stories about great people in a biographical book series for children. I especially liked female protagonists such as Murasaki Shikibu, Marie Curie, and Helen Keller. Murasaki Shikibu was a female Japanese author who, in the early 11th century, wrote what is considered to be one of the world's first novels. These female protagonists' charming personalities and sincerity toward their work left a strong impression on me.

I chose science as my major after thinking about my future career in high school and university, because I wanted to scientifically investigate various materials and living creatures that exist in the natural world. Although there were few women among the faculties of science and engineering at universities, I did not hesitate to make that choice. In retrospect, I may have somehow been influenced by my two older brothers, who both have a PhD degree in science and were already pursuing their careers as researchers. In my mid-twenties, I joined Toshiba Corporation. The company, as a general electronics manufacturer, had many technical areas for research and development; this aspect appealed to me. In addition, several female seniors from the same university where I studied were already working there as researchers, and their advice was extremely helpful when I was thinking about my future line of work.

My life as a researcher in the company started with the development of memory devices. This became an interesting and challenging job for me. It was the generation when the 1 Mbit DRAM was still under development. I felt that we were at the forefront of research in this field. It was a few years before my country passed the Equal Employment Opportunity Act. Female researchers were restricted in some aspects of labor management, such as the total number of hours worked per year. Despite being in that era, I was fortunate to be given the same opportunities as other male researchers in many aspects of my work, such as choosing research themes and planning experiments. I am grateful to my laboratory heads, bosses, and colleagues for their consideration and encouragement. There was also an in-house network of approximately 30 female researchers at that time, including a few with careers spanning over 20 years. I was fortunate to have exchanged information with them on various other issues in addition to work.

However, when I returned to work after about a year of childcare leave in my mid-thirties, I felt restless with my colleagues' activities. This was because in only one year, the main research subjects of my group had already shifted a few generations from the 0.25 μm generation

Members of the Center for Semiconductor Research & Development in Toshiba Corporation under cherry blossoms in full bloom in 2006. Dr. Momose is on the far right side of the front row

technologies to 0.1 μm generation technologies. Nevertheless, taking on challenges with a fresh mind seemed to have a positive effect; consequently, I was able to obtain interesting research results. The research I conducted at that time enabled me to become an IEEE Fellow later.

My research theme at that time was the development of high-performance and highly reliable MOS transistors of the 0.1 μm generation. For approximately three years, I had repeated trial and error approaches to fabricate high-quality stacked thin-film insulators for the 0.25 μm generation containing thin nitride and oxide films. The knowledge I had gained at that time effectively contributed to my new research. After my return from childcare leave, I found for the first time that ultra-thin gate oxide transistors with small gate lengths operate normally and exhibit significantly higher DC performance even in the direct-tunneling regime. That was the highest value at that time. I can still vividly remember that my boss and colleagues were surprised at the high drive current when I first showed them the experimental results at our group meeting.

After some additional evaluations and discussions, at the 1994 IEDM, I presented my paper, which was press-released before the meeting as one of the remarkable technical highlights of the meeting. The work demonstrated for the first time that transconductance of over 1.0 S/mm is possible in Si devices, as long as a very-high-capacitance gate insulator is used. It was also confirmed that the MOSFETs have the suppression of the short-channel effects for Vth rolling because of the improved gate bias controllability of the channel potential through the thinner gate insulator. Subsequently, the prediction of gate insulator thinning in the International Technology Roadmap for Semiconductors (ITRS) was aggressively changed from the 1994 edition to the 1997 edition. When I visited the Semiconductor Industry Association (SIA), I was honored to hear that they had considered my research results when writing the roadmap. In addition, as a corporate researcher, I was pleased that this work was included in the periodic brochure for the shareholders of my company as a promising study.

Thereafter, I became increasingly curious about the various properties and concerns regarding the MOSFETs with thin gate insulator. Over several years, I thoroughly investigated the transistors, including their AC and RF characteristics, uniformity, reliability, noise, and channel orientation dependence. It was exciting for me to choose a theme that I was interested in as well as plan, perform, and discuss the experiments. In these studies, I presented nearly ten papers accepted by the IEDM and VLSI Symp as the first author. I was pleased to learn that these were timely studies that matched the interests of the audience at the time. These studies provided me with many opportunities to conduct seminars and lectures for young engineers in this field and students. In my mid-forties, I became the first female IEEE Fellow in Japan; hence, I also had several opportunities to share my experience at the domestic WIE meeting.

At Toshiba, we had many talented researchers and engineers involved in design, process, evaluation technology, materials, and so on. They were sufficiently kind to lend special equipment for sample preparation and to perform TEM evaluations. The opportunity for discussions with them while conducting cutting-edge research and development was extremely significant and beneficial. I believe that this was the key to improving the quality of my research and I was fortunate to have been in this environment.

Since then, the subjects of my research gradually changed and expanded along with the changes in the times and society, such as toward analog devices, thin-film transistors, and imaging devices. I also had the opportunity to conduct joint research with external research institutes, according to need. After moving to a university in my mid-fifties, in addition to pursuing my own study, I had more opportunities to support the research activities of young professors and researchers. When I was developing novel materials such as organic photoconductive films, I recalled discussing the experimental results and future applications with professors and students who specialize in organic films. Such discussions with various experts outside my field always made me feel refreshed.

The experience I gained through activities in the EDS Society was beneficial for expanding my interests and identifying new research subjects. Fortunately, I had many opportunities to discuss research trends with EDS members and received advice on my research from them. In addition, I served as one of the editors in the field of MOS devices in *IEEE Transactions on Electron Devices* for 10 years and handled more than 400 manuscripts in the area. This was a worthwhile experience for me.

In my long research journey, I enjoyed thinking deeply and planning studies to solve difficult problems. The results obtained, whether expected or not, also provided me with many opportunities to consider and ponder the root causes. This process was always thoroughly enjoyable. I hope that young people will be able to enjoy their research life by focusing on what they are interested in, and to make giant strides in good research environments.

Semiconductor products in today's IT society require an extremely large variety of technologies, and their development has involved the wisdom and efforts of numerous people in the past as well as the present. Although my research itself might only be a negligible part of that endeavor, I am honored that I was able to contribute even a little to the overall development. I express my gratitude to everyone who worked with me for more than 30 years at Toshiba Corporation and Yokohama National University for their encouragement, support, and discussions.

Dr. Momose *has more than 30 years of experience in research and development at Toshiba Corporation, Japan*

(1984-2015) and Yokohama National University, Japan (2015-2017). She was a guest professor at National Yang Ming Chiao Tung University, Taiwan (2017–2021). She was engaged in the research and development of Si transistors ranging from 1.2 μm to sub-50 nm, static RAMs, CMOS/BiCMOS logic LSIs, RF/MS analog CMOS, thin-film transistors, oxide semiconductors, imaging devices, and photoconductive devices. She has authored or co-authored nearly 200 papers published in technical journals and the proceedings of international/domestic conferences.

In recognition of her contributions, she was awarded an IEEE Fellow (2005), and a Fellow of the Japan Society of Applied Physics (2009). She has also received several awards and honors, including the Commendation for Science and Technology from the Minister of Education, Culture, Sports, Science and Technology, Japan (2009). She served as a member of the technical program committee at more than ten academic symposia in the field, including IRPS (1992-1994) and IEDM (1997-1998 (CMOS and Reliability), 2013-2014 (Display and Sensors)). In addition, she served on several EDS executive committees, including EDS fellows committee (2007-2014). She served as an editor on the IEEE Transactions on Electronic Devices (2005-2014), and then as EDS Vice President of Publications and Products (2016-2018).