IIT22 Ion Implantation & Annealing School: Sept 22-24, 2022
Topics & Teachers

1. History of Integrated Circuits & Ion Implantation:

James F. Ziegler. (US Naval Academy; retired.)

ABSTRACT: Ion implantation was the critical innovation the catalyzed the integrated circuit industry in 1975-77 into an exponential growth in the following decides. This history reviews the landmarks of solid-state electronics, showing its early slow growth of about 10% per year for its first 70 years. Suddenly 3 innovations associated with ion implantation in the early 1970's cut the cost of integrated circuit manufacturing by 70%. This enabled the growth of microprocessors for computers, micro-controllers for autos and machinery, and large-scale memory chips, all leading to an explosive growth in complex software.

TEACHER BIO: Dr. James Ziegler started the Ion Implantation Technology Conference in 1976 and the IIT School in 1982.He has done research in ion implantation since 1967 and helped to introduce the fabrication process into IBM's first manufacturing line for integrated circuits. Dr. Ziegler has written/edited 25 books in the fields of ion beams and the effects of radiation on integrated circuits. He is presently a retired professor at the United States Naval Academy in Annapolis, MD, USA.

2. Applications of Ion Implantation in CMOS: Logic:

Leonard Rubin. (Axcelis Technologies)

ABSTRACT: Ion implantation is essential for fabrication of advanced CMOS devices. The flexibility and precision of ion implantation in the selection of dopant species, spatial location with the device, and subtle control of concentration profiles enables rapid introduction of new process technologies with optimization or even elimination of performance tradeoffs. This presentation will review the history, present functions and future trends of ion implantation for doping and non-doping (material modification) application for planar and three-dimensional (FinFET) CMOS transistors.

TEACHER BIO: Dr. Leonard Rubin received an B.S. degree in Materials Science and Engineering and M.S and PhD. degrees in electronic materials from Massachusetts Institute of Technology. He worked at Zilog Inc. in Nampa, ID in ion implantation, diffusion and rapid thermal processing. He has been at Axcelis since 1995, where he is Chief Device Scientist and an Axcelis Fellow. He has been engaged in research and development of high energy ion implantation, rapid thermal processing, the effects of implant temperature and implant beam incidence angle on advanced CMOS devices.

3. Commercial Ion Implantation Systems:
Michael I. Current, (Current Scientific)

ABSTRACT: Ion implantation processing of electronic materials and devices use a wide variety of acceleration components and target chambers (end stations) as well as many special technologies. Each of the components are designed and combined to operate in a diverse array of operating conditions for ion energy, beam current and dose. After an outline of the form and function of typical implanter components, examples of commercial ion implantation systems will be reviewed for medium and high currents, high energy, plasma immersion as well as specialized tools for doping of large-area flat-panels of Si-on-glass and photo-voltaic cells.

TEACHER BIO: Dr. Michael Current has been active in the use of ion beams for doping, lamination and analysis of electronic materials and metals for 5 decades and has been an instructor at the IIT school since 1982. After his PhD in Physics at RPI and 4 years on the research faculty at Cornell, he has worked as a process engineer, researcher and teacher in Silicon Valley, Texas, Japan and Taiwan for such companies as Signetics/Philips, Xerox/PARC, Applied Materials, Frontier Semiconductor and number of start-up operations. Dr. Current was the founding president of the Silicon Valley Ion Implant Users Group in 1983 and has taught implant and metrology courses at Kyoto U., Stanford, UC Berkeley, Santa Clara U. and Cheng Kung U.(Taiwan). He has published over 250 papers and book chapters and remains active in several start-ups.

4. Development of Ion Implantation Technology: 1987-2022:
Anthony Renau, (Varian Semiconductor, retired)

ABSTRACT: This lecture will discuss some of the major challenges to ion implantation over the last 3 decades and more, which had they not been faced and overcome, ion implantation and the entire semiconductor electronics industry would be in a far less advanced state today. These challenges emerged as the semiconductor electronics evolved with each shift in scaling node, materials and device scale and function. The key innovations to be discussed are the development of plasma flood guns for control of wafer charging, indirectly heated cathode ion sources, single wafer implantation, plasma doping, elimination of ion energy contamination during ion deceleration and development of methods for hot and cold implants. The concluding remarks will outline some of the present-day challenges.

TEACHER BIO: Dr. Tony Renau, formerly the CTO at Varian Semiconductor Equipment, recently retired as vice president of Technology for the Varian, now a business unit of Applied Materials. Dr. Renau received a Ph.D. in electron and ion optics from the University of London, following physics degrees at Manchester and Leicester Universities. He holds over 60 patents with decades managing R&D and coinventor of some of the most successful ion Implantation systems. Dr. Renau has served on International Committee for the Ion implant Technology conference and the advisory board for the materials processing center at MIT.

5. Radiation Damage in Silicon:
Kevin S. Jones. (U. Florida)

ABSTRACT: This talk will explore the origin of radiation damage that occurs during ion implantation of Silicon. This includes the formation of point defects, vacancies and interstitials, damage accumulation and amorphization of Si by both dopant and non-dopant ions.

TEACHER BIO: Kevin S. Jones is a professor and former chairman of the department of Materials Science and Engineering at the University of Florida (Gainesville). He is co-director off the Software & Analysis of Advanced Materials Processing Center (SWAMP). He has spent the past 30 years as a professor studying processing-induced defects in semiconductors, focusing mainly on transmission elector microscopy (TEM) characterization of defects after ion implantation of various materials and developing an understanding of how defect evolution influences dopant diffusion in electronic materials. He has published over 300 papers in the field of ion implantation and is Chairman off the International Committee on Ion Implantation Technology.

6. Ion Implantation Annealing:
Kevin S. Jones. (U. Florida)

ABSTRACT: This talk will discuss the processes that occur during thermal annealing of ion implanted Si. This includes the crystallization of any ion-induced amorphous regions as well as the evolution of excess point defects during annealing and their effects on junction formation and dopant activation.

TEACHER BIO: Kevin S. Jones is a professor and former chairman of the department of Materials Science and Engineering at the University of Florida (Gainesville). He is co-director off the Software & Analysis of Advanced Materials Processing Center (SWAMP). He has spent the past 30 years as a professor studying processing-induced defects in semiconductors, focusing mainly on transmission elector microscopy (TEM) characterization of defects after ion implantation of various materials and developing an understanding of how defect evolution influences dopant diffusion in electronic materials. He has published over 300 papers in the field of ion implantation and is Chairman off the International Committee on Ion Implantation Technology.

7. Advancements in Ion Implant Annealing for Si, Ge, SiC and GaN:
Wilfried Lerch. (SkyLark.Solutions)

ABSTRACT: Thermal processes are key steps in semiconductor device manufacturing. A critical goal is the formation of highly conductive, ultra-shallow (and ultra-thin) junctions for source-drain extensions. Lamp-based annealing, for a period of seconds, evolved to "spike" anneals of one second at peak temperature and then shorter and higher temperature anneals like flash-lamps and lasers anneals. This talk reviews the form and function of various annealing equipment and their process ranges (including controlled ambient environments) and provides insights in annealing technology. Deactivation of dopants due to defects created and released during thermal anneal cycles along with with annealing of Si, Ge and wide band-gap materials such as SiC and GaN.

TEACHER BIO: Dr. Wilfried Lerch received his PhD in physics from the Westfaelische Wilhelms-University in Muenster, Germany. At Centrotherm International AG he was responsible for R&D and technology of all front-end and back-end semiconductor products (tools for annealing of electronic materials, horizontal and vertical furnaces, RTP, low-temperature plasma oxidation and high temperature tools for SiC and GaN as well as soldering tools). Dr. Lerch is presently Technology Officer for SkyLark.Solutions, a technology company in the field of semiconductor process technology and equipment development. In 2020 he joined the Fraunhofer EMFT as head of the SiD department. Dr Lerch is co-chair of the German RTP User Group and works in the Semiconductor Technology Committee of SEMI Europe. Dr. Lerch has published over 100 papers on the topic of annealing and a book on RTP technology.

8. Cluster Ion Beams: History and Technology:
Jiro Matsuo. (Kyoto U.)

ABSTRACT: This talk reviews the milestones in the development of cluster ion beam technology, fundamental characteristics of cluster ion impacts on surfaces and emerging industrial applications. Effects that occur when cluster ions, containing a substantial number of atoms in each ion, hit a solid surface are fundamentally different from those that occur with single atom ion impacts. Cluster-surface collisions produce important non-linear effects which can be applied to shallow junction formation, film deposition, etching and smoothing of diverse materials, semiconductors, metals and dielectrics. Cluster ion can also probe spatial distributions of elements in fragile surfaces.

TEACHER BIO: Dr. Jiro Matsuo is a professor in the Graduate School of Engineering at Kyoto University. Previously, he had worked at Fujitsu developing advanced CMOS devices and processes. At Kyoto U, he has served as deputy director of various collaborative research projects, linking university and industry groups, to develop industrial applications of ion cluster technology, such as the MITI sponsored "Advanced Quantum Beam Project". Presently he is leading an exploration of solid-liquid interface analysis with cluster ion beams. This and other projects are expanding surface analysis techniques beyond high-vacuum environments to near ambient pressures.

9. Ion Transport and Beam Controls:
Bo Vanderberg. (Axcelis Technologies)

ABSTRACT: Ion implanters for semiconductor applications use beamlines to transport ions to wafers, process chambers and end stations to handle wafers, and complex control systems to ensure the ion implant remains within desired process windows. In this lecture, we will cover the basic theories and concepts applied to charged particle transport and implant control, including energy control, beam filtration and focusing, dosimetry, and charge and implant angle control.

TEACHER BIO: Dr. Bo Vanderberg, an Axcelis Fellow and Manager in the Technology Development Group. Prior, he served as Postdoctoral Fellow at Uppsala University in Sweden and was subsequently invited as Visiting Scientist to the Massachusetts Institute of Technology and Northeastern University in Boston. He then joined the staff of Axcelis Technologies, where for the last 26 years he has been working on all aspects of ion implanter development and applications, including being the main architect of the Axcelis Purion high current platform. He is the author of several book chapters on ion implantation systems.

10. Ion Sources:
Tom Horsky, (Tom Horsky Consulting)

ABSTRACT: This talk will be a detailed discussion of ion source technology as it relates to commercial ion implantation. The goal of the presentation is to provide a concrete aid to students and professionals working in, or seeking to work in, the ion implantation industry. Practical guidance will be given regarding operation and troubleshooting, as well as the conceptual underpinnings of ion sources in use today.

TEACHER BIO: Dr. Thomas N. Horsky is a consultant to the semiconductor equipment industry. He is credited with the development of the indirectly-heated cathode source, the leading implanter source in use today. Tom has authored more than fifty U.S. patents, and has published over seventy-five articles. He is also a founder of SemEquip, Inc., a company focused on developing commercial ion sources and related technologies. SemEquip was eventually merged with Nissin to form the Nissin Ion Equipment USA R&D center (Billerica, MA), which he managed until 2017.

11. Safety Considerations in Ion Implantation:
Ewald Wiltsche. (Infineon)

ABSTRACT: Ion implanters have several inherent hazards associated with their operation and maintenance. Although manufacturers of ion implant equipment include safety features into the design, the potential for serious injury remains, particularly when safety checks are overridden and recommended procedures are not followed. Safety incidents are more likely to occur during maintenance operations, where interactions of personnel and equipment are much more direct. The major categories of safety risks are: hazardous materials, high-voltage, radiation, mechanical and ergonomic issues. Specifics of each category, including complicating interactions and differences in operational, maintenance and service conditions are discussed as well as recommended safe operating conditions.

TEACHER BIO: Ewald Wilrsche has worked with ion implantation equipment for 3 decades, starting as a maintenance technician with Siemens and then with Infineon since the beginning of the company. He is responsible for radiation safely with ion implanters as well as equipment engineering for ion implanters and laser annealers. Among his many contributions are the development of single wafer handling for thinned 300 mm wafers and a high efficiency ion source for sputtered ions.

12. Ion Beam Purity and Elemental Contamination:
Michael I. Current, (Current Scientific)

ABSTRACT: Many factors in the design, construction materials and operation of ion implanters can compromise the expected precision and cleanliness of ion implantation processes. The list of commonly used ions has greatly expanded beyond the classic set of dopants for Si, complicating the issues for beam purity. Issues to be discussed are: (1) "mass overlaps" resulting from molecular ion breakups and charge exchanges resulting from ion collisions with residual gases along the ion path, (2) transport of energetic and vapor phase metals and dopants, (3) wetting of device structures by contaminant-laden atmospheric water vapor during load-lock pump down and following cryo-implants, (4) organic contamination from vacuum pump oils, o-rings, and outgassing of photoresist materials, (5) particle transport, adhesion, ion blocking and out-diffusion effects.

TEACHER BIO: Dr. Michael Current has been active in the use of ion beams for doping, lamination and analysis of electronic materials and metals for 5 decades and has been an instructor at the IIT school since 1982. After his PhD in Physics at RPI and 4 years on the research faculty at Cornell, he has worked as a process engineer, researcher and teacher in Silicon Valley, Texas, Japan and Taiwan for such companies as Signetics/Philips, Xerox/PARC, Applied Materials, Frontier Semiconductor and number of start-up operations. Dr. Current was the founding president of the Silicon Valley Ion Implant Users Group in 1983 and has taught implant and metrology courses at Kyoto U., Stanford, UC Berkeley, Santa Clara U. and Cheng Kung U.(Taiwan). He has published over 250 papers and book chapters and remains active in several start-ups.

13. Applications of Ion Implantation in CMOS: Memory & Image Sensors:
Leonard Rubin. (Axcelis Technologies)

ABSTRACT: This presentation will explain the device concepts and new features in ion implantation for advanced memory and CMOS image sensors. The talk will also discuss ion implantation into heated and cooled wafers.

TEACHER BIO: Dr. Leonard Rubin received an B.S. degree in Materials Science and Engineering and M.S and PhD. degrees in electronic materials from Massachusetts Institute of Technology. He worked at Zilog Inc. in Nampa, ID in ion implantation, diffusion and rapid thermal processing. He has been at Axcelis since 1995, where he is Chief Device Scientist and an Axcelis Fellow. He has been engaged in research and development of high energy ion implantation, rapid thermal processing, the effects of implant temperature and implant beam incidence angle on advanced CMOS devices.

14. Power Devices in Si and New Materials:
Werner Schustereder. (Infineon)

ABSTRACT: Ion implantation processes are essential for advanced power devices. This talk will address the front and backside processes and bulk materials role in key parameters such as power densities and minimal loss switching behavior. Implant challenges for creation of power devices in Si, still the dominant substrate material for power devices, as well as wide-gap materials such as SiC and GaN are discussed.

TEACHER BIO: Werner Schustereder received his PhD degree in Ion Physics at the University of Innsbruck, Austria. After working at the Max Planck Institute for Plasma Physics in Munich on material science for nuclear fusion power plants, he joined Infineon Technologies in 2008. Werner is responsible lead principle engineer for process development in ion implantation and laser annealing at Infineon. He teaches courses on ion implantation at various levels, supervises diploma and PhD students and presents at international conferences on topics including mass spectrometry, nuclear fusion physics and defect engineering in semiconductors. Werner is co-author of more than 60 peer-reviewed publications and about 50 active patents on methods for fabricating power devices. As a member of the steering group of the German Ion Implantation Users Group he is co-organizer of periodic knowledge exchange forums of the German-speaking implanter community.

15. CMOS Scaling Beyond 2 nm Node:
Santosh K Kurinec (Rochester Institute of Technology)

ABSTRACT: This tutorial presents the latest developments in CMOS technology and options for beyond 2 nm nodes. Performance improvements beyond FinFETs, involving adopting Gate-All-Around (GAA) device architectures, such as stacked Nanosheet transistors, offering superior short channel control and allowing performance scaling by increasing the number of nanosheet stacks, will be discussed. Also discussed will be the development status of vertically stacked device architectures that will eventually replace the conventional “horizontal” device architecture. The tutorial will also briefly review applications of CMOS for neuromorphic computing.

TEACHER BIO: Santosh K. Kurinec is a Professor of Electrical and Microelectronic Engineering at Rochester Institute of Technology (RIT). She is a Fellow of IEEE and a Member of the New York Academy of Sciences. She received her Ph.D degree in Physics from University of Delhi, India and worked as a Scientist at National Physical Laboratory, New Delhi. Her current research activities include advanced integrated circuit materials and photovoltaics. She received the 2012 IEEE Technical Field Award for integrating research in teaching to prepare microelectronic engineers for future challenges. She was inducted in the Women in Technology International Hall of Fame in 2018. She has over 120 publications in research journals and conference proceedings. She recently edited books on Energy Efficient Computing & Electronics: Devices to Systems, and Nanoscale Semiconductor Memories: Technology and Applications, and Emerging Photovoltaic Materials: Silicon & Beyond.