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EUV-IUCC Extreme Ultraviolet - Industry University Collaboration Center

EUV LITHO, INC.

Vivek Bakshi (EUV Litho, Inc.), Chair

Jinho Ahn (EUV-IUCC and Hanyang University), Co-Chair

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Abstracts

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SS1

LEGO like Multi-function Actinic tool for Cost-effective EUV Production

Byung Gook Kim and Dong Gun Lee

ESOL, Inc.

www.euvsol.com

ESOL is a company established to provide cost-effective solutions for anyone who wants to use innovative EUV technology to their R&D and mass production. As EUV enters the HVM era, various EUV actinic capabilities should be necessary for EUV mask shops, material providers, and chip makers. Developing various actinic tools for each specific application requires substantial investment resources, long delivery time, and large fab spaces at customer sites. Thus, ESOL proposes a more effective path to introduce EUV actinic solutions into potential EUV customers. ESOL has been developing EUV common platform on which various functions such as EUV mask defect review, EUV mask phase measurement, EUV reflectivity, EUV pellicle transmittance, and EUV resist patterning can be implemented. This platform acts like Lego to build customized and flexible actinic function. Once users engage with an ESOL platform, various actinic applications can be introduced depending on their specific demand. ESOL is willing to contribute to the semiconductor industry by lowering the entry barrier of EUV technology, making EUV technology more accessible to the industry.

Presenting Author

Byung Gook Kim received his B.S. and M.S. degrees in physical chemistry from Yonsei University and MBA degree from the Kelley School of Business, Indiana University at Bloomington in the U.S. He joined Samsung Electronics in 1995 as a photomask engineer. He has been a leader of various mask development projects and mask production for advanced lithography. He has authored and co-authored over 50 technical papers and invented more than 30 patents. He worked as an assignee of Lucent Bell Laboratory in the U.S. and SELETE (Semiconductor Leading Edge Technologies) in Japan. He is now a program committee member of SPIE photomask technology and committee member of Photomask Japan conference. He received several R&D achievement awards during his work at Samsung Electronics. He joined ESOL, Inc. as a CEO in 2019.

SS3

Development of EUV Mask Blank and EUV Pellicle

Gilwoo Kong

S&STECH

http://www.snstech.co.kr/renew/eng/

S&STECH has started research and development to target for localization of mask blank from 2001 finished development and research for mask blank background with superior manpower who gained abundant experience with semiconductor element and photomask company on June 2002 S&STECH is supplying mask blank to home and foreign semiconductor and photomask company with quality approval. Our R&D center successfully localized mask blanks for semiconductor in 2002 and display in 2005. Through continuous R&D and investment, we are developing cutting-edge mask blanks for semiconductors and displays. In addition, we have consistently succeeded in developing EUV pellicle, and beyond optical blank mask (EUV mask blanks), we are committed to develop the next generation technologies in EUV industries.

Research and development of EUV mask blanks and EUV pellicles is as follows:

- EUV mask blanks : LTEM, ABS, ML, CAP performance maximization
- EUV Pellicle : Optical / Thermal / Mechanical / Chemical characteristic optimization

Presenting Author

Gilwoo Kong is a Process Development Engineer with S&STECH's IC Advanced Technology Team. He joined S&STECH in 2016, and has over 10+ years of experience in semiconductor materials development. He received a M.D. in Advanced Materials Engineering from UCLA.

SS4

PAL-EUV Infrastructure to Support Material Evaluation

Sangsul Lee, Kanghyun Kim, Byeong-Gyu Park, Jangwoo Kim, Il-Hyung Lee, Jong-Won Lee, Geonhwa Kim, Jang-Hui Han, Ki Jeong Kim, Juho Hong, Hong-Gi Lee, Sei-Jin Kwon, Sangbong Lee

Pohang Accelerator Laboratory, POSTECH

POHANG ACCELERATOR LABORATORY

http://pal.postech.ac.kr

Due to the technical challenges in the EUV manufacturing process, technical advances in materials such as blank mask, pellicle and photo resist are needed. Securing EUV R&D infrastructure is also essential, EUV light and analytical infrastructure based on synchrotron can help develop EUV materials.

To overcome the shortage of EUV research infrastructures, Pohang Accelerator Laboratory (PAL), which operates Pohang Light Source-II (PLS-II) synchrotron and XFEL, plans to build related infrastructure to support EUV R&D work. PAL recently started basic research support such as photoresist evaluation and plan to support optical characteristics evaluation of blank mask, patterned mask and pellicle in the future.Through the showcase, we would like to share and discuss PAL's plans for EUV infrastructure construction, which will be operated separately from the existing synchrotron facilities.

Presenting Author

Sangsul Lee is the head of the PAL-EUV metrology and inspection at Pohang Accelerator Laboratory, POSTECH. He is also the chief technology officer of Xavisoptics, an X-ray solution and equipment company. He received PhD in materials science and engineering from the Hanyang University in 2012. He currently runs X-ray nanoscale imaging beamline and EUV test beamline at PAL. His research interest is synchrotron based nanoscale imaging such as EUV metrology, inspection and nanoscale tomography.

SS5

Role of EUV-IUCC (Industry-University Collaboration Center)

Jinho Ahn

EUV-IUCC & Hanyang University

https://euv-iucc.org/

EUV-IUCC (Industry-University Collaboration Center) is a non-profit organization supported by industry members. EUV-IUCC was organized in September 2019 to help member companies to initiate their business in the field of EUV Lithography through providing information, education, networking and research collaboration. During the presentation, the academic members, their research activities and main facilities will be introduced. And it will be also mentioned how we are collaborating with the member companies.

Current member companies: S&S Tech, FST, Youngchang Chemical, Nextin Solutions, SK Siltron, Taihan Fiberoptics, Dongwoo Finechem, PSK, Soulbrain, E-sol, Alpha Graphene, The Elec, PeDiSem, Gangwon Technopark

Presenting Author

Jinho Ahn received his B.S. and M.S. degrees from Seoul National University, and Ph.D. degree from the University of Texas at Austin all in Materials Science and Engineering. He worked for Microelectronics Research Laboratory at NEC, Tsukuba, Japan, and joined Hanyang University in 1995 as a professor of Materials Science and Engineering. He has been a leader of several national projects for advanced lithography. He has authored over 200 technical papers and invented more than 50 patents. He worked as a Director of Nano and Convergence Technology at National Research Foundation of Korea, and the Vice President of Academic Research, the President of Industry-University Cooperation Foundation at Hanyang University. He is now a Committee Member of National Science & Technology Council, Member of the National Academy of Engineering of Korea, and a board member of National Nano Infrastructure. He also works as a Director of EUV-IUCC since 2019. He received the Semiconductor Technology Lifetime Achievement Award in 2015 from the President of Korea.

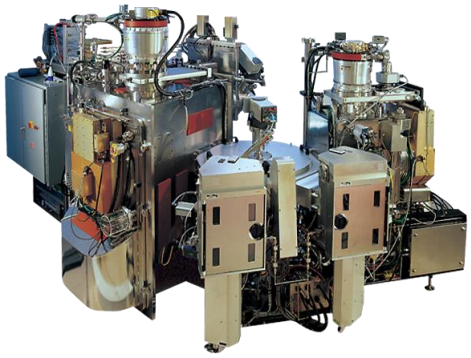
SS6

An Overview of Ion Beam Technology for EUV Photomask

Meng Lee, Katrina Rook

1 Terminal Drive, Plainview, New York 11803, USA

https://www.veeco.com/technologies-and-products/ion-beam-systems-and-sources/



EUV Photomask manufacturing demands the highest levels of particle control while depositing sophisticated multiple-layer film structures and Ru capping layer. These challenges are met with Veeco's Ion Beam Deposition System (IBD-LDD).
IBD-LDD key benefits:

- Production-proven platform
- Lowest defect density
- Excellent uniformity and repeatability
- High reflectivity
- Deposit multiple materials in same chamber
- Can be integrated into other process modules into a cluster too

In addition to Ion Beam deposition, Veeco ion beam etch is also a viable option for patterning of next generation EUV-mask absorber materials. This presentation provides an overview of Veeco Ion Beam technology enabling future EUV photomask requirements.

Presenting Author:
Meng Lee, Marketing director of EUV mask Ion Beam Deposition (IBE) and Ion Beam Etch IBE) product line.

SS7

Preparing for The Next Generation of EUV Lithography at the Center for X-ray Optics

Ryan Miyakawa

CXRO

THE CENTER FOR X-RAY OPTICS

http://www.cxro.lbl.gov/

The Center for X-ray Optics (CXRO) at Berkeley Lab has been a leader in EUV research for the past 25 years. Leveraging 13.5-nm EUV light from the Advanced Light Source synchrotron facility, CXRO is home to several EUV research tools that have provided important research insights into EUV resists, masks, and coatings.

The 0.5-NA MET5 is a newly commissioned projection lithography tool that is capable of printing feature sizes down to 8 nm half-pitch. A new radiation chemistry program is deploying several techniques aimed at dissecting the role of primary photo-electrons and secondary electrons in EUV resists. The SHARP microscope has been outfitted with anamorphic zone plate lenses which can emulate the geometry of next generation EUV scanners. And the reflectometer has been applied to new scattering experiments for the purpose of understanding the 3D effects of EUV mask multilayers as well as determining mask properties using scattering profiles. In parallel with these tools, the CXRO wavefront sensing program is developing high-resolution wavefront sensors suitable for measuring aberrations at high NA. This paper presents an overview of these programs and describes how they will address the primary challenges that face the EUV community as it moves to the next generation of EUV lithography.

Presenting Author

Ryan Miyakawa is a research scientist at CXRO specializing in EUV optical system modeling and design. After receiving his Ph.D. from UC Berkeley in 2011, Ryan's work has focused on the development wavefront sensors for next-generation EUV systems including the MET5 shearing interferometer, the AIS wavefront sensor on SHARP, and the zone plate test stand (ZTS).

SS8

Showcase of the Fundamental Research to Resolve the Technical Issues in EUV Lithography at NewSUBARU Synchrotron Light Facility of University of Hyogo

Takeo Watanabe

Center for EUVL,
Laboratory of Advanced Science and Technology for Industry,
University of Hyogo

https://www.lasti.u-hyogo.ac.jp/sr-nanotechnology/index-e.html

As described on the IRDS roadmap, logic foundry producers have used EUV lithographic technology to adapted in HVM from 2019. However, the technical issues remain which are 1) EUV resist which satisfy high resolution, high sensitivity, low LER, and low outgassing, simultaneously, 2) pellicle with high transparency and long lifetime, 3) defect free EUV mask fabrication, and 4) high power and stable EUV light source.

Since 1995, EUV R&D has been started at the middle size NewSUBARU synchrotron light source of University of Hyogo, which is the largest synchrotron facility operated by university in Japan. Up to now, many significant technology research and development in EUV lithography were done by our research group. The showcase for resolving EUVL technical issues will be presented for the wide range technologies including resist, mask, pellicle, optical element evaluation, and so on. For the resist, it is including that the sensitivity under EUV and OoB exposure, outgassing, in-situ contamination growth, patterning using EUV-IL, chemical reaction analysis using synchrotron, and so on. The most significant issue in EUV resist is to achieve low LWR. And to achieve it, the spatial distribution of the chemical contents of EUV resist should be uniform. Thus, it is introduced that the soft X-ray resonant scattering method in transmission mode to measure the chemical contents spatial distribution in a EUV resist film. In addition, preventing from the pattern collapse is necessary to achieve high resolution, the adhesion control is needed for the fine pattern achievement. Thus, it is introduced that the layer analysis method in EUV resist film using the soft X-ray resonant scattering method in transmission mode. For the mask, it is including that the defect inspection using bright field EUV microscope and coherent EUV scatterometry microscope, outgassing, multilayer reflectivity measurement using EUV and OoB light, material stability under high power EUV light in hydrogen and water vapor atmosphere. In addition, for the collector mirror reflectivity measurement in the significant usage for EUV LPP light source, the large reflectometer is presented.

Presenting Author

Takeo Watanabe received his Ph.D. from Osaka City University in 1990. He is dean of Laboratory of Advanced Science and Technology for Industry, Director of Center for EUV, Full Professor, at University of Hyogo. He is an expert of the EUV lithographic technology, including optics, exposure tool, mask, and resist technologies. He has authored over 200 technical papers, and has many patents related to EUV lithography.

He is international affair, the organizing and program committee members, of the International Conference of Photopolymer Science and Technology (ICPST). He is also Chair of organizing committee of the International Conference of Photomask Japan. And he is a program committee member of the International Conference on Electron, Ion, and Photon Beam Technology and Nanofabrication (EIPBN).

SS9

Advanced Tools & Infrastructure for R&D and Prescreening of EUV Resists and related Design and Fab of Electronic Devices at Indian Institute of Technology (IIT) Mandi, India

Kenneth E. Gonsalves [a,#]

Indian Institute of Technology at Kamand
[a]School of Basic Sciences & bSchool of Computing & Electrical Engineering, cCenter for Design & Fabrication of Electronic Devices (C4DFED), IIT Mandi Himachal Pradesh 175075, India
[#]Davidson, NC USA

www.iitmandi.ac.in *www.photoresistgroup.com*
www.c4dfed.com

Since EUV photons are still scarce and expensive, protocols based on readily available Electron Beam Lithography (EBL), Helium Ion Beam Lithography (HIBL) tools and FESEM/AFM for metrology have been developed in-house for screening resists for sensitivity, CD, LER/LWR, etch. A cost and time effective prelude to successful EUV patterning. One of the key metrics for EUV resist is the sensitivity towards EUV radiation. However, it is observed that the exposure energy within the resist film is mainly responsible for the chemistry. This applies to both high KeV electrons, He+ ions and EUV photons. Thus EBL (and more recently HIBL) have been demonstrated as rapid inexpensive approximating experimental tools for simulating EUVL for resists prescreening.

State-of-the-art clean synthesis labs, materials characterization facilities at a:Advanced Materials Research Center (AMRC), class 100 clean room at b: Center for Design and Fabrication of Electronic Devices (C*4*DFED) with all relevant major tools EBL, HIBL, FESEM, AFM, Ellipsometry, RIE are available onsite. Industrial outreach for R&D for rapidly screening potential resists for EUV based on *ab initio* synthesis or modifications thereof are possible due to in-house synthesis labs and extensive materials characterization tools ranging from NMR/IR/XPS/HRTEM/XRD to MWD by GPC/DLS, separation chromatography, thermal analysis amongst others. Device design and fab are also the expertise of C*4*DFED professional staff and engineers along with device testing leading to implementation. In addition to EUV, resists for industrial DUV/MUV/EBL/HIBL have also been successful. Highly trained experienced personnel, organic/inorganic chemists, physicists and engineers are available for various projects related to the above objectives.

Presenting Author

Kenneth E. Gonsalves is Visiting Distinguished Professor at IIT Mandi since Jan 2012 to the present. Prior to that he was the Celanese Acetate Distinguished Professor of Polymer Science at UNC Charlotte, North Carolina USA. He also served as Associate Director S&T oversight for Americas, Office of Naval Research Global from 2009 to 2011. He is the author and or editor of over 300 publications, several technical proceedings/monographs and numerous patents primarily in resist technology. His projects have been funded by NSF, DARPA and several industry related to resist technology, e.g., SEMATECH, Intel, Rohm and Haas/Du Pont. Projects for advanced resists have also been funded by DST, MHRD as well as industry in India.

SS10

Solutions for Actinic EUV Stand-alone Metrology Tools based on Available Building-blocks and Experience

A. Biermanns-Föth, C. Pampfer, T. Missalla, C. Phiesel, C. Piel , R. Lebert

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https://research-instruments.de/

With the EUV high volume manufacturing becoming reality there is a growing need for actinic, at EUV wavelength, stand-alone metrology tools for qualifying crucial elements in the EUV supply chain, such as EUV masks, pellicles, resists and optics.

For the actinic qualification of such components and elements with 13.5 nm radiation few off-the-shelf metrology tools are readily available. Often, a novel qualification method is required.

At RI Research Instruments we design, manufacture, test and deliver systems and solutions based on existing building blocks and tailored to the needs of our customers. RI's EUV application experience is based on a broad source portfolio with stand-alone DPP and LPP sources for XUV together with an established supply chain in advanced EUV optics, detectors and spectral filtering. We have 20 years of experience in design, machining and assembly of ultra-clean components in ultra-high vacuum and cleanroom applications, including ultra-clean sample handling, loading and manipulation. Our stand-alone tools offer fully automated, fail safe electronic control including custom tailored data evaluation and reporting solutions.

Applying this expertise actinic tools for the EUV-lithography infrastructure were built, as e.g. EUV mask blank reflectometers for spectral reflectometry and fast, full area inband EUV reflectance mapping, EUV Pellicle Reflection and Transmission Tools, Nano-printing tools and sensitivity calibrated stand-alone resist exposer. Concepts, use of building blocks and results are presented.

EUV Pellicle reflection and transmission tool

EUV mask blank reflectometer
Inserts: AIMER Reflectivity map and reflectance curves over blank

Presenting Author

Andreas Biermanns-Föth is Business Manager for EUV Systems and Photon Instrumentation at RI Research Instruments. He received his PhD in Physics at the University of Siegen, working on the characterization of semiconductor nanostructures. In his scientific career he has been developing synchrotron-based nano-focusing techniques and novel coherent diffraction methods. After joining RI Research Instruments as project manager in 2014, he has been focusing on developing custom tailored EUV metrology tools for the semiconductor supply chain.

SS11

Energetiq EUV Light Sources

Sam Gunnel

Energetiq

https://www.energetiq.com/

Energetiq's EUV light sources are the industry standard source for EUV infrastructure R&D, inspection, resist development, outgassing, mirror testing, and more. The Electrodeless Z-Pinch™ EUV Source is a reliable and stable source of EUV photons and is being operated in the field 24/7 with consistent operation over many years. This talk focuses on how this light source is used to overcome fundamental obstacles and advance research, enabling the introduction of EUV lithography to high volume manufacturing environments.

Presenting Author

Sam Gunnell is a Product Manager at Energetiq Technology, focused on EUV light sources for semiconductor applications. Before becoming a Product Manager, Sam served as Energetiq's Technical Sales Engineer for both Laser-Driven Light Source and EUV light sources.

SS12

Rigaku EUV Optics and Detector Technology

Peter Oberta

Rigaku Innovative Technologies Europe s.r.o.
Novodvorská 994, Praha 4, 142 21, Czech Republic

https://www.rigaku.com/division/rigaku-innovative-technologies-europe-sro

This commercial presentation is an overview of the EUV applicable optics and detectors RITE can offer. RITE was established in 2008 as a Rigaku Corporation R&D center in Europe. One of the three RC research units worldwide. RITE is producing lens coupled and fiber coupled X-ray cameras. The lens coupled camera has the highest real spatial resolution on the market. Another core product is replicated optics, which is a rotationally symmetric optics used as a collector (elliptical shape) or collimator (parabolic shape). Newly available is also Wolter shape optics. Various metallic single layer coatings, including e.g. gold and ruthenium, are available.

Presenting Author

Peter Oberta made his PhD in physics in the field of X-ray optics. Has working experience from the Swiss Light Source, where he was responsible for optics beamline layout design. At Rigaku his responsibilities are sale and R&D project management.

SS13

Nanostructured optics for EUV and X-ray applications

Floriam Doering

XRnanotech

https://www.xrnanotech.com/

XRnanotech is a spin-off company from the Paul Scherrer Institut in Switzerland that designs and fabricates innovative EUV and X-ray optics. With our advanced nanofabrication processes, we are able to structure a variety of materials allowing accessing a wide range of the electromagnetic spectrum. For EUV applications at synchrotrons and free electron lasers, we offer diffractive optics with high resolution and unique functionalities.

Presenting Author

SS14

TEUS: Laser-produced Plasma EUV Light Source with High-brightness and Low-debris

Slava Medvedev

ISAN

https://isan.troitsk.ru/en/

Companies of RnD-ISAN group (EUV Labs, TRDC and ISTEQ) have developed and started manufacturing the TEUS (Tin Extreme Ultraviolet Source) product line. TEUS technology is based on a laser-produced plasma (LPP) source employing a high-speed rotating target. The fast rotating target provides the following important features of the source: 1) redirection of the droplet debris away from both the EUV and laser light channels, 2) undisturbed target surface for a high rep rate laser system (up to 1 MHz), 3) excellent inherent source spatial stability. The fast target rotation in combination with the magnetic field, gas protection systems and membrane filter allow effective mitigation of the LPP debris thus enabling the production of ultimately clean EUV photons. Depending on the power of the driving laser radiation and the EUV source size, the brightness of the source at the operating wavelength of 13.5 nm varies in the range of 100 - 1000 W/mm^2-sr.

The TEUS product line has been designed for service and reliability, with high uptime and most of all for a long collector lifetime hence a low cost of ownership (CoO). Currently, the partners are manufacturing three EUV sources according to specific customers' requirements. These sources will be delivered to customers early Q1-2021.

Besides EUV sources, we also manufacture ultrabright broadband UV-VIS-NIR light sources (XWS product line) based on continuous optical discharge and custom-design spectral metrology equipment for X-ray, EUV and longer wavelengths.

Presenting Author

SS15

EUV Interference Lithography @ PSI: A platform for EUV resist testing

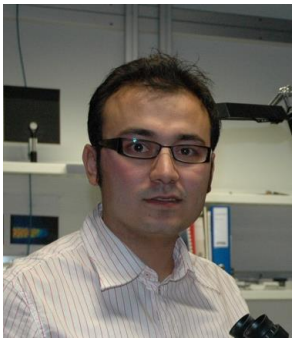
Yasin Ekinci

Paul Scherrer Institute, Switzerland

https://www.psi.ch/en/lmn

EUV lithography entered into the high-volume manufacturing (HVM) phase in 2019, and the development of the high-NA EUV scanner is in its way. To ensure the introduction of high-NA EUVL to HVM, the development of EUV resists that could deliver the required resolution, line-edge roughness, and sensitivity is essential, which is a significant challenge. To improve the performance of EUV resists for high-NA, it is crucial to develop, evaluate, and understand the underlying mechanisms of EUV resists. EUV interference lithography (EUV-IL) has been an effective method for almost two decades to evaluate the resist performance. The advantages of this technique are its resolution, flexibility and simplicity. The XIL-IL PSI's platform has achieved a record resolution of 6 nm HP. In this presentation, I will provide detailed information about the tool and how we contribute to the global resist development programs.

Presenting Author



Yasin Ekinci is head of the Laboratory of Micro and Nanotechnology at Paul Scherrer Institute, Switzerland. He obtained his PhD in Max-Planck Institute for Dynamics and Self-Organization, Göttingen, Germany in 2003. In 2004, he joined Paul Scherrer Institute as a postdoctoral researcher. Between 2006 and 2012 he worked as a postdoctoral researcher and subsequently as a senior scientist and a lecturer in Department of Materials at ETH Zürich. He is at PSI since 2009 working on various topics of nanoscience and technology, including EUV lithography, resist materials, lensless imaging, plasmonics, semiconductor nanostructures, and nanofluidics. He is author/co-author of more than 200 papers and 7 patent applications. He is a fellow of SPIE.

SS16

Synchrotron-radiation based EUV metrology at PTB

Michael Kolbe, Victor Soltwisch, Frank Scholze

Physikalisch-Technische Bundesanstalt (PTB),Berlin, Germany

https://www.ptb.de/cms/en/ptb/fachabteilungen/abt7/fb-71/ag-712.html

PTB is the German national metrology institute. It supports cooperation partners from industry and science with metrological capabilities and know-how within joint research projects. PTB uses synchrotron radiation in the THz, IR, UV, EUV, VUV, and soft X-ray spectral ranges at the electron storage rings Metrology Light Source (MLS) and BESSY II for basic and applied metrological tasks. For more than 20 years, the EUV-Radiometry group develops and provides metrology services for the characterization of optical components and radiation detectors as well as the measurement of optical material properties in the spectral range from 1 nm to 40 nm. It is worldwide recognized as a well-established partner for EUV metrology. PTB uses its synchrotron radiation laboratories also for lifetime investigations of optical components and radiation detectors. PTB offers services to determine the spectral responsivity of radiation detectors with traceability to a cryogenic radiometer as a primary detector standard in the full spectral range from UV to X-ray. The EUV-Radiometry group uses two measurement stations at the storage rings BESSY II and MLS: an EUV reflectometer which can accommodate large optical components like collector mirrors for EUV plasma sources, and an EUV Ellipso-Scatterometer for reticle-size samples supporting measurements of reflection and scattering under arbitrary polarization conditions.

The EUV nanometrology group develops methods for the actinic characterization for EUV optical components, e.g., the surface and interface roughness of multilayer mirrors can be characterized by resonant diffuse EUV scattering. It also investigates methods for the characterization of nanostructured surfaces, e.g., on wafer, by EUV and soft X-ray scattering and fluorescence.

Presenting Author

Michael Kolbe received his Ph.D. (focusing on X-ray based analysis) in 2002. Since 2003 he is a scientist at PTB focusing on Metrology with synchrotron radiation. His research activities include X-ray spectrometry, UV/VUV radiometry, and EUV radiometry. Based on these activities, he accumulated expertise in employing analytical techniques in the UV to soft X-ray spectral range. In 2020 he became head of PTB's EUV radiometry group.

SS17

High Power EUV Sources, EUV Nanostructuring and Metrology Services at Fraunhofer ILT

Serhiy Danylyuk, Jochen Vieker, Klaus Bergmann

Fraunhofer Institute for Laser Technology - ILT
Steinbachstr. 15, 52074 Aachen, Germany
Lukas Bahrenberg, Sophia Schröder, Sascha Brose
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Steinbachstr. 15, 52074 Aachen, Germany

https://www.ilt.fraunhofer.de/en.html

Fraunhofer ILT has been active in the field of EUV research and development for more than 2 decades. In collaboration with Philips and Ushio, ILT has substantially contributed to the development of discharge based source-collector modules, which have been integrated in the first EUV lithography scanners for chip production. Further development of this source technology towards a more compact form factor has not only resulted in the 40W-class FS5440 EUV source, but also powered the development of several industry-relevant applications of EUV radiation.

As a result, ILT is uniquely equipped to perform measurement services and investigations in almost all aspects of EUV technology development. Resist tests, actinic mask and pellicle inspection, narrow-band and broadband EUV reflectometry for optics characterisation, accelerated lifetime testing of in-beam components and corresponding modelling and analysis can all be performed in-house with high accuracy and reproducibility.

Beyond the general overview of capabilities, this presentation will focus on two recently developed test processes: Dual-beamline (high throughput broadband and in-band 13.5 nm) operation of the EUV laboratory exposure tool (EUV-LET) for resists characterization and the utilisation of broadband EUV reflectometry for high-sensitivity CD metrology at future lithography nodes.

Presenting Author

Dr. Serhiy Danylyuk received his diploma in physics from Volyn State University, Ukraine, in 1999. In 2005, he obtained his Ph.D. in semiconductor physics from RWTH Aachen University in Germany. Between 2005 and 2008, he was a post-doctoral researcher at the Research Center Juelich in Germany. In August 2008, he joined the Chair for Technology of Optical Systems at RWTH and from 2011 to 2019 he led the EUV Technology group in which he worked on applications of EUV radiation for nanopatterning, microscopy and thin film characterization. He joined Fraunhofer ILT in 2019 to further drive EUV technology towards industrial application. He is an author and co-author of more than 90 scientific publications in the fields of semiconductor physics and applications of short-wavelength radiation.

SS18

NIST At-wavelength EUVL metrology

C. Tarrio, R. E. Vest, R. F. Berg, T. B. Lucatorto

NIST, Gaithersburg, MD, USA

https://www.nist.gov/laboratories/tools-instruments/beamline-7-euv-reflectometry

At the National Institute of Standards and Technology we have been involved in extreme-ultraviolet metrology for over 50 years and more specifically in direct support of the developers of EUV Lithography for 30 years. Our program began with characterization of EUV detectors and other optical elements. In the last couple of decades, we have responded to the needs of the EUVL community by developing a more specialized suite of capabilities including accurate reflectometry of large mirrors, pulsed detector measurements, and contamination measurement and modeling. We will describe our capabilities and offer a few recent highlights.

Presenting Author

SS19

TNO, R&D service provider for the EUV Semicon Industry

Norbert Koster

TNO

https://www.tno.nl/en/focus-areas/industry/roadmaps/semiconductor-equipment/

TNO is an independent research institute partly funded by Dutch and European governments to support the industry with innovation and new technologies. The majority of the projects for industrial applications are based on contract research and are company confidential. TNO has been and still is in close cooperation with ASML and Carl Zeiss since the beginning of the EUV development in 2000. Much of the knowledge developed by TNO is now being used for screening of materials and modules for EUV applications. TNO continues to invest in cooperation with the main players in EUV resulting in a strong background, knowledge, skills and facilities for the EUV community. TNO is capable of performing EUV exposures and contamination experiments to understand the damage mechanisms occurring in a.o. EUV optics, masks, pellicles and new absorber materials as well as realization of sensors and opto- mechatronic (sub)systems for equipment makers and realization of lab-tools. As independent organization TNO offers a high degree of reliability, flexibility, openness and transparency while respecting the required secrecy of research results for individual customers

Presenting author

Norbert Koster is Principal Scientist at TNO in the group for Nano-instrumentation, he has worked in vacuum technology and EUV lithography since 1992. After graduation he worked at the former FOM Institute for Plasma Physics Rijnhuizen. There he was involved in the fabrication and optimization of Multilayer Mirrors for EUVL applications and space astronomy as well as the improvement of the deposition tools. In 1999 he started at TNO as vacuum engineer. Together with ASML and partners he stood at the birthplace of the EUV Alfa demo tools and their successors. During his career he developed interest in vacuum engineering, systems engineering and contamination control. As Principal Scientist he is involved in projects for EUV Lithography, plasma technology, contamination control, nuclear fusion (ITER). His current topic of interest is contamination control for optical systems which use highly energetic particles like ions, electrons and photons. Recently he was deeply involved in the realization of a new EUV exposure facility (EBL2) for EUV optics lifetime research at TNO in Delft.

SS20

Transmission Grating Spectrometer for Broadband Spectroscopy of EUV Light Sources

Muharrem Bayraktar

Industrial Focus Group XUV Optics, MESA + Institute for Nanotechnology
University of Twente, The Netherlands

https://www.utwente.nl/xuv/

Extreme ultraviolet (EUV) lithography light sources are designed to supply narrowband EUV light (13.5 nm ± 1%) that is matching the transmission spectra of the optics and sensitivity of the photoresist. On the other hand, the source emission inevitably contains radiation outside the desired wavelength band, extending into the deep ultraviolet (DUV) and visible/IR range. This undesired radiation may influence the lithography process by causing contrast loss in the exposed photoresist or heat load on the delicate optics. Moreover, spectral characteristics of the in-band and out-of-band ranges contain a wealth of information about the conditions of the plasma. A broadband spectral diagnostic can assess the conditions of the plasma towards optimizing it for higher in-band and lower out-of-band emission. Here we present a compact, broadband spectrometer based on a set of free-standing transmission gratings that can be reconfigured to record EUV and DUV/visible bands without breaking the vacuum. The recorded spectra can be immediately related to specific charge states in the plasma allowing optimization of the source conditions.

Presenting Author

Muharrem Bayraktar earned his BSc degree from Bilkent University in 2007, MSc degree from Sabanci University in 2010 and PhD degree from University of Twente in 2015. He is working as an assistant professor in the Industrial Focus Group XUV Optics in University of Twente since 2019. His research explores broadband spectroscopy techniques for Extreme Ultraviolet (EUV) light sources and novel adaptive optical components based on piezoelectric thin films.

SS21

An Overview of EUVL Bandpass Capabilities at Luxel Corporation

Travis Ayers

Luxel

https://luxel.com/products/generalfilters-8/

Founded in 1973, Luxel Corporation offers a wide variety of bandpass filters for Soft X-ray and EUV wavelengths. Our first spaceflight application was for the Apollo X-ray Telescope that flew on Skylab. In the following years, Luxel expanded into other applications including laser targets, synchrotron beamline filters, pressure windows, and electron microscopy supports. The first zirconium filter for EUV lithography was produced for the Engineering Test Stand at Sandia National Lab in the early 2000s and today, Luxel offers a wide variety of materials for EUV Lithography applications with a large installed base throughout the world.

Presenting Author

Travis Ayers is President and owner of Luxel Corporation. He holds a Mechanical Engineering degree from the University of Colorado and an MBA from the University of San Francisco. Prior to purchasing Luxel, he worked in the semiconductor industry producing wire-bonding consumables. Outside of work, Travis is also passionate about aviation. He often flies himself from San Juan Island, WA to various destinations for work and pleasure.

SS22

Patterning and Process Resources and Requirements for Future MRAM Products

Thomas Boone

Spin Memory

WWW.SPINMEMORY.COM

The emerging memory technology, Magnetic Random Access Memory (MRAM), is the most promising option for replacing embedded Flash and eSRAM in the near future. Spin Memory Inc. is a leading innovator of this enabling technology and is currently developing HiRel memory products for the Defense and Aerospace industry. One of the unique challenges facing MRAM is the requirement for very high resolution patterning and fabrication near the back-end of wafer manufacturing. In this presentation we will review Spin Memory's innovative IP and resources including the Spin Technology Center located in Fremont, CA. This site includes a unique 200 mm BEOL class 100 fabrication line and full wafer characterization/testing facility. The cornerstone of the Center's fabrication capability is the JEOL 9500 E-beam lithography system, which is coupled with 248 nm scanning photolithography for larger features. Spin's testing capability is uniquely specialized in MRAM device and magnetic materials characterization and leverages the company's custom 4Mb memory test chip design to rapidly evaluate MRAM process experiments. We will review the company's progress in this space and discuss how EUV photolithography will likely impact MRAM products in the future.

Presenting Author

Thomas Boone is the Senior Director of the Defense and Aerospace Business for Spin Memory, Inc. in Fremont, CA. He joined Spin Memory in 2012 and has held director level positions in nanofabrication, photolithography, test and reliability before transitioning to his current role in managing the company's HiRel product business for military and space applications. Currently his team is developing strategic rad-hard memory products for the U.S. DoD and space industry. Before joining Spin Memory, Tom was a lead technologist for the optoelectronic development of Heat Assisted Magnetic Recording at HGST, a Western Digital Company. Previously, he spent 5 years building and managing the photovoltaic device design and testing team at the thin film solar power company SoloPower. Prior to this period, he was a Research Staff Member at Hitachi Global Storage Technologies, where his contributions resulted in three separate world record recording areal density demonstrations for hard disk drive technology. He has spent over a decade within the magnetic data memory and storage industry and has over 25 patents and 30 peer reviewed journal articles. He received his Ph.D. in Electrical Engineering and Applied Physics from Yale University in 2004, an M.S. Electrical Engineering from Purdue University in 1997 and his B.S. in Electrical Engineering from the University of Texas at Arlington in 1994.

SS23

Update of >300W High Power LPP-EUV Source Challenge for Semiconductor HVM

Hakaru Mizoguchi, Hiroaki Nakarai, Tamotsu Abe, Hiroshi Tanaka, Yukio Watanabe, Tsukasa Hori, Yutaka Shiraishi, Tatsuya Yanagida, Georg Soumagne, Tsuyoshi Yamada and Takashi Saitou

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https://www.gigaphoton.com/en/

Gigaphoton develops CO_2-Sn-LPP EUV light source which is the most promising solution as the 13.5nm high power light source for HVM EUVL. Unique and original technologies including; combination of pulsed CO_2 laser and Sn droplets, dual wavelength laser pulses for shooting and debris mitigation by magnetic field have been applied. We have developed first practical source for HVM; "GL200E" [1]) in 2014. Then it is demonstrated which high average power CO_2 laser more than 20kW at output power in cooperation with Mitsubishi Electric[2]). Pilot#1 is up running and it demonstrates HVM capability; EUV power recorded at 111W on average (117W in burst stabilized, 95% duty) with 5% conversion efficiency for 22 hour operation in October 2016[3]). Availability is achievable at 89% (2 weeks average), also superior magnetic mitigation has demonstrated promising mirror degradation rate (= 0.5%/Gp) at 100W or higher power operation with dummy mirror test. We have demonstrated >300W operation data (short-term) and actual collector mirror reflectivity degradation rate is less than 0.15%/Gp by using real collector mirror around 125W (at I/F clean) in burst power > 10 Billion pulses operation[4]). Also we will update latest challenges for >250W average long-term operation with collector mirror at the conference.

REFERENCE
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4) Hakaru Mizoguchi et al.:" Challenge of >300W high power LPP-EUV source with long collector mirror lifetime for semiconductor HVM", Proc. SPIE 11323, Extreme Ultraviolet (EUV) Lithography XI (2019) [11323-28]

Presenting Author

Hakaru Mizoguchi is a Senior Fellow in Gigaphoton Inc., Fellow of The International Society of Optical Engineering (SPIE), and member of The Laser Society of Japan and The Japan Society of Applied Physics. He received a diplomat degree in plasma diagnostics field from the Kyushu university, Fukuoka, Japan in 1982 and join Komatsu ltd. He joined CO2 laser development program in Komatsu for 6 years. After that he was a guest scientist of Max-Plank Institute Bio-Physikalish-Chemie in Goettingen in Germany 2 years, from 1988 to 1990. Since 1990 he concentrated on KrF, ArF excimer laser and F2 laser research and development for lithography application. He was general manager of research division in Komatsu Ltd. until 1999. He got PhD degree in high power excimer laser field from Kyushu university in 1994. In 2000 Gigaphoton Inc. was founded. He was one of the founders of Gigaphoton Inc.. From 2002 to 2010 he organized EUV research group in EUVA program. Now he is promoting EUV light source product development with present position. He got Sakurai award from OITDA Japan in 2018.

SS24

Multitrigger (MTR): An Irresistible Photoresist

Warren Montgomery[1,3], Mark Shepherd[1], David Ure[1], Alex Robinson[1], Alexandra McClelland[1], Carmen Popescu[1], Alan Brown[1,,] Tom Lada[2], John Roth[2], and Ed Jackson[2]

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Over the past few months, the World has been grappling with issues associate with the pandemic. Irresistible Materials Ltd has not been an exception to this worldwide slowdown. However, IM has been able to make progress in spite of the slowdown. IM's product portfolio includes high Carbon content Spin on Carbon (SoC) materials and a highly tunable new EUV resist platform which we have named Multitrigger (MTR). I focus here on MTR resist which has proven that it is a flexible platform capable of high sensitivity, excellent CD resolution, and continuous improvement in the key metric needed for EUV insertion. MTR, which happens to be a multi-wavelength capable system, continues to show that it is a viable approach to EUV lithographic patterning. The information, which I will show, has been generated on a multiplicity of EUV sources.

In this presentation, I will update you on the latest performance we have obtained and give a brief overview of our 'irresistible' product offerings.

Presenting Author

Warren currently working with Irresistible materials in several roles. He is doing account management, technical materials development, commercialization and strategy. Formerly, as VP of Technical and Consortia Program Development at CNSE (formally Albany Nanotech), Warren led process development efforts associated with new photoresists focused on EUV lithography. Prior to CNSE, Warren worked at Applied Materials, LSI Logic, ASML, AZ Microelectronic and IBM in various technical and leadership roles related to photoresist processes and lithography. During his extensive career in Lithography, Warren has written over 50 technical and marketing publications and been awarded 30 US and European patents: primarily focused on lithography materials and processes. Warren served as BACUS President and Conference Chair. He has a B.S. in Chemistry from Marist College, a B.S. Business Administration from Mount St. Mary College, a graduate certificate in Program Management from SUNY Empire State College and an MBA from City University.

SS25

optiXfab Product Review

Torsten Feigal

optiXfab

http://www.optixfab.com/

Presenting Author

SS26

Advanced Multilayer Coating and High-quality Cleaning – Process Equipment for EUVL

Marcel Demmler

scia Systems

https://www.scia-systems.com/

scia Systems provides precise surface processing equipment based on advanced ion beam and plasma technologies. Especially for EUVL applications we designed equipment for multilayer deposition on large area substrates. In addition, we have expertise in high-quality cleaning and qualification systems for substrates with up to three meter diameter.

Presenting Author

Marcel Demmler graduated in Physical Engineering in 2007. After his graduation, he had a position in the R&D team in a company specified in ion beam and plasma process technologies. In 2011 he started working as a Sales Director for the US and Japanese markets in that company. Marcel Demmler joined scia Systems as Sales Director right from the beginning in 2013.

SS27

Solutions for EUV Mask Making (KEYNOTE PRESENTATION)

Thomas Scherübl

Zeiss SMS

www.zeiss.com/mask-solutions

EUV lithography is currently on its way to production. As in optical lithography the photomask is a key element in achieving best chip performance and yield. ZEISS Semiconductor Mask Solutions (SMS) provides solutions for mask manufacturing already for more than a decade. Compared to optical masks, EUV mask making has specific challenges for the mask maker. Most important is to deliver a defect free mask. This requires adequate repair processes to in place. The repair success must be verified by using Aerial Imaging Technology where the mask is analyzed under scanner conditions. Another challenge arises from mix and match of EUV and DUV. As EUV and DUV scanner have complete different set-up, the correction of overlay errors is limited. In this presentation an overview about mask EUV challenges and solutions as well as related technologies offered by ZEISS Semiconductor Mask Solutions (SMS) will be given. Focus will be repair solutions using e-beam based mask repair in combination with a EUV Aerial Imaging Measurement System (AIMS™ EUV). Finally, mask registration metrology and technologies to correct scanner intrafield overlay contributions in the case of DUV EUV mix and match will be discussed and presented.

Presenting Author

Thomas has more than 20 years' experience in the semiconductor industry. After joining ZEISS in 1996 as a scientist, his first position related to photomasks was the lead of system engineering and development of AIMS® systems (at this time for DUV). Since then Thomas held various management positions at ZEISS in R&D and engineering as well as in product and product line management for photomask products. Currently, Thomas is Head of Field of Business Mask Tuning and Head of Product Strategy and Strategic Business Development at ZEISS Semiconductor Mask Solutions (ZEISS SMS).

SS28

Ultra Clean Contactless Vacuum Handling

Herbert Wituschek

Mafu Robotics, Rosenfeld, Germany

https://www.mafu-robotics.de/index.php/en/home-kopie-22132576.html

Mafu Robotics is a supplier for Ultra Clean Handling solutions in vacuum and atmosphere. An innovative, particle and lubrication free transport system for HV and UHV applications based on a highly advanced planar motor will be presented. Major benefits, like flexibility, cleanliness, the absence of friction and wear will be shown in combination with layout examples. Loadlocks for wafers and reticles will be shown on one side and interfaces to deposition, etch and metrology tools on the other side to complete the system. A short video will give an impression of the flexible and dynamic performance.

Presenting Author

Herbert Wituschek has a PHD in Physics. He has been at MAFU Robotics for two years. He has experience in Ion Implantation and PVD. He also had 30 years of experience in automation and 20 years of experience in vacuum handling. He has been involved for 10 years in EUVL.


EUV
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