Bruce W. Smith, Ph.D.

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Microelectronic Engineering Department
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EXPERIENCE SUMMARY

- Rochester Institute of Technology, Professor of Microelectronic Engineering, 1988 – present
  Intel Professor of Research and Technology (RIT), 2000 - present
  Associate Dean of Graduate Programs, Kate Gleason College of Engineering, 2001 – 2004
  Director, Center for Nanolithography Research, 2004 - present
- Lithographic Technology Corp, Amphibian Systems, President / CEO, 1998 - present
- IMEC at University of Leuven, Belgium, Visiting Professor, 2001
- International SEMATECH, Austin Texas, Visiting Scholar, 1997
- Rutherford Appleton Laboratories, Oxford, U.K., Visiting Scientist, 1995
- Digital Equipment Corp., Hudson, Mass., Advanced Development Center, 1986-1988
- Gould AMI Semiconductor, Santa Clara, Calif., Process Development Group, 1983-1986

EDUCATION

- B.S., M.S. Rochester Institute of Technology, Photographic and Imaging Science, Thesis: "Optically Transparent Heat Mirror Films of ZnS-Ag-ZnS," 1988.
- Ph.D., Rochester Institute of Technology, Center for Imaging Science, Thesis: "Excimer Laser Microlithography at 193nm," 1994.

ACADEMIC ACTIVITIES

- Professor of Microelectronic Engineering at RIT, teaching graduate and undergraduate course sequences in Microlithography Systems - optics, optical lithography, Fourier optics, linear systems, non-optical lithography, image evaluation, image modelling; Microlithography Materials and Processes – polymer chemistry, photochemistry, photoresist systems, multilayer materials, processing, and process modelling
- Developed distance learning courses in Microlithography Materials and Processes (I) and Microlithography Systems (II) Masters of Engineering and Masters of Science degree programs in Microelectronic Engineering.
- Associate Dean of Graduate Programs, College of Engineering, 2001-2004
- Core Faculty Member, Microsystems Engineering, Ph.D. program, RIT College of Engineering
- Graduate Faculty of the Materials Science and Engineering Program, RIT College of Science
- Extended Faculty, Ph.D. program, Center for Imaging Science, RIT College of Science
- Advise student research in areas including immersion lithography, evanescent wave imaging, UV/VUV lithography, aberration theory, illumination systems, photopolymeric materials, lithographic modeling and simulation, UV optical thin films, microlithographic processing with various organization
- Department Representative for College of Engineering (COE) Tenure Committee (2000-2002), COE Co-op Committee (1999-present) and COE Graduate Committee (2001-present)
- College of Engineering Representative, University Graduate Council (2001-2004)
- College of Engineering Representative, Intellectual Property Committee (2001-2004)

GRADUATE STUDENT ADVISING

- Peng Xie – PhD Microsystems Eng
- Anatoly Bourov - PhD Imaging Science / MS Microelectronics Eng (2002)
- Andrew Estroff - PhD Microsystems Eng
- Yongfa Fan - PhD Microsystems Eng (2005) / ME Microelectronics Eng (2003)
- Neal Lafferty - PhD Microsystems Eng
- Lena Zavyalova – PhD Imaging Science / MS Imaging Science (2001)
- Jianming Zhou - PhD Microsystems Eng / MS Microelectronics Eng (2005)
- Frank C. Cropanese - MS Imaging Science (2005)
- Hoyoung Kang - PhD Imaging Science (2005)
- Yang Liu – MS Materials Science (2004)
- Ralph Schlief - MS Imaging Science (2000)

- Michael Cangemi - MS Imaging Science (2005)
- P. Venkataraman - MS Imaging Science (2002)
- Lay-Cheng Choo - MS EEE Nanyang Technological University, Singapore (1999)
- Fumikatsu Uesawa - Visiting student, Sony, Japan (1997)
- Shahid Butt - MS Materials Science (1997)
- Nathan Bergman - ME Microelectronic Engineering (1995)
- Ehab Daoud – ME Microelectronic Engineering (1995)
- Sriram Ramomoorthi – ME Microelectronic Engineering (1995)
- Zulfiqar Alam - MS Materials Science (1997)
- John Yik – ME Microelectronic Engineering (1993)
- Rosaline Tan - ME Microelectronic Engineering (1995)
- Huijaing Dai - MS Chemistry (1997)
- Suleyman Turgut – ME Microelectronic Engineering (1994)
- Joe Summa- MS Imaging Science (1993)
- Neil Langille – MS Chemistry (1996)
- Liling He – MS Chemistry (1995)
- Todd Eakin – MS Material Science (1993)
- Ghojiang Zhang – ME Microelectronic Engineering (1993)
- Patrick Drennan – MS Electrical Engineering (1993)
- Richard Holscher – MS Microelectronic Engineering (1992)
- Phil Sa – ME Microelectronic Engineering (1991)
- Michael Dussaault– ME Microelectronic Engineering (1991)
- Sonu Meheshwary – ME Microelectronic Engineering (1991)
- Timothy Tobin – ME Microelectronic Engineering (1991).
- Stephen Carlson – MS Imaging Science (1990)
- Michael Jenneson – ME Microelectronic Engineering (1990)

PROFESSIONAL SOCIETIES

- Fellow, SPIE International Society for Optical Engineering (SPIE)
- Senior Member, Institute of Electrical and Electronics Engineers (IEEE)
- Optical Society of America (OSA)
- American Vacuum Society (AVS)

CONFERENCES AND COMMITEES

- Conference Chairman, SPIE ML04 Microlithography Symposium, Optical Microlithography 2004
- Conference Chairman, SPIE ML05 Microlithography Symposium, Optical Microlithography 2005
- SPIE Optical Microlithography, Program Committee, 1997-2006
- EIPBN Program Committee 1997-2002
- SPIE Microlithography Award Committee, 2003-2006
- Chairman, Lithography Technical Group, Optical Society of America, 1995-97
- Faculty Advisor, SPIE Student Chapter, Rochester Institute of Technology, 1990-1996.
- SPIE/ISMA Singapore (1997) Program Committee member

GRANTS AND CONTRACTS

Principal investigator on numerous grants and contracts with federal agencies, research consortia, and industrial groups.

- "DUV Lithography Research", W. M. Keck Foundation, 1990.
- "Migration Xerography for Lithographic Applications," Xerox Corp., 1991.
- "KrF Microlithography," Texas Instruments, D. Harvey Award, 1991.
- "Performance Evaluation of Photomask Blanks," DuPont Corp., 1992.
- "Silicon Micromachining for Gas Chromatography," Perkin-Elmer Corp., 1989-1992.
- "Small Field Lithography Equipment for 248 nm Lithography," Sematech Equipment Funding, 1992.
- "Electron Beam Resist Research," Sematech, 1993.

- "193nm ArF Lithography," Texas Instruments D. Harvey Award, 1993.
- "Silylation Processes for ArF Lithography," Samsung, 1994.
- "Multilevel Phase Masks," Micron Technology, 1995.
- "193nm Lithography for 0.15 micron Patterning," Sony Corp., 1995.
- "193nm Lithography Materials Research," Semiconductor Research Corporation, 1995-1999.
- "Attenuated Phase Shift Masks," International Sematech, 1998.
- "Determining the Limits of Optical Lithography (DELPHI)," International Sematech, 1998.
- "193nm Optical Masking Research," IBM Corp., 1999.
- "UV/VUV Lithography research," Semiconductor Research Corporation, 1999-2002.
- "Materials Research for 157nm," International Sematech, 2000-2001.
- "Optical Extensions for sub-100nm Lithography," IMEC/ Univ. of Leuven Faculty Fellowship, 2001.
- "Intel Professor of Research and Technology," Intel Corp., 2000-2006
- "Water Immersion Optical Lithography at 193nm for sub-0.25 k1 Imaging," DARPA / Air Force Research Laboratories (AFRL), 2002-2006.
- "Immersion Optical Lithography," Semiconductor Research Corporation, 2003-2006.
- "Optical Imaging Enhancement for High-NA and Polarization," Semiconductor Research Corporation, 2002-2003.
- "Resist Imaging Research for High NA and Polarization," International Sematech, 2002-2004
- "Development of Exposure Tool Capability and Tooling Support for 193nm Immersion Lithography," International Sematech, 2003.
- "Immersion Lithography at 193nm," International Sematech, 2003-2005.
- "Mentor Graphics Collaborative Research Program," Mentor Graphics, Corp., 2004-2007.
- "Leading Microelectronic Engineering Education to New Horizons, "Co-PI, National Science Foundation, 2005-2008.
- Evanescent Wave Lithography for sub-32nm Technology, Semiconductor Research Corporation, 2006-2009.
- High Index Immersion Fluids, Sematech, 2007-2008.
- Aberration Metrology for EUV Optics, Albany Nanotech, 2006-2007.

EDITORIAL REVIEW

Editorial review of IEEE, JVAC, JM3, SPIE, and Applied Optics journals.

AWARDS AND HONORS

- Texas Instruments, Douglas Harvey Award, 1991 and 1993
- RIT Inventor Award, Rochester Institute of Technology, 1999
- Intel Professor of Research and Technology, Intel Corp., 2000 - present
- Intellectual Property Productivity Award, Rochester Institute of Technology, 2002
- Million Dollar PI Award, Rochester Institute of Technology, 2005
- Patenting Productivity Award, Rochester Institute of Technology, 2005
- Nominated for RIT Eisenhart Teaching Award (8) 1995-2006

PUBLICATIONS

"Evanescent wave imaging in optical lithography," Bruce W Smith, Yongfa Fan, Jianming Zhou, Neal Lafferty, Andrew Estroff, Proc. SPIE Optical Microlithography XIX, 6154, 2006.

"Effects of beam pointing instability on two-beam interferometric lithography," Yongfa Fan, Anatoly Bourov, Michael Slocum, Bruce W Smith, Proc. SPIE Optical Microlithography XIX, 6154, 2006.

"Resist process window characterization for the 45-nm node using an interferometric immersion microstepper," Anatoly Bourov, Stewart A Robertson, Bruce W Smith, Michael A Slocum, Emil C Piscani, Proc. SPIE Advances in Resist Technology and Processing XXIII, 6153, 2006.

"Comparison of immersion lithography from projection and interferometric exposure tools," Stewart A Robertson, Joanne M Leonard, Bruce W Smith, Anatoly Bourov, Proc. Optical Microlithography XIX, 6154, 2006.

"Three-dimensional imaging of 30-nm nanospheres using immersion interferometric lithography," Jianming Zhou, Yongfa Fan, Bruce W Smith, Proc. Optical Microlithography XIX, 6154, 2006.

"Experimental measurement of photoresist modulation curves, "Anatoly Bourov, Stewart A Robertson, Bruce W Smith, Michael Slocum, Emil C Piscani, Proc. Optical Microlithography XIX, 6154, 2006.

"Practical approach to full-field wavefront aberration measurement using phase wheel targets," Lena V Zavyalova, Bruce W Smith, Anatoly Bourov, Gary Zhang, Venugopal Vellanki, Patrick Reynolds, Donis G Flagello, Proc. Optical Microlithography XIX, 6154, 2006.

"High NA 193nm Immersion Lithography for 32nm Half-Pitch Imaging'" J. Zhou, Y. Fan, A. Bourov, B.W. Smith, Appl. Opt., 2006.

"25nm Immersion Lithography at a 193nm Wavelength," B. W. Smith, Y. Fan, M. Slocum, L. Zavyalova, , Proc. SPIE Optical Microlithography, vol. 5754, 2005.

"Amphibian XIS: An Immersion Lithography Microstepper Platform," B. W. Smith, A. Bourov, Y. Fan, F. Cropanese, Proc. SPIE Optical Microlithography, vol. 5754, 2005.

"ILSim - A compact simulation tool for interferometric lithography," Y. Fan, A. Bourov, L. Zavyalova, J. Zhou, A. Estroff, N. Lafferty, B.W. Smith, , Proc. SPIE Optical Microlithography, vol. 5754, 2005.

"Air bubble-induced light-scattering effect on image quality in 193 nm immersion lithography," Yongfa Fan, Neal Lafferty, Anatoly Bourov, Lena Zavyalova, Bruce W. Smith , Appl. Opt., Vol. 44 Issue 19 , 3904, 2005.

"Photoresist Modulation Curves," A. Bourov, Y. Fan, F. C. Cropanese, B. W. Smith, Proc. SPIE Optical Microlithography, vol. 5754, 2005.

"Automated Aberration Extraction using Phase Wheel Targets," L. Zavyalova, A. Bourov, B.W. Smith, Proc. SPIE Optical Microlithography, vol. 5754, 2005.

"Synthetic defocus in interferometric lithography," Frank C. Cropanese, Anatoly Bourov, Yongfa Fan, Jianming Zhou, Lena Zavyalova, Bruce W. Smith, SPIE Optical Microlithography, vol. 5754, 2005.

"Hyper NA water immersion lithography at 193 nm and 248 nm," Bruce W. Smith, Yongfa Fan, Jianming Zhou, Anatoly Bourov, Lena Zavyalova, Neal Lafferty, Frank Cropanese, and Andrew Estroff, J. Vac. Sci. .Technol. B: Microelectronics and Nanometer Structures 22(6), 3439-3443, 2004.

"Amplification of the index of refraction of aqueous immersion fluids by ionic surfactants,"Kwangjoo Lee, Joy Kunjappu, Steffen Jockusch, Nicholas J Turro, Tatjana Widerschpan, Jianming Zhou, Bruce W Smith, Paul Zimmerman, Will Conley, SPIE Advances in Resist Technology and Processing XXII, vol. 5373, 2005.

"Mask-induced polarization effects at high NA," Andrew Estroff, Yongfa Fan, Anatoly Bourov, Bruce Smith, Philippe Foubert, L. H. Leunissen, Vicky Philipsen, Yuri Aksenov, SPIE Optical Microlithography, vol. 5754, 2005.

"Immersion lithography fluids for high NA 193 nm lithography", Jianming Zhou, Yongfa Fan, Anatoly Bourov, Neal Lafferty, Frank Cropanese, Lena Zavyalova, Andrew Estroff, Bruce W. Smith, SPIE Optical Microlithography, vol. 5754, 2005.

"Water immersion optical lithography at 193 nm," Bruce W. Smith, Anatoly Bourov, Hoyoung Kang, Frank Cropanese, Yongfa Fan, Neal Lafferty, and Lena Zavyalova, J. Microlith., Microfab., and Microsys., 3(1), pp. 44-51, 2004.

"Approaching the numerical aperture of water - immersion lithography at 193nm," B.W. Smith, A. Bourov, Y. Fan, L. Zavyalova, N. Lafferty, F. Cropanese, Proc. SPIE 5377, 2004.

"Study of Air Bubble Induced Light Scattering Effect On Image Quality in 193 nm Immersion Lithography,"Y.Fan, N. Lafferty, A. Bourov, L. Zavyalova, B.W. Smith, , Proc. SPIE 5377, 2004.

"Immersion microlithography at 193nm with a Talbot prism interferometer,"A.Bourov, Y. Fan, F. Cropanese, N. Lafferty, L. Zavyalova, H. Kang, B.W. Smith, , Proc. SPIE 5377, 2004.

"Mask Induced Polarization Effects at High NA," A. Estroff, Y. Fan, A. Bourov, B.W. Smith, P. Foubert, L.H.A. Leunissen, Y. Aksenov, , Proc. SPIE 5754, 2005.

"Benefiting from polarization - effects of high-NA on imaging," B.W. Smith, L. Zavyalova, A. Estroff, , Proc. SPIE 5377, 2004.

"Mask induced polarization," A. Estroff, Y. Fan, A. Bourov, F. Cropanese, N. Lafferty, L. Zavyalova, B.W. Smith," Proc. SPIE 5377, 2004.

“In-situ aberration monitoring using phase wheel targets,” L. Zavyalova, B.W. Smith, T. Suganaga, S. Matsuura, T. Itani, J. Cashmore, Proc. Proc. SPIE 5377, 2004.

“Gray assist bar OPC,” N. Lafferty, G. Vandenberghe, B.W. Smith, M. Lassiter, P. Martin, Proc. SPIE 5377, 2004.

“Synthesis of projection lithography for low k1 via interferometry,” F. Cropanese, A. Bourov, Y. Fan, A. Estroff, L. Zavyalova, B.W. Smith, Proc. SPIE 5377, 2004.

“Forbidden Pitch or Duty-Free: Revealing the Causes of Across-Pitch Imaging Differences,” B.W. Smith, SPIE Optical Microlithography XV, Vol. 5040, 2003.

“Water Immersion Optical Lithography for the 45nm Node,” B. W. Smith, H. Kang, F. Cropanese, Y. Fan, SPIE Optical Microlithography XV, Vol. 5040, 2003.

“Optimizing vacuum ultraviolet attenuated phase shift masking materials,” B. W. Smith, A. Y. Bourov, and Y. Liu, J. Vac. Sci.Technol. B: Microelectronics and Nanometer Structures , 20(6) 6, 2578-2582. 2002.

“OPC and image optimization using localized frequency analysis,” B. W. Smith, D. E. Ewbank, SPIE Optical Microlithography XV, Vol. 4691, 2002.

“Challenges in High NA, Polarization, and Photoresists,” B. W. Smith, J. Cashmore , M. Gower, SPIE Optical Microlithography XV, Vol. 4691, 2002.

“OPC and Image Optimization Using Localized Frequency Analysis,” B. W. Smith, J. Fung Chen, SPIE Optical Microlithography XV, Vol. 4691, 2002.

“Image Enhancement Through Square Illumination Shaping,” B. W. Smith, G. Vandenbergh, SPIE Optical Microlithography XV, Vol. 4691, 2002.

“Mutually Optimizing resolution enhancement techniques,” B.W. Smith, J. Microlit., Microfab., Microsys., 1 (2), 7 (2002).

“Spatial filtering effects of the attenuated PSM and assist bar OPC,” B.W. Smith, SPIE Lithography for Semiconductor Manufacturing II, Vol. 4404, 2001.

“Optical lithography at a 126nm wavelength,” B.W. Smith, H. Kang, SPIE Optical Microlithography XIV, Vol. 4343, 2001.

“Mutually Optimizing resolution enhancement techniques,” B.W. Smith, SPIE Optical Microlithography XIV, Vol. 4343, 2001.

“A study of obscuration in catadioptric lenses,” M. McCallum, B.W. Smith, SPIE Optical Microlithography XIV, Vol. 4343, 2001.

“Investigation of the interplay between illumination, mask patterning, and aberrations from the lens perspective,” R. Schlief, B.W. Smith, SPIE Optical Microlithography XIV, Vol. 4343, 2001.

“Frequency filtering in alternative pupil planes,” B.W. Smith, H. Kang, J. Vac. Soc. B 2000.

“Aberration of steppers using phase shifting point diffraction interferometry,” P. Venkataraman, B.W. Smith, SPIE Optical Microlithography XIII, Vol. 4000, 2000.

“Properties and potential of VUV lithographic thin film materials,” M. Cangemi, M. Lassiter, A. Bourov, B.W. Smith, SPIE Optical Microlithography XIII, Vol. 4000, 2000.

“Spatial frequency filtering in the pellicle plane,” B.W. Smith, H. Kang, SPIE Optical Microlithography XIII, Vol. 4000, 252, 2000.

“Understanding lens aberration and influences to lithographic imaging,” B. W. Smith, SPIE Optical Microlithography XIII, Vol. 4000, 2000.

“Fabrication of small contacts using practical pupil filtering,” H. Kang, B.W. Smith, SPIE Optical Microlithography XIII, Vol. 4000, 2000.

"Variations to the influence of lens aberration invoked with PSM and OAI," B.W. Smith, Proc. SPIE Optical Microlithography XII, 1999.

"Resolution and DOF improvement through the use of square shaped illumination," B.W. Smith, J.S. Petersen, Proc. SPIE Optical Microlithography XII, 1999.

"Design and development of thin film materials for 157 nm and VUV wavelengths:

APSM, binary masking, and optical coatings applications, "B.W. Smith, A. Bourov, L. Zavyalova, M. Cangemi, Proc. SPIE Emerging Lithographic Technologies III, 1999.

"Influence of off-axis illumination on optical lens aberration," B. W. Smith and J. S. Petersen, J. Vac. Soc. B Vol. 16, 6, 3398 1998.

"Assessment of a hypothetical roadmap to extend optical lithography through the 70nm SIA technology node," J.S. Petersen, B.W. Smith, M. McCallum, N. Kachwala, R. Socha, J.F. Chen, T. Laidlaw, R. Gordon, C. Mack, SPIE BACUS Proceedings, 1998.

"Illumination pupil filtering using modified quadrupole apertures," B.W. Smith, L. Zavyalova, J.S. Petersen, Proc. SPIE Optical Microlithography XI, 3334, 1998.

"Revalidation of the Rayleigh resolution and DOF limits," B.W. Smith, Proc. SPIE Optical Microlithography XI, v3334, 1998.

"Aberration evaluation and tolerancing of 193 nm lithographic objective lenses," B.W. Smith, J. Webb, J.S. Petersen, J. Meute, Proc. SPIE Optical Microlithography XI, v3334, 1998.

"Resist design concepts for 193nm lithography: Opportunities for innovation and invention," E. Reichmanis, O. Nalamasu, T.I. Wallow, R. Cirelli, G. Dabbagh, R.S. Hutton, A.E. Novembre, B.W. Smith, J. Vac. Soc. Am. B, 15 (6), 2528, 1997.

"Investigation into excimer laser radiation damage of DUV optical phase masking films," B.W. Smith, L. Zavyalova, A. Bourov, S. Butt, C. Fonseca, J. Vac. Soc. Am. B, 15 (6), 2444, 1997.

"Plasma reactive ion etching of 193nm attenuated phase shift mask materials," B.W. Smith, C. Fonseca, L. Zavyalova, Z. Alam, A. Bourov, J. Vac. Soc. Am. B, 15 (6), 2259, 1997.

"A Negative Acting Single Layer Resist for 193 nm Lithography, P(SI-CMS)", B.W. Smith, A.E. Novembre, D. Mixon, Microelectronic Engineering 34(2), 137, 1997.

"The effects of excimer laser radiation on attenuated phase-shift masking materials", B. Smith, L. Zavyalova, S. Butt, A. Bourov, N. Bergman, C. Fonseca, Z. Alam, Proc. SPIE 3051, 1997.

"Development and characterization of nitride and oxide based composite materials for sub-0.18mm attenuated phase shift masking,", B.W. Smith, Z. Alam., S. Butt, S. Kurinec, R. Lane, G. Arthur, Microelectronic Engineering 35, 201, 1997.

“New Materials Families for 193 nm and DUV Attenuating Embedded Phase Shifter Photomasks”, R. H. French, P. F. Carcia, K. G. Sharp, J. S. Meth, B. W. Smith, R. M. Cannon, Annual Meeting, American Ceramic Society, Cincinnati, OH, May 1997.

"Attenuated phase shift mask materials for 248 and 193 nm lithography", B.W. Smith, S. Butt, Z. Alam. S. Kurinec, R. Lane, J. Vac. Soc. Am. B, 14 (6), 1996.

"Optical and dielectric properties of sputtered aluminum nitride thin films", A. Randolf, S. Kurinec, B. Smith, Proc. MRS Symposium on Materials Research, Rochester, N.Y., 1996.

"Optical characterization of tantalum silicide ($TaSi_2$), Z. Alam, B. Smith, S. Kurinec, Proc. MRS Symposium on Materials Research, Rochester, N.Y., 1996.

"Materials screening for attenuated embedded phase-shift photoblanks for DUV and 193 nm photolithography", P.F. Carcia, R.H. French, K. Sharp, J.S. Meth, B.W. Smith, Proc. 16th Annual BACUS Symposium on Microlithography, 1996.

"Optical films for attenuated phase shift mask application at 193nm," B.W. Smith, S. Butt, Z. Alam, IEEE Lithography Workshop, conference abstracts, Maui, 1996.

"Materials screening for attenuated embedded phase shift photomasks for DUV and 193nm lithography," P.F. Carcia, R.H. French, B.W. Smith, R.M. Cannon, 16th Annual BACUS Symposium on Photomask Technology and Management, SPIE 2884, 1996.

"Optical properties and optimization of SixNy as an anti-reflective layer for 193 nm photolithography," Bruce W. Smith, David Stern, Zulfiqar Alam, Shahid Butt, Second Intl. Symp. on 193nm Lithography (conference abstracts), 1996.

"193nm imaging using a small-field high-resoultion resist exposure tool," N. Rizvi, M. Gower, D. Ashworth, B. Smith, P. Rumbsy, F. Goodall, R. Lawes, SPIE 2726, 1996.

"Evaluation of Commercial and Experimental Resist Materials for use in Electron beam Application," C. Sauer, B. Smith, R. Dean, E. Morita, Z. Tan, D. Ewbank, S. Duttagupta, Proc. 15th Annual BACUS Symposium on Microlithography, 1995.

"Attenuated Phase-Shift Masks for 193nm," B. Smith, S. Butt, Z. Alam, R. Crow, S. Turgut, First Intl. Symp. on 193nm Lithography (conference abstracts), 1995.

"The Impact of Optical Aberrations and Flare on High NA 193nm Lithography: Resist Requirements for DOF," B. Smith, S. Ramamoorthi, First Intl. Symp. on 193nm Lithography (conference abstracts), 1995.

"Design and Characterization of Poly(trimethylsilylmethyl methacrylate-co-chloromethyl styrene) for 193 nm exposure", B.W. Smith, S.A. Butt, A.E. Novembre, D.A. Mixon, SPIE Advances in Resist Technology and Processing XII, 2438, (1995).

"Direct Measurement of Optical Constants of Metals from a KrF Excimer using Polarization Methods", S. Turgut, B.W. Smith, SPIE Integrated Circuit Metrology, Inspection, and Process Control IX, 2439, (1995).

"Photolithography Process Characterization and 3D Modeling using DRM Data", M. Goldman, D. Alexander, S.D. Chowdhury, P.G. Drennan, L. Karklin, B.W. Smith, SPIE Advances in Resist Technology and Processing XII, 2438, (1995).

"A Negative Acting Single Layer Resist for 193 nm Lithography, P(SI-CMS)", B.W. Smith, A.E. Novembre, Proc. Tenth International Conference on Photopolymers, (1994).

"Deep UV Chemically Amplified Dissolution Inhibited Photoresists," J.V. Crivello, S.Y. Shim, B.W. Smith, Chem. of Matls., Vol. 6, No. 11, 2167 (1994).

"Phase-shift Mask Issues for 193 nm Lithography," B.W. Smith, SPIE Optical/Laser Microlithography V, 2194, (1994).

"Characterization of Safe Solvent PMMA Resist Variables for Electron Beam Lithography," B.W. Smith, T.D. Eakin, SPIE E-Beam, X-Ray, and I-Beam Submicron Lithography, 2195, (1994).

"Optimization of a Liquid Phase Silylation Process for 248 nm Lithography using EL IR Photoresists," G. Zhang, B.W. Smith, SPIE Advances in Resist Technology and Processing, 2195, (1994).

"Near-field Optical Microscopy Characterization of ICs," R.T. Crow, M.V. Iravani., B.W.Smith, SPIE IC Metrology, Inspection, and Process Control, 2196, (1994).

"Technique for the Measurement of the In-Situ Development Rate of DNQ/Novalac Resists," P. Drennan, B.W. Smith, SPIE IC Metrology, Inspection, and Process Control, 2196, (1994).

"Extraction of Process Specific Photolithography Model Parameters," P. Drennan, B.W. Smith, SPIE IC Metrology, Inspection, and Process Control, 2196, (1994).

" A 193 nm Deep-UV Lithography System using a Line-narrowed ArF Excimer Laser," B.W. Smith, M. Gower, SPIE Optical/Laser Microlithography VI, 1927, (1993).

"Comparison of Scalar and Vector Diffraction Theory for Deep-UV Lithography," B.W. Smith, D. Flagello, SPIE Optical/Laser Microlithography VI, 1927, (1993).

"Characterization of Atomic Force Microscopy and Electrical Probing Techniques for IC Metrology," B.W. Smith, R.T. Crow, SPIE Integrated Circuit Metrology, Inspection, and Process Control, 1926, (1993).

"Response Surface Modelling of Phase-Shift Mask Process Simulation," R. Holscher, B.W. Smith, SPIE Advances in Resist Technology IX, (1993).

"Advanced lithography simulation tools for development and analysis of wide-field high NA projection optical systems," J. E. Connors, T.M. Kos, R.C. Pack, B.W. Smith, SPIE Optical/Laser Microlithography VI, 1927, (1993).

"Response Surface Modelling Utilizing Lithographic Process Simulation," B.W. Smith, W.M. Shaio, SPIE Integrated Circuit Metrology and Process Control IV, 1673, (1992).

TEXTBOOKS AND CHAPTERS

- Microlithography:Science and Technology, J. Sheats and B.W. Smith, ed. , Marcel Dekker: New York, 1997.
- "Resist processing," B.W. Smith, Microlithography: Science and Technology, Ch. 9, J. Sheats and B.W. Smith, ed. , Marcel Dekker: New York, 1997.
- "Multilayer resist technology," B.W. Smith, Microlithography: Science and Technology, Ch. 10, J. Sheats and B.W. Smith, ed. , Marcel Dekker: New York, 1997.
- "Optics for microlithography," B.W. Smith, Microlithography: Science and Technology, Ch. 2, J. Sheats and B.W. Smith, ed. , Marcel Dekker: New York, 1997.

TEXTBOOK MANUSCRIPTS IN PROGRESS

- Principles of Optical Nanolithography, Bruce W. Smith, CRC Press (Taylor and Francis), 2006.

SHORTCOURSE WORKBOOKS

- Understanding the Limits of Optical Lithography, 1999
- Understanding Lens Aberrations and Influences with RET, 1999
- The Fundamental Limits of Optical Lithography, 2000-2005
- Advancing the Limits of Optical Lithography, 2000-2005
- Principles of Microlithography, 1995-2005
- Maskmaking for IC Microlithography, 1998
- Deep – Ultraviolet (DUV) Lithography, 1997 - 2003
- Multilayer Resist Systems for Optical Lithography, 1997
- Polarization, Immersion, and Optical Enhancement Technology, 2003-2005

CONFERENCES AND INVITED PRESENTATIONS

- "Nanolithography and the Future of the IC," Western NY Meeting of the Optical Society of America, Rochester, NY, November 2006.
- "Metrology for EUV Projection Optics," Albany Nanotech Workshop on EUV Optics, Albany, NY, June 2006.
- "Solid Immersion and Evanescent Wave Lithography at Numerical Apertures > 1.60," Sematech Immersion Symposium, Kyoto, Japan, Oct. 2006.
- "Research Activities in Immersion Interferometric Lithography," Sematech Immersion Symposium, Kyoto, Japan, Oct. 2006.
- "Interferometric Immersion Nanopatterning," DARPA NanoFab Workshop, Salt Lake City, UT, November 2006.
- "Immersion Optical Microlithography," OSA Optical Fabrication and Testing , OMA2, Rochester, NY, Oct. 2004.
- "Optical Lithography at the Limits of Diffraction" Optical Society of America, Rochester Section, October 2003.
- "Impact of Aberrations of Optical Extension OE Lens Code," Sematech OE Workshop, Burlington, VT, June 2000.
- "157nm Aberration Parameter Modeling Using Phase Ring Structures," 157nm Technical Data Review, Orlando, FL, December 2001.
- "Tolerancing of aberrations for resolution enhancement technology: Issues involed in optimizing," Sematech OE Workshop, Austin, TX, January 2000.
- "Pupil Plane Filtering Near Mask and Image Planes," IEEE Lithography Workshop St. John, USVI , December 2000.
- "Challenges in Microlithography for Sub-100 nm Device Patterning," 25th Annual EDS/CAS Conference, Rochester, NY, November 2001.
- "Optical Lithography Challenges for Sub-100nm Imaging," IBM Semiconductor Division, East Fishkill, October 2001.
- "Optical research for UV and VUV," SRC Review, Madison, WI, June 2000.
- "Extreme-NA Water Immersion Lithography for 35-65 nm Technology," Third International Symposium on 157nm Lithography, Antwerp, Belgium, September 2002.
- "Optimizing VUV Attenuated Phase Shift masking Materials," 46th International Conference EIPBN, Anaheim, CA May 2002.
- "Federal and State Research Funding Opportunities in Engineering," Government Relations Committee Meeting, Rochester Institute of Technology, November, 2001.
- "OPC and RET with Gray Bars for the100nm Technology Node," IMEC Lithography Review, Leuven, Belgium, June 2001.
- "Extreme NA Lithography at 0.8 to 1.4," IMEC Lithography Review, Leuven, Belgium, June 2002.
- "Customizing Illumination and Square Pupil Shapes," IMEC Lithography Review, Leuven, Belgium, June 2001.
- "Spatial Filtering Effects of the Attenuated PSM and Assist Bar OPC," SPIE Symposium on Microelectronic and MEMS Technology, Edinburgh, Scotland June, 2001
- "Optical research for UV and VUV," SRC Review, Madison, WI, July 2001.
- "Optical research for UV and VUV," SRC Review, Austin, TX, July 2002..
- "Optics in Microlithography," University of Leuven Engineering Talent Night, Leuven, Belgium, November 2001.
- "193nm - 248nm Immersion Lithography: Water and Beyond," IMEC Lithography Review, Leuven, Belgium, June 2004.

- "Lithography at 134nm and 6.42eV (193nm Water Immersion Lithography)," Sematech Immersion Workshop, Almaden, CA, December 2003.
- "High NA and Polarization Considerations with Immersion Lithography, ARCH Interface 2004 Microlithography Symposium, Phoenix, AZ, September 2004.
- "Hyper-NA Water Immersion Lithography at 193nm and 248nm," EIPBN 2004, San Diego, CA, May 2004.
- "Water-based 193nm Immersion Lithography," Sematech Immersion Lithography Workshop, Los Angeles, CA, January 2004.
- "Water Immersion Optical Lithography at 193nm for sub-0.25 k1 Imaging," DARPA Microlithography Program Review, Santa Fe, NM, September 2003.
- "Water Immersion Lithography at Excimer Laser Wavelengths," DARPA Microlithography Program Review, Las Vegas, NV, January 2004.
- "Lithographic Challenges for 130nm Devices, "IEEE Computer and Electron Device Society Maine Chapter, May , 2000.
- "Pushing the limits of optical lithography," Optical Fabrication & Testing 2004, OSA Annual Meeting, Rochester, NY, October 2004.
- "Optical microlithography: will the party ever end?," OSA Rochester New York Section, Rochester, NY, November 2003.
- "Optical enhancement techniques for 193-nm lithography: modified illumination and attenuated phase-shift masking," ISMA'97, Singapore, June 1997.
- "Optical extension technology," MaskTools OE Workshops, Taiwan , February, 1999, Semicon West 1999, San Jose 1998.
- "Semiconductor Microlithography for sub 0.25-micron," Rutherford Appleton Laboratories (RAL), Oxford, UK, 1995.
- "Sub-0.25 micron optical lithography technology," SEMICON, Korea, 1996.

RECENT ARTICLES

- "Under Water: Immersion techniques carry 193-nm lithography beyond the 65-nm node," OE Magazine, July 2004.
- "Immersion Optical Lithography at 193nm," Future Fab Intl., Volume 15, Bruce W. Smith, 2003.
- "Strategies toward sub-0.25 micron lithography"' B. Smith, Optics and Photonics News 8, 3, 23 (1997).
- "Attenuated phase shift mask materials for 248 and 193 nm lithography," B.W. Smith, S. Butt, Z. Alam, Microlithography World, 6(2), 7 1997.

PATENTS

- 7,136,143 Method for aberration detection and measurement
- 7,092,073 Method of illuminating a photomask using chevron illumination
- 6,934,010 Optical proximity correction method utilizing gray bars as sub-resolution assist features
- 6,881,523 Optical proximity correction method utilizing ruled ladder bars as sub-resolution assist features
- 6,846,595 Method of improving photomask geometry
- 6,835,505 Mask for projection photolithography at or below about 160 nm and a method thereof
- 6,791,667 Illumination device for projection system and method for fabricating
- 6,788,388 Illumination device for projection system and method for fabricating
- 6,556,361 Projection imaging system with a non-circular aperture and a method thereof
- 6,541,750 Modification of a projection imaging system with a non-circular aperture and a method thereof
- 6,525,806 Apparatus and method of image enhancement through spatial filtering
- 6,480,263 Apparatus and method for phase shift photomasking
- 6,466,304 Illumination device for projection system and method for fabricating
- 6,395,433 Photomask for projection lithography at or below about 160 nm and a method thereof
- 6,388,736 Imaging method using phase boundary masking with modified illumination
- 6,368,755 Masks for use in optical lithography below 180 nm
- 6,309,780 Attenuated phase shift mask and a method for making the mask
- 5,939,227 Multi-layered attenuated phase shift mask and a method for making the mask

PUBLISHED PATENT APPLICATIONS

- 20050076321 Method of photomask correction and its optimization using localized frequency analysis
- 20050057735 Reduction Smith-Talbot interferometer prism for micropatterning
- 20040174506 Method for aberration detection and measurement

- 20030211400 Method of improving photomask geometry
- 20030112421 Apparatus and method of image enhancement through spatial filtering

SEMINARS AND SHORTCOURSES

- 2000-2003 SPIE Advancing the Limits of Optical Lithography
- 2000-2005 SPIE The Fundamental Limits of Optical Lithography
- 2004-2005 SPIE Pushing the Limits: Optical Enhancement, Polarization, and Immersion Lithography
- 2003-2004 BACUS (Sc117, SC124)
- July 2004 SEMICON West SC117-124
- 1995-2005 Intel University two-day course "Principles of Microlithography" held in Chandler, AZ; Rio Rancho, NM; Santa Clara, CA; Hudson, MA; Leixlip, Ireland; Colorado Springs, CO (18 offerings total)
- 1995-2005 Industrial short course "Principles of Microlithgraphy" held at Chartered Semiconductor (Singapore), TI-Tech (Singapore), Sony (San Antonio, TX), Motorola (Phoenix, AZ and Austin, TX), Rockwell Semiconductor (Colorado Springs, CO and San Diego, CA), Analog Devices (Boston, MA), Acer Semiconductor (Taiwan), Micron Semiconductor (Boise, ID), Infineon Semiconductor (Richmond, VA), Sematech (Austin, TX)

BUSINESS STARTUPS

- Lithographic Technology Corporation, consulting and technology development for integrated Circuit Microlithography applications, New York State S-corporation, 1998.

- Amphibian Systems, manufacturer of specialty micro-and nano-lithography equipment for semiconductor and nanotechnology applications, specializing in immersion lithography imaging systems and metrology, New York State S-corporation, 2005.

EXPERT CONSULTING AND TESTIMONY

- (2005-2006) Expert Witness, Advanced Micro Devices v. Oki Electronics, photoresist processing infringements and patent validity case.

- (2004-2005) Expert witness, Ultratech Stepper, Inc. v. ASM Lithography, Inc., scanning optical system patent infringement and invalidity case

- (1997-2002) Expert consultant, IBM Fishkill, NY and Essex, VT, including Union Carbide Corp., Eastman Kodak, J. T. Baker Chemical, KTI, Shipley, Ashland Oil, E. I. DuPont de Nemours and Industri-Chem, suppliers of solvents for the IBM cleanroom operations (multi-state litigation)

- (1997-2002) Expert Witness and Consultant, San Jose IBM Workers Litigation involving allegations regarding various chemicals used in an IBM manufacturing facility in San Jose, California