

Frances Anne Houle
Lawrence Berkeley National Laboratory
Berkeley, CA 94720
(510) 495-8135 FAHoule@lbl.gov

Research Interests

Chemical modification of nanoparticle, semiconductor, metal and polymer interfaces, surfaces and films. Atmospheric aerosol transformations. Nanoscale pattern formation. Development of novel experimental methods for characterization of nanoparticle, thin film, surface and interface physics and chemistry including nanoscale composition, reaction mechanisms, nanomechanical properties. Stochastic simulation methods for complex chemical reactions including transport.

Education

Ph.D. Chemistry California Institute of Technology, 1979
B.A. Chemistry University of California at Irvine, *cum laude*, 1974
Whittier College, Whittier, California (1970 - 1972)

Employment

3/2013-present Department Head, Joint Center for Artificial Photosynthesis – North
Staff Scientist, Chemical Sciences Division
8/2011-3/2013 Director of Strategic Initiatives, Chemical Sciences Division
Lawrence Berkeley National Laboratory, Berkeley, CA
5/2011-present Principal, Columbia Hill Technical Consulting, Fremont, CA
4/2009 – 4/2011 Manager, Materials Development
InVisage Technologies, Inc, Menlo Park, CA
12/80 – 3/2009 Research Staff Member, Research Division
Science and Technology Department
International Business Machines Corporation, San Jose, CA
5/79 - 11/80 Postdoctoral Research Associate
University of California at Berkeley Department of Chemistry and
Lawrence Berkeley Laboratory

Technical Leadership Accomplishments

Lawrence Berkeley National Laboratory, Division of Chemical Sciences – Director of Strategic Initiatives

- Responsible for planning and development of new technical programs and alliances for the Division and support of new proposals, played a direct role in 4 successful awards of new funding in 2012
- Named Associate Director and key personnel for Critical Materials Hub bid by the lead Laboratory, co-leader of LBNL proposal team (approx 15 primary participants)
- Appointed member of LBNL Opportunity Board to shape processes for future initiatives

InVisage Technologies - Manager

- Responsible for key nanoparticle based material in image sensor device at approx. 26 person startup company. Led and actively participated in the following areas
 - Delivery of film composition and scaled-up processes that met integration and imaging performance targets and milestones. 1 invention disclosure.

- Development of measurement techniques suitable for quality assurance of wafers, solutions and nanoparticle and other films, process diagnostics
- Technical program planning and execution as a team with integration, production and device engineering functions
- People manager for 18 months

IBM - Selected technical team leadership experiences

- Built and led team (3 full-time and 15 part-time members) that developed nanoimprint materials systems joint with 2 external corporate partners. Defect mechanisms and design of new materials to reduce them. 10 patents.
- Co-led multisite 36-member team addressing a critical photomask degradation problem involving nanoscale Cr migration. 1 IBM recognition and 1 patent.
- Co-led 4-member multidisciplinary team investigating fundamental issues in photoresist extendability. Innovative experimental and modeling techniques created for discovery of factors limiting resolution of chemically amplified photoresists to 50nm. Results have led to new chemically amplified resist design paradigms used throughout the industry. 4 patents. 2 IBM recognitions.

Additional relevant experiences

Failure analysis - IBM

Member, Reticle Growth Defect working group (2005-2008)

Task force on disk drives (2002)

Task force on head-disk interface failure mechanisms (1984)

Business planning - IBM

Member and sub-team co-leader, IBM Academy of Technology study group on eScience (2006)

Study group on Physical Sciences Strategy (2002)

Study group on cross-functional teams (1995)

Assignment to Scientific and Technical Application Software department for product commercialization project (1994-1995)

Task force on Research-Market Management Interface and New Business Opportunities (1994-1995)

External alliances – IBM and InVisage Technologies

Managed relationships with materials and characterization services vendors, Invisage (2009-2011)

Member, Nanoimprint Advisory Group, International SEMATECH (2008-2009)

Technical lead, nanoimprint activities under IBM-JSR joint research agreement (2008-2009)

IBM representative to the Industrial Advisory Board, NSF EUV Engineering Research Center (2007-2009)

Member, International SEMATECH Resist Outgassing Work Group (2004-2006)

Member, IBM team, Resist group, EUV LLC (2001- 2002)

Health and safety – InVisage Technologies

Managed health and safety programs, regulatory documentation, hazardous materials handling and documentation

Responsible for employee training and record keeping

Awards, Honors and Fellowships

John A. Thornton Memorial Award and Lecture, American Vacuum Society, 2009.

IBM Research Division Accomplishment recognition for Mask Defect Root Cause, 2008

IBM Research Division Technical Group Award for Photoresist Limits, 2004
Gomes School Parent-Teachers Association Award (for developing the Science Fair), 2003
IBM Research Division Accomplishment recognition for Photoresist Limits, 2002
AIChE Northern California Section Chemical Engineering Excellence Award: Research Project of the Year (for Chemical Kinetics Simulator), 1999
IBM Corporate Environmental Affairs Excellence Award (for Chemical Kinetics Simulator), 1998
Fellow of the American Vacuum Society, 1996
IBM Supplemental Patent Issue Award for US patent 5446870, 1996
Fellow of the American Physical Society, 1992
IBM Outstanding Innovation Award for Laser Deposition of Metals, 1990
First Prize, IBM Computational Chemistry Challenge, 1990
IBM Invention Achievement Awards, First-Seventh Plateaus, 1985-2010
IBM Postdoctoral Fellowship, UCB/LBL, 1979-80
Herbert Newby McCoy Award for Outstanding Contributions in Chemistry, CIT, 1979
IBM Predoctoral Fellowship, CIT, 1977-78
Dean's Award for Outstanding Senior in Chemistry, UCI, 1974
ACS (Orange County Section) Award, UCI, 1974

Selected Professional Activities

Professional Society Memberships -

American Chemical Society, American Physical Society (Fellow), American Vacuum Society (Fellow), Materials Research Society

Editorial -

Co-Editor, "Laser Chemical Processing of Semiconductor Devices", F. A. Houle, T. F. Deutsch and R. M. Osgood, Jr., Materials Research Society, Pittsburgh, 1984.
Associate Editor, Journal of Vacuum Science and Technology A (1989-1993)
Co-Editor, "Surface Chemistry and Beam-Solid Interactions", H. Atwater, F. A. Houle and D. Lowndes, Materials Research Society, Pittsburgh, 1991.
Member of the Editorial Committee, Annual Reviews of Physical Chemistry (2001-2005)
Associate Editor, Journal of Vacuum Science and Technology B (2001-2003)

Professional Society Governance-

Board of Directors, Northern California Chapter, AVS (1982-1986)
AVS Thin Film Division Executive Committee (1988-1989)
AVS Board of Scholarship Trustees (1990-1992)
Vice Chair (1993), Program Chair (1994) and Chair (1995), Electronic Materials and Processing Division, AVS
Selection and Scheduling Committee, Gordon Research Conferences (1996-2002)
Council of the Gordon Research Conferences (1994, 1996-2002)
Nominations Committee, Division of Physical Chemistry, American Chemical Society (1998)
Nanometer-scale Science and Technology Division Executive Committee, AVS (2001-2002)
Nominating Committee, Division of Laser Science, American Physical Society (2001)
General Councilor, American Physical Society (2002-2005)
Chair, American Physical Society Task Force on Professional Ethics, Standards and Practices (2002-2003)
Member of the Executive Board, American Physical Society (2004-2005)
Member, Budget Committee, American Physical Society (2004-2006)
Member, Committee on Committees, American Physical Society (2005)

Member-at-large, Executive committee of the California Section, American Physical Society (2008-2010)
Member, American Physical Society Panel on Public Affairs (2009-2011).
Member, Fellowship Committee, American Physical Society (2010-2012).
Member, New Meetings Subcommittee, Materials Research Society (2012- present).
Member-at-large, Executive committee of the Division of Condensed Matter Physics, American Physical Society (2014-2016)

Conference Organization -

American Chemical Society National Meeting Program Committee (1983)
Materials Research Society Fall Meeting, Symposium Co-chair (1984, 1990)
Society of Photo -Instrumentation Engineers LA'84 Program Committee (1984)
Conference on Lasers and Electro - Optics Program Subcommittee Chair (1987), member (1988)
American Vacuum Society National Symposium Program Committee (1987, 1990, 1994 – EMPD Program Chair)
Microphysics of Surfaces, Beams and Adsorbates Topical Meeting Organizing Committee (1991,1995)
Chemistry of Electronic Materials Gordon Research Conference, Vice-chair (1992), Chair (1994 – theme of conference was chemical control in nanofabrication)
International Advisory Committee, 2nd International Conference on Laser Advanced Materials Processing, Japan (1992)
International Advisory Committee, First International Symposium on Laser and Optoelectronics Technology and Applications, Singapore (1993)
International Advisory Committee, 10th International Conference in Solid Films and Surfaces, Princeton, NJ (2000)
Advances in Resist Technology and Processing Program Committee, SPIE International Symposium on Microlithography, Santa Clara (2001-2003)
International Advisory Committee, 3rd African Materials Research Society Symposium, Casablanca, Tunisia (2005)
Resist Section, Electron, Ion and Photon Beams and Nanolithography Program Committee (2008)
Alternative Lithographic Technologies Program Committee, SPIE Advanced Lithography Symposium (2008-2009)
International Conference on Nanoimprint and Nanoprint Technology (2009)
Council for Chemical Research Chemical Innovation Forum and Annual Meeting, Washington DC (2013)

Committees -

Student Awards Judge, Materials Research Society Spring Meeting (1994)
Scientific Advisory Panel, Alice in Wonderland Project, an NSF-funded project at the Children's Discovery Museum, San Jose, California (1998-1999)
Industrial Advisory Board, Graduate Training Program in Optical Sciences and Engineering, University of Colorado, Boulder (1998-1999)
Discussion Leader, Advanced and Emerging Materials Group, US-Africa Materials Workshop (Pretoria, South Africa, 2000)
Advisory Committee, African Materials Science Gateway project, Northwestern University and University of Witwatersrand (2001)
Organizing committee, 75th Anniversary of the Gordon Research Conferences (2002-2006)
ACS awards committee (2003 – 2005)
ACS awards committee (2006 – 2008)

Industrial Advisory Board, NSF Engineering Research Center for Extreme Ultraviolet Science and Technology, Colorado State University, University of Colorado, UC Berkeley and Lawrence Berkeley National Laboratory (2007- 2009).

American Institute of Physics Statistics Advisory Committee (2007-2009).

APS Ethics Education Web Site committee (2007- present)

National Academies committee to revise *On being a scientist* (booklet on scientific ethics) (2007-2008)

APS Panel on Public Affairs - MRS study on Energy – Critical Elements (2010-2011)

APS Physics Policy Committee - POPA study on innovation (2011-2012)

Review panels -

Review Panel for the Proposed Department of Energy Combustion Dynamics Facility (1989)

Review Panel, Materials Synthesis and Processing Initiative, National Science Foundation (1992)

NRC Board of Assessment for NIST, Subpanel for JILA (1996 - 1998)

NSF Panel for Materials Research Science and Engineering Centers (1996)

NSF Site Review Committee, Science and Technology Center (1996)

Committee of Visitors, Physics Division, National Science Foundation (1997)

NSF Site Review Committee, Proposed Science and Technology Center (1999)

Chair, NRC Board of Assessment for NIST, Subpanel for JILA (1999-2002)

NSF Site Review Committee, Materials Research Science and Engineering Center (2000)

NSF Review Panel for LIGO, Caltech/MIT (2001)

NSF Site Review Committee, Materials Research Science and Engineering Center (2005)

DOE BES EFRC Review Panel (2014)

DOE EERE Annual Merit Review, 2 panels (2014)

Funding History

ONR grant for the 1994 Chemistry of Electronic Materials Gordon Research Conference, \$6000.

NSF grant for the 1994 Chemistry of Electronic Materials Gordon Research Conference, DMR-9321393, \$6000.

NATO grant CRG 951452, "Stochastic Simulation of Chemical Vapor Deposition of Amorphous Hydrogenated Silicon" with Prof. Dr. Peter Hess, Heidelberg University, Germany (1996-1998)

NIST ATP grant 70NANB7H7025 subaward from Anasys (2008-2009), support for a postdoc to provide nanoimprint materials for nanoscale IR characterization

DOE Facility User, Molecular Foundry, Lawrence Berkeley National Laboratory (2008-2009)

LBNL LDRD Award, "Computational-Experimental Studies of Aerosol Transformations from the Liquid to Glassy State" (2014, renewal proposal submitted for 2015)

Refereed publications

1. The Nature of the Bonding of Li^+ to H_2O and NH_3 ; Ab Initio Studies
R. L. Woodin, F. A. Houle and W. A. Goddard, III
Chem. Phys. **14**, 461 (1976).
2. The First Ionization Potential of Ethyl Radical by Photoelectron Spectroscopy
F. A. Houle and J. L. Beauchamp
Chem. Phys. Lett. **48**, 457 (1977).
3. Detection and Investigation of Allyl and Benzyl Radicals by Photoelectron Spectroscopy
F. A. Houle and J. L. Beauchamp
J. Am. Chem. Soc. **100**, 3290 (1978).
4. On Exit Channel Coupling Effects in the Unimolecular Decomposition of Triatomics
D. L. Bunker, K. R. Wright, W. L. Hase and F. A. Houle
J. Phys. Chem. **83**, 933 (1979).
5. Photoelectron Spectroscopy of Methyl, Ethyl, Isopropyl and tert-Butyl Radicals. Implications for the Thermochemistry and Structures of the Radicals and their Corresponding Carbonium Ions
F. A. Houle and J. L. Beauchamp
J. Am. Chem. Soc. **101**, 4067 (1979).
6. Effects of Molecular Structure and Basicity. The Gas Phase Proton Affinities of Cyclic Phosphites
R. V. Hodges, F. A. Houle, J. L. Beauchamp, R. A. Montag and J. G. Verkade
J. Am. Chem. Soc. **102**, 932 (1980).
7. Simulation Methods in Kinetics Courses
F. A. Houle and D. L. Bunker
J. Chem. Educ. **58**, 405 (1981).
8. The Effect of Vibrational and Translational Energy on the Reaction Dynamics of the $\text{H}_2^+ + \text{H}_2$ System
S. L. Anderson, F. A. Houle, D. Gerlich and Y. T. Lee
J. Chem. Phys. **75**, 2153 (1981).
9. Vibrational Effects in Proton and Charge Transfer in the $\text{H}_2^+ + \text{Ar}$ System
F. A. Houle, S. L. Anderson, D. Gerlich, T. Turner and Y. T. Lee
Chem. Phys. Lett. **82**, 392 (1981).
10. Thermal Decomposition Pathways of Alkyl Radicals by Photoelectron Spectroscopy. Application to Cyclopentyl and Cyclohexyl Radicals
F. A. Houle and J. L. Beauchamp
J. Phys. Chem. **85**, 3456 (1981).
11. Nonadiabaticity in Ion-Molecule Reactions: Coupling of Proton and Charge Transfer in the H_2^+ and $\text{D}_2^+ + \text{Ar}$ System
F. A. Houle, S. L. Anderson, D. Gerlich, T. Turner and Y. T. Lee
J. Chem. Phys. **77**, 748 (1982).
12. Laser-Induced Chemical Etching of Metals and Semiconductors
F. A. Houle and T. J. Chuang
J. Vac. Sci. Technol. **20**, 790 (1982).
13. Gaseous Products from the Reaction of XeF_2 with Silicon
H. F. Winters and F. A. Houle
J. Appl. Phys. **54**, 1218 (1983).
14. Nonthermal Effects in Laser-Enhanced Etching of Silicon by XeF_2
F. A. Houle
Chem. Phys. Lett. **95**, 5 (1983).

15. Photoeffects on the Fluorination of Silicon. I. Influence of Doping on Steady-State Phenomena
F. A. Houle
J. Chem. Phys. **79**, 4237 (1983).
16. Photoeffects on the Fluorination of Silicon. II. Kinetics of the Initial Response to Light
F. A. Houle
J. Chem. Phys. **80**, 4851 (1984).
17. Photoelectron Spectroscopy of 1-Propyl, 1-Butyl, Isobutyl, Neopentyl and 2-Butyl Radicals: Free Radical Precursors to High Energy Carbonium Ions
J. C. Schultz, F. A. Houle and J. L. Beauchamp
J. Am. Chem. Soc **106**, 3917 (1984).
18. Photoelectron Spectroscopy of Isomeric C₄H₇ Radicals. Implications for the Thermochemistry and Structures of the Radicals and their Corresponding Carbonium Ions
J. C. Schultz, F. A. Houle and J. L. Beauchamp
J. Am. Chem. Soc. **106**, 7336 (1984).
19. Mechanism of Laser-Enhanced Etching of Silicon
F. A. Houle
MRS Symp. Proc. **29**, 203 (1984).
20. Photochemical Generation and Deposition of Copper from the Gas Phase
C. R. Jones, F. A. Houle, C. A. Kovac and T. H. Baum
Appl. Phys. Lett. **46**, 97 (1985).
21. Laser Chemical Vapor Deposition of Copper
F. A. Houle, C. R. Jones, T. H. Baum, C. Pico and C. A. Kovac
Appl. Phys. Lett. **46**, 204 (1985).
22. Composition, Structure and Electric Field Variations in Photodeposition
R. J. Wilson and F. A. Houle
Phys. Rev. Lett. **55**, 2184 (1985).
23. Surface Processes Leading to Carbon Contamination of Photochemically Deposited Copper Films
F. A. Houle, R. J. Wilson and T. H. Baum
J. Vac. Sci. Technol. A **4**, 2452 (1986).
24. A Reinvestigation of the Etch Products of Silicon and XeF₂: Doping and Pressure Effects
F. A. Houle
J. Appl. Phys. **60**, 3018 (1986).
25. Basic Mechanisms in Laser Etching and Deposition
F. A. Houle
Appl. Phys. A **41**, 315 (1986) (*invited*).
26. Fundamental Aspects of Photon Assisted Processing
F. A. Houle
"Reduced Temperature Processing for VLSI", Electrochemical Society Symposium Proceedings **86-5**, 32 (1986).
27. Heat and Light in Laser-Materials Interactions
F. A. Houle
J. Vac. Sci. Technol. A **4**, 665 (1986).
28. Optical Self-Regulation during Laser-Induced Oxidation of Copper
L. Baufay, F. A. Houle and R. J. Wilson
J. Appl. Phys. **61**, 4640 (1987).
29. Dynamics of Desorption of SiF₄ During Etching of Silicon by XeF₂
F. A. Houle
J. Chem. Phys. **87**, 1866 (1987).

30. On the Relative Importance of Physical and Chemical Sputtering in Ion-Enhanced Etching of Silicon by XeF₂
F. A. Houle
Appl. Phys. Lett. **50**, 1838 (1987).
31. Real-Time Studies of Laser-Oxidation of Copper: Characteristics of an Optical Heat Source
L. Baufay, F. A. Houle and R. J. Wilson
MRS Symp. Proc. **75**, 281 (1987).
32. Interdependence of Optical Excitation and Surface Chemistry in Laser Induced Deposition and Etching
F. A. Houle
Laser Chemistry **9**, 107 (1988) (*invited*).
33. Origin of Contaminants in Photochemically Deposited Chromium Films
K. A. Singmaster, F. A. Houle and R. J. Wilson
Appl. Phys. Lett. **53**, 1048 (1988).
34. Photostimulated Desorption in Laser-Assisted Etching of Silicon
F. A. Houle
Phys. Rev. Lett. **61**, 1871 (1988).
35. Desorption Dynamics of SiF₄ Etch Product
F. A. Houle
J. Vac. Sci. Technol. **A6**, 840 (1988).
36. Laser Deposition of Films from Acetylacetonate Complexes
F. A. Houle, T. H. Baum and C. R. Moylan
"Laser Chemical Processing for Microelectronics", K. Ibbs and R. M. Osgood, Jr.,
Editors, Cambridge University Press, Cambridge (1989), Chapter 2 (*invited*).
37. Photochemical Etching of Silicon: the Influence of Photogenerated Charge Carriers
F. A. Houle
Phys. Rev. **B39**, 10 120 (1989).
38. Surface Reactions Leading to Contamination of Metal Films Photochemically Deposited from the Hexacarbonyls
K. A. Singmaster, F. A. Houle and R. J. Wilson
MRS Symp. Proc. **131**, 469 (1989).
39. Surface Photoprocesses in Laser Assisted Etching and Film Growth
F. A. Houle
J. Vac. Sci. Technol. **B7**, 1149 (1989).
40. Photochemical Deposition of Thin Films from the Metal Hexacarbonyls
K. A. Singmaster, F. A. Houle and R. J. Wilson
J. Phys. Chem. **94**, 6864 (1990).
41. Effect of Laser Heating on Compositions of Films Deposited from the Metal Hexacarbonyls
K. A. Singmaster and F. A. Houle
MRS Symp. Proc. **201**, 159 (1991).
42. Doping Effects on the Etching Chemistry of GaAs and Si
F. A. Houle
MRS Symp. Proc. **204**, 25 (1991).
43. Fundamental Aspects of Laser Deposition of Thin Metal Films: Chemistry of Contamination
K. A. Singmaster and F. A. Houle
"Symposia on Reliability of Semiconductor Devices/Interconnections and Dielectric Breakdown and Laser Processes for Microelectronic Applications", Electrochemical Society Proceedings 92-4, 265 (1992).

44. Continuous Wave Visible Laser-Assisted Decomposition of $\text{Cr}(\text{CO})_6$ on a Growing Film: In Situ Observations
F. A. Houle and L. I. Yeh
J. Phys. Chem. **96**, 2691 (1992).
45. Chemical Changes Accompanying Facet Degradation of AlGaAs Quantum Well Lasers
F. A. Houle, D. L. Neiman, W. C. Tang and H. J. Rosen
J. Appl. Phys. **72**, 3884-3896 (1992).
46. Visible Laser Induced Nucleation and Growth of Cr, Mo and W Films from the Hexacarbonyls. Reactivity of CO on Film Surfaces
F. A. Houle and K. A. Singmaster
J. Phys. Chem. **96**, 10425-10439 (1992).
47. Electron Impact Fragmentation of Gases by Molecular Beam Mass Spectrometry. Application to AsCl_3 and a $\text{GaCl}_3/\text{Ga}_2\text{Cl}_6$ Mixture
F. A. Houle
Int. J. Mass. Spec. Ion Proc. **123**, 243-252 (1993).
48. Laser Assisted Chemical Vapor Deposition from the Metal Hexacarbonyls
K. A. Singmaster and F. A. Houle
Laser Chemistry of Organometallics, J. Chaiken, Ed. ACS Symposium Series **530**, Chapter 21 (1993).
49. Thermal and Acid-Catalyzed Deprotection Kinetics in Deep UV Resist Materials
G. Wallraff, J. Hutchinson, W. Hinsberg, F. A. Houle, P. Seidel, R. Johnson, and W. Oldham
J. Vac. Sci. Technol. **B12**, 3857-3862 (1994).
50. Kinetics of Thermal and Acid-Catalyzed Deprotection in Deep UV Resist Materials
J. Hutchinson, G. Wallraff, W. Hinsberg, F. Houle and P. Seidel
Microelectronic Engineering, **27**, 397-400 (1995).
51. Stochastic Simulations of Temperature Programmed Desorption Kinetics
F. A. Houle and W. D. Hinsberg
Surface Science, **338**, 329-346 (1995).
52. Simulations of Thermal Decomposition and Film Growth from the Group VI Metal Hexacarbonyls
F. A. Houle and W. D. Hinsberg
J. Phys. Chem. **99**, 14477-14485 (1995).
53. Stochastic Simulation of Heat Flow with Application to Laser-Solid Interactions
F. A. Houle and W. D. Hinsberg
Appl. Phys. A **66**, 143-151 (1998).
54. In Situ FTIR Spectroscopy and Stochastic Modelling of Surface Chemistry of Amorphous Silicon Growth
U. Wetterauer, J. Knobloch, P. Hess and F. A. Houle
J. Appl. Phys. **83**, 6096-6105 (1998).
55. Mechanistic Studies of Chemically Amplified Photoresists
W. D. Hinsberg, G. Wallraff, F. A. Houle, M. Morrison, J. Frommer, R. Beyers and J. Hutchinson
Organic Thin Films, ACS Symposium Series, C. Frank, ed., Amer. Chem. Soc., Washington DC, vol **695**, 344-359 (1998).
56. Deep UV Interferometric Lithography as a Tool for Assessment of Chemically Amplified Resist Performance
W. D. Hinsberg, F. A. Houle, J. Hoffnagle, M. Sanchez, G. Wallraff, M. Morrison and S. Frank
J. Vac. Sci. Technol. B **16**, 3689-3694 (1998).

57. Factors Controlling Pattern Formation in Chemically Amplified Resists at Sub-100 nm Dimensions.
W. Hinsberg, F. Houle, G. Wallraff, M. Sanchez, M. Morrison, J. Hoffnagle, H. Ito, C. Nguyen, C. Larson, P. Brock and G. Breyta
J. Photopolym. Sci. Tech., **12**, 649-662 (1999).
58. Liquid Immersion Deep-UV Interferometric Lithography
J. Hoffnagle, W. D. Hinsberg, M. Sanchez and F. A. Houle
J. Vac. Sci. Technol. B **17**, 3306 (1999).
59. Determination of Coupled Acid Catalysis-Diffusion Processes in a Positive Tone Chemically Amplified Photoresist
F. A. Houle, W. D. Hinsberg, M. Morrison, G. Wallraff, C. Larson, M. Sanchez and J. Hoffnagle
J. Vac. Sci. Technol. B **18**, 1874-1885 (2000).
60. Chemistry and Physics of the Post-expose Bake Process in Chemically Amplified Resists
W. Hinsberg, F. Houle, M. Sanchez and G. Wallraff
IBM Journal of Research and Development, **45**, 667 (2001) (*invited*).
62. The influence of resist components on image blur in a patterned positive-tone chemically amplified photoresist
F. A. Houle, W. D. Hinsberg, M. I. Sanchez and J. A. Hoffnagle
J. Vac. Sci. Technol. B **20**, 924-931 (2002).
63. Product volatilization as a probe of the physics and chemistry of latent image formation in chemically amplified resists
W. D. Hinsberg, F. A. Houle, G. M. Poliskie, D. Pearson, M. I. Sanchez, and H. Ito
J. Phys. Chem. A **106**, 9776-9787 (2002), *invited*
64. High NA lithography imagery at Brewster's angle
T. A. Brunner, J.A. Hoffnagle, W. D. Hinsberg, F. A. Houle, M. I. Sanchez
J. Microlith. Microfab. Microsys. **1**, 188 (2002).
65. A method to measure the spatial resolution of a photoresist
J. A. Hoffnagle, W. D. Hinsberg, M. I. Sanchez and F. A. Houle
Optics Lett. **27**, 1776-1778 (2002).
66. Kinetic model of positive-tone resist dissolution and roughening
F. A. Houle, W. D. Hinsberg and M. I. Sanchez
Macromolecules **35** 3591-3600 (2002).
67. Use of interferometric lithography to characterize the spatial resolution of a photoresist film
J. A. Hoffnagle, W. D. Hinsberg, F. A. Houle and M. I. Sanchez
J. Photopolymer Sci. Technol. **16**, 373 (2003).
68. Statistical limitations of printing 50 and 80 nm contact holes by EUV lithography
G. M. Gallatin, F. A. Houle, and J. L. Cobb
J. Vac. Sci. Technol. B **21**, 3172-3176 (2003).
69. Acid-base reactions in a positive tone chemically amplified photoresist and their effect on imaging
F. A. Houle, W. D. Hinsberg and M. I. Sanchez
J. Vac. Sci. Technol. B **22**, 747-757 (2004).
70. Ethics and the Welfare of the Physics Profession
K. Kirby and F. A. Houle
Physics Today, November, 2004, pages 42-46.
71. Sub-50nm half-pitch imaging with a low activation energy chemically amplified photoresist
G. M. Wallraff, D. R. Medeiros, M. Sanchez, K. Petrillo, W.-S. Huang, C. Rettner, B. Davis, C. E. Larson, L. Sundberg, P. J. Brock, W. D. Hinsberg, F. A. Houle, J. A. Hoffnagle, D. Goldfarb, K. Temple, S. Wind and J. Bucchingano
J. Vac. Sci. Technol. B **22**, 3479-3484 (2004).

72. Characterization of polymer reactive dissolution and swelling using a quartz crystal microbalance and reflectance interferometry
W. Hinsberg, F. Houle, S-W. Lee, H. Ito and K. Kanazawa
Macromolecules **38**, 1882-1989 (2005).
73. Numeric analysis of the role of liquid phase UV photochemistry in 193nm immersion lithography
W. D. Hinsberg and F. A. Houle
J. Vac. Sci. Technol. B **23**, 2427-2435 (2005).
74. Real-world kinetics via simulations
F. A. Houle and W. D. Hinsberg
Annual Reports in Computational Chemistry **2**, 3 (2006) *Invited*.
75. Numerical analyses of the roles of gas phase and liquid phase UV photochemistry in conventional and immersion 193 nm lithography
William Hinsberg and Frances A. Houle
Journal of Photopolymer Science and Technology **19**, 623 (2006).
76. Adhesion between template materials and UV-cured nanoimprint resists
F. A. Houle, Eric Guyer, D. C. Miller and Reinhold Dauskardt
J. Vac. Sci. Technol. B **23**, 2427 (2007).
77. Anti-adhesion considerations for UV nanoimprint lithography
F. A. Houle, C. T. Rettner, D. C. Miller and R. Sooriyakumaran
Appl. Phys. Lett. **90**, 213103 (2007).
78. Characterization of volatile species formed during exposure of photoresists to ultraviolet light
F. A. Houle, V. R. Deline, H. Truong and R. Sooriyakumaran
Macromolecules **40**, 7505-7512 (2007).
79. Nanoimprint Materials Systems
F. A. Houle, D. C. Miller, A. Fornof, H. Truong, S. Raoux, R. Sooriyakumaran, H. Ito and M. Hart
J. Photopolymer Sci Technol **21**, 563-572 (2008)
80. Metal-containing release layers for use with UV-cure nanoimprint lithographic template materials
F. A. Houle, S. Raoux, D. C. Miller, C. Jahnes and S. Rossnagel
J Vac Sci Technol B **26**, 1301-1304 (2008).
81. Quantification of outgassing of C, Si and S-containing products during exposure of photoresists
F. A. Houle, N. Maxim, J. Huijbregtse, V. R. Deline, H. Truong and W. van Schaik
J Vac Sci Technol B **27**, 654 (2009).
82. Introduction of Role Playing to a Research Ethics Module for the Undergraduate
D. C. Miller, F. A. Houle, J. Stemwedel, J. Pesek and C. Wade
Mater. Res. Soc. Proc. 1233, 1233-PP09-06 (2009).
83. Energy Critical Elements: Securing Materials for Emerging Technologies.
APS Panel on Public Affairs and the Materials Research Society
American Physical Society, 2011.
84. Life-cycle net energy assessment of large-scale hydrogen production via photo-electrochemical water-splitting
Roger Sathre, Corinne D. Scown, William R. Morrow III, John C. Stevens, Ian D. Sharp, Joel W. Ager, Karl Walczak, Frances A. Houle and Jeffery B. Greenblatt
Energy Environ. Sci. (in press, 2014)

Other Publications

1. Rapid Laser-Induced Chemical Etching of Semiconductors
F. A. Houle
Proc. SPIE **385**, 127 (1983).
2. Adducts of Cu(II) β -Diketonates with Oxygen Donor Ligands: Molecular Structure of Bis(hexafluoroacetylacetonate) Copper(II) (Ethanol)
C. A. Kovac, C. R. Jones, T. H. Baum and F. A. Houle
IBM Research Report RJ 4174 (1984).
3. Laser-Assisted Chemical Etching
F. A. Houle
Proc. SPIE **459**, 110 (1984).
4. Book Review, "Chemical Processing with Lasers", D. Bauerle, Springer-Verlag, Berlin (1986)
F. A. Houle
IEEE Circuits and Devices Magazine, **4**(6) 27 (1988).
5. Mechanistic Studies of Etching of Silicon by XeF₂
F. A. Houle
Symposium on Dry Process, Electrochemical Society Proceedings **88-7**, 17 (1988).
6. Mechanisms of Contamination in Photochemical Deposition of Thin Metal Films
K. A. Singmaster, F. A. Houle and R. J. Wilson
Proc. SPIE **1190**, 152 (1990)
7. Surface Chemistry of Laser-Assisted Film Growth
F. A. Houle
Proceedings of Laser Advanced Materials Processing, High Temperature Society of Japan, 203 (1992).
8. Modelling the Chemistry of Chemically Amplified Resists using a Stochastic Kinetics Simulator
J. Hutchinson, G. Walraff, F. A. Houle, W. Hinsberg and P. Seidel
Preprints, Topical Conference on the Synthesis and Processing of Electronic Materials, AIChE, San Francisco, 341-346 (1994).
9. Kinetics of Chemically Amplified Resists
G. Walraff, W. Hinsberg, F. Houle, P. Seidel and J. Hutchinson
Photopolymers - Principles, Processes and Materials Regional Technical Conference, Society for Plastics Engineering (1995).
10. Kinetics of Chemically Amplified Resists
G. Walraff, W. Hinsberg, F. Houle, J. Opitz, D. Hopper and J. Hutchinson
SPIE Advances in Resist Technology and Processing XII, **2438**, 182-190 (1995).
11. Reactivity and Kinetic Parameters of UVII-HS
G. Walraff, J. Opitz, W. Hinsberg, F. Houle, J. Thackeray, T. Fedynyshyn, D. Kang and M. Rajaranam
SPIE Advances in Resist Technology and Processing XIV, **3049**, 490-500 (1997).
12. Effect of Aerial Image Contrast on Resist Line-Edge Roughness
M. I. Sanchez, W. D. Hinsberg, F. A. Houle, J. A. Hoffnagle, H. Ito and C. Nguyen
Microlithography World **8** (3) 19-21 (1999).
13. Experimental Method for Quantifying Acid Diffusion in Chemically Amplified Resists
G. Walraff, W. D. Hinsberg, F. A. Houle, M. Morrison, C. Larson, M. Sanchez, J. Hoffnagle, P. J. Brock and G. Breyta
Proc. SPIE, Advances in Resist Technology and Processing XVI, **3678**, 138 (1999).

14. Line-Edge Roughness Comparison of Photoresists using Interferometric Lithography
M. I. Sanchez, W. D. Hinsberg, F. A. Houle, J. Hoffnagle, H. Ito and M. Morrison
Proc. SPIE, Advances in Resist Technology and Processing XVI, **3678**, 160 (1999).
15. Real-time Analysis of Volatiles Formed during Processing of a Chemically Amplified Resist
F. A. Houle, G. M. Poliskie, W. D. Hinsberg, D. Pearson, M. I. Sanchez, H. Ito, J. A. Hoffnagle
Proc. SPIE, Advances in Resist Technology and Processing XVII, **3999**, 181 (2000).
16. Effect of Resist Components on Image Spreading during Post-Exposure Bake of Chemically Amplified Resists
W. D. Hinsberg, F. A. Houle, M. I. Sanchez, M. E. Morrison, G. M. Wallraff, C. E. Larson, J. A. Hoffnagle, P. J. Brock, G. Breyta
Proc. SPIE, Advances in Resist Technology and Processing XVII, **3999**, 148 (2000).
17. Chemistry and Physics of the Post-exposure Bake Process in a Chemically Amplified Resist
W. D. Hinsberg, J. Hoffnagle, F. A. Houle, H. Ito, M. Sanchez, M. Sherwood and G. Wallraff
Microlithography World, **9**(2), 16 (2000).
18. Chemistry and Physics of the Post-exposure Bake Process in a Chemically Amplified Resist
W. D. Hinsberg, J. Hoffnagle, F. A. Houle, H. Ito, M. Sanchez, M. Sherwood and G. Wallraff
Solid State Technology, August 2000, 95.
19. Real-time Analyses of Volatiles Formation during Chemically Amplified Resist Processing
W. Hinsberg, F. Houle, M. Poliskie, D. Pearson, M. Sanchez, H. Ito, J. Hoffnagle, M. Morrison
Proceedings of the 12th International Conference on Photopolymers, Society of Plastics Engineers, 249 (2001).
20. Effect of Resist Components on Image Blur during Post-Exposure Bake of Chemically Amplified Resists
M. I. Sanchez, W. D. Hinsberg, F. A. Houle, M. Morrison, G. M. Wallraff, C. Larson, J. A. Hoffnagle, P. J. Brock, G. Breyta
Proceedings of the 12th International Conference on Photopolymers, Society of Plastics Engineers, 283 (2001).
21. Studies of Acid Diffusion in Polymers for 248, 193, and 157 nm Photoresist Applications
G. M. Wallraff, S. Bangsaruntip, W. Hinsberg, F. Houle, M. Sanchez, C. Larson, G. Breyta
Proceedings of the 12th International Conference on Photopolymers, Society of Plastics Engineers, 375 (2001).
22. EUV photoresist performance results from the VNL and the EUV LLC
J. L. Cobb, P. M. Dentinger, A. Fisher, J. E. Goldsmith, L. L. Hunter, D. J. O'Connell, G. M. Gallatin, W. D. Hinsberg, F. A. Houle, M. I. Sanchez, W. Domke, S. Wurm, U. Okoroanyanwu, S. Lee, E. M. Panning
Emerging Lithographic Technologies VI, SPIE Proceedings **4688** (2002).
23. High NA lithography imagery at Brewster's angle
T. A. Brunner, J. A. Hoffnagle, W. D. Hinsberg, F. A. Houle, M. I. Sanchez
Optical Microlithography XV, SPIE Proceedings **4691** (2002).
24. High numerical aperture: imaging implications for chemically amplified photoresists
M. I. Sanchez, F. A. Houle, J. A. Hoffnagle, T. A. Brunner, W. D. Hinsberg
Adv. Resist technology and processing XIX, Proc. SPIE **4690** (2002).
25. Estimated impact of shot noise in extreme ultraviolet lithography
J. L. Cobb, F. A. Houle and G. M. Gallatin
Emerging Lithographic Technologies VII, Proc. SPIE **5037**, 397 (2003).

26. Characterization of photoresist spatial resolution by interferometric lithography
J. A. Hoffnagle, W. D. Hinsberg, F. A. Houle, M. I. Sanchez
Metrology, Inspection and Process Control for Microlithography XVII, SPIE **5038** (2003).
27. Extendability of chemically amplified resists: another brick wall? (invited)
W. D. Hinsberg, F. A. Houle, M. I. Sanchez, J. A. Hoffnagle, G. M. Wallraff, D. R. Medeiros, J. L. Cobb
Advances in Resist Technology and Processing XX, SPIE Vol **5039**, 1 (2003).
28. Using the critical ionization model for resist development to estimate contrast curves and roughening
F. A. Houle, W. D. Hinsberg and M. I. Sanchez
Advances in Resist Technology and Processing XX, SPIE Vol **5039**, 334 (2003).
30. Kinetics of reactive dissolution of lithographic polymers
W. Hinsberg, F. A. Houle, S. Lee, K. Kanazawa, H. Ito, and L. Sundberg
Proceedings of the 13th International Conference on Photopolymers, Society of Plastics Engineers (2003).
31. Evaluation of resist-liquid interactions for 193-nm liquid immersion lithography
W. Hinsberg, G. Wallraff, C. Larson, B. Davis, V. Deline, S. Raoux, D. Miller, F. Houle, H. John, L. Sundberg, R. Dammel, W. Conley
Advances in Resist Technology and Processing XXI, SPIE Vol **5376** (2004).
32. Reactive dissolution kinetics of lithographic copolymers
W. Hinsberg, F. Houle and H. Ito
Advances in Resist Technology and Processing XXI, SPIE Vol **5376** (2004).
33. Fast calculation of images for high numerical aperture lithography
A. E. Rosenbluth, G. Gallatin, R. L. Gordon, W. Hinsberg, J. Hoffnagle, F. Houle, A. Lvov, M. Sanchez, M. Seong
Optical Microlithography XVII, SPIE Vol **5377** (2004).
34. Evaluation of Functional Properties of Imaging Materials for Water Immersion Lithography
W. D. Hinsberg, J. A. Hoffnagle, G. M. Wallraff, C. E. Larson, F. A. Houle, L. Sundberg, H. D. Truong, B. W. Davis and R. D. Allen
Advances in Resist Technology and Processing XXII *SPIE* **5753**, 508-518 (2005)
35. Studies of acid diffusion in low E_a Chemically Amplified Photoresists
Gregory M. Wallraff, Carl E. Larson, David Medeiros, Martha I. Sanchez, Karen E. Petrillo, Charles T. Rettner, William D. Hinsberg, Frances A. Houle and John A. Hoffnagle, Advances in Resist Technology and Processing XXII *SPIE* **5753**, 309-318 (2005).
36. Numeric analyses of the roles of gas phase and liquid phase UV photochemistry in conventional and immersion 193 nm lithography
William Hinsberg and Frances A. Houle, Proc. SPIE 6153, 615303 (2006).
37. Direct determination of photoresist composition changes during UV exposure
Frances A. Houle, Vaughn R. Deline, Hoa Truong, and Ratnam Sooriyakumaran
Proc. SPIE 6153, 61530Z (2006).
38. Adhesion between template materials and UV-cured nanoimprint resists
Frances A. Houle, Eric Guyer, Dolores C. Miller, Reinhold Dauskardt, Emily Rice, and Jeremy Hamilton, Proc. SPIE 6153, 61531B (2006).
39. Vinyl ether resist system for UV-cured nanoimprint lithography
Hiroshi Ito, Frances A. Houle, Mark W. Hart, and Rick A. DiPietro, Proc. SPIE 6153, 61531A (2006).

40. Impact of curing kinetics and materials properties on imprint characteristics of resists for UV nanoimprint lithography
Frances A. Houle, Ann Fornof, Ratnam Sooriyakumaran, Hoa Truong, Dolores C. Miller, Martha I. Sanchez, Blake Davis, Teddie Magbitang, Robert D. Allen, Mark W. Hart and Geraud Dubois, Proc. SPIE 6519, 65191C (2007).
41. Chemical and mechanical properties of UV-cured nanoimprint resists and release layer interactions
Frances A. Houle, Ann Fornof, Dolores C. Miller, Simone Raoux, Hoa Truong, Eva Simonyi, Christopher Jahnes, Stephen Rossnagel, Proc. SPIE, 6921, 69210B (2008).
42. Evaluation of 32nm Advanced Immersion Lithography Pellicles
N. Zhou, K. Racette, M. Hibbs, T. Mizoguchi, D. Hasselbeck, M. Barrett, R. Nolan, F. Houle, J. Ritter, A. Wagner, M. Caterer
Proc SPIE, 7122, 71220B (2008).
43. Characterization of vinyl ether UV-cure nanoimprint resist
T. Furukawa, F. A. Houle, D. L. Casher and D. C. Miller
Proc. SPIE 7271, 727129 (2009).
44. Quantitative measurement of resist outgassing during exposure
N. Maxim, F. A. Houle, J. Huijbregtse, V. R. Deline, H. Truong and W. van Schaik
Proc. SPIE 7273, 72733Z (2009).
45. Cr migration on 193nm binary photomasks
J. Bruley, G. Burr, R. E. Davis, P. Flaitz, W. D. Hinsberg, F. A. Houle, D. C. Miller, M. Pike, J. Rankin, A. Wagner, A. Watts
Proc. SPIE 7272, 727215 (2009).

Technical Software Products

MSIM4: Stochastic Mechanism Simulator. D. L. Bunker and F. A. Houle, Quantum Chemistry Program Exchange, Indiana University, Bloomington, Indiana, Program No. 293 (1974).

MSIMPC - An Interactive Discrete Chemical Mechanism Simulator for the IBM PC. W. D. Hinsberg and F. A. Houle, Quantum Chemistry Program Exchange, Indiana University, Bloomington, Indiana, Program No. QCMP 069 (1989).

MSIMPC v2.0 - An Interactive Discrete Chemical Mechanism Simulator for the IBM PC (Laboratory and Classroom Version). W. D. Hinsberg and F. A. Houle, Quantum Chemistry Program Exchange, Indiana University, Bloomington, Indiana, Program No. QCMP 069 (1991)

Chemical Kinetics Simulator (CKS) W. D. Hinsberg and F. A. Houle. A powerful, easy-to-use package based on stochastic methods for simulation of a broad variety of chemical kinetics systems in the gas, liquid and solid phases. Available since 1996 for a no-cost license from <www.almaden.ibm.com/st/past_projects.ck/>. Was in wide use throughout the world in education and in university, government and industrial laboratories.

Visual Simulator (VSIM) W. D. Hinsberg and F. A. Houle. Extended version of Chemical Kinetics Simulator for stochastic simulations of coupled reaction-diffusion and reactive multicompartment systems. Originally proprietary to IBM, placed in open access in 2012, code.google.com/p/chemical-kinetics-simulator/

Kinetiscope W. D. Hinsberg and F. A. Houle. Merged and upgraded version of CKS and VSIM currently in beta, to be placed in open access.

e-DVD project in Physical Chemistry Education

“Physical Chemistry in Practice” with Professor G. Weaver, Department of Chemistry, Purdue University. Collaboration to create a module on chemical kinetics using IBM Almaden Research Center Resist group’s work (2002-2006). Work described in “Use of a multimedia DVD for Physical Chemistry: analysis of its effectiveness for teaching content and applications to current research and its impact on student views of physical chemistry”, K. T. Jennings, E. M. Epp and G. C. Weaver, *Chemistry Education Research and Practice*, **8**, 308-326 (2007).

Patent Activities

Issued Patents

1. Selective Deposition of Copper
T. H. Baum, F. A. Houle, C. R. Jones and C. A. Kovac
U.S. Patent No. 4,574,095 (March 4, 1986)
2. A Rapid Etching Method for Silicon by SF₆. Gas
T. J. Chuang, F. A. Houle and K. Petersen
U.S. Patent No. 4,617,086 (October 14, 1986)
3. Process for Depositing Metallic Copper
T. H. Baum, F. A. Houle and C. R. Jones
Canadian Patent No. 1225363 (August 11, 1987)
4. Spatially Resolved Stochastic Simulation Systems
W. D. Hinsberg and F. A. Houle
U.S. Patent No. 5,446,870 (August 29, 1995)
5. Method for Producing Thin Film Magnetic Structure
R. Fontana, F. A. Houle and C. Tsang
U. S. Patent No. 5,503,870 (April 2, 1996)
6. Method for Producing Thin Film Magnetic Structure
R. Fontana, F. A. Houle and C. Tsang
U. S. Patent No. 5,582,860 (December 10, 1996)
7. Stochastic Simulation Method for Processes Containing Equilibrium Steps
W. D. Hinsberg and F. A. Houle
U. S. Patent No. 5,625,579 (April 29, 1997)
8. Method for Stochastic and Deterministic Timebase Control in Stochastic Simulations
W. D. Hinsberg and F. A. Houle
U. S. Patent No. 5,745,385 (April 28, 1998)
9. Software Architecture for Stochastic Simulation of Non-Homogeneous Systems
W. D. Hinsberg and F. A. Houle
U. S. Patent No. 5,826,065 (October 20, 1998)
10. Self-Longitudinally Biased Magnetoresistive Read Transducer
R. Fontana, F. A. Houle and C. Tsang
U. S. Patent No. 6,188,550 (February 13, 2001)
11. Low silicon outgassing resist for bilayer lithography
M. M. Khojasteh, R. W. Kwong, K-J Chen, P. R. Varanasi, R. D. Allen, P. Brock, F. Houle, R. Sooriyakumaran.
U. S. Patent No. 6,770,419 (August 3, 2004)

12. Apparatus for characterization of photoresist resolution, and method of use
W. Hinsberg, J. Hoffnagle, F. A. Houle, M. Sanchez
U. S. Patent No. 7,046,342 (May 16, 2006).
13. Fast model-based optical proximity correction
G. M. Gallatin, R. L. Gordon, W. Hinsberg, J. Hoffnagle, F. A. Houle, A. Lvov, A. E. Rosenbluth, M. Sanchez, N. Seong
U. S. Patent No. 7,079,223 (July 18, 2006).
14. Process for forming features of 50 nm or less half-pitch with chemically amplified resist imaging
D. R. Medeiros, W.-S. Huang, G. M. Wallraff, W. D. Hinsberg, F. A. Houle
U. S. Patent No. 7,090,963 (August 15, 2006).
15. Apparatus for characterization of photoresist resolution, and method of use
W. Hinsberg, J. Hoffnagle, F. A. Houle, M. Sanchez
U. S. Patent No. 7,179,571 (February 20, 2007).
16. Processes and materials for step and flash imprint lithography
R. DiPietro, M. W. Hart, F. A. Houle, H. Ito
U. S. Patent No. 7,419,611 (September 2, 2008).
17. Stabilization of vinyl ether materials
F. A. Houle, H. Ito
U. S. Patent 7,488,771 (February 10, 2009).
18. Phase change materials and associated memory devices
Y. Chen, F. A. Houle, S. Raoux, C. T. Rettner, A. Schrott
U. S. Patent No. 7,501,648 (March 10, 2009)
19. Release layer for imprinted photocationic curable resins
R. D. Allen, M. W. Hart, F. A. Houle, H. Ito
U. S. Patent No. 7,749,422 (July 6, 2010)
20. Phase change materials and associated memory devices
Y. Chen, F. A. Houle, S. Raoux, C. T. Rettner, A. Schrott
U. S. Patent No. 7,875,873 (January 25, 2011)
21. Amorphous nitride release layers for imprint lithography, and method of use
F. A. Houle, C. Jahnes, S. Raoux, S. Rossnagel
U. S. Patent No. 8,029,716 (October 4, 2011)
22. Amorphous oxide release layers for imprint lithography, and method of use
F. A. Houle, S. Raoux
U. S. Patent No. 8,114,331 (February 14, 2012)
23. Processes and materials for step and flash imprint lithography
R. DiPietro, M. W. Hart, F. A. Houle, H. Ito
U. S. Patent No. 8,128,832 (March 6, 2012)

24. Stabilizers for vinyl ether resist formulations for imprint lithography
T. Furukawa, F. A. Houle, S. A. Swanson
U. S. Patent No. 8,168,109 (May 1, 2012)
25. Vinyl ether resist formulations for imprint lithography and processes of use
T. Furukawa, F. A. Houle
U. S. Patent No. 8,168,691 (May 1, 2012)
26. Method and apparatus for sub-pellicle defect reduction on photomasks
J. Burnham, F. A. Houle, L. Kindt
U. S. Patent No. 8,173,331 (May 8, 2012)
27. Aromatic vinyl ether based reverse-tone step and flash imprint lithography
R. DiPietro, M. W. Hart, F. A. Houle, H. Ito
U. S. Patent No. 8,262,961 (Sept 11, 2012)
28. Stabilization of Vinyl Ether Materials
F. A. Houle and H. Ito
U. S. Patent No. 8,637,602 (Jan 28, 2014)

Published Invention Disclosures

1. Laser Induced Chemical Etching of Ferrites
J. Addy, T. J. Chuang and F. A. Houle
IBM Technical Disclosure Bulletin, **25**(7A), 3256 (1982).
2. Rapid Etching of Surface Relief in Solids
J. Hitchner, F. A. Houle and B. Martin
IBM Technical Disclosure Bulletin, **26**(8), 4237 (1984).
3. Gas-Phase, Laser- and Light-Induced Metal Deposition from Metal Substituted Fluorinated Compounds
T. H. Baum, F. A. Houle, C. R. Jones and C. A. Kovac
IBM Technical Disclosure Bulletin, **27**(7A), 4108 (1984).
4. Resistless Patterned Laser Etching
F. A. Houle, J. Paraszczak and J. Wylczynski
IBM Technical Disclosure Bulletin, **33**(5), 412 (1990).

Invited Papers at International Conferences, 1984-present

1. *Laser Assisted Chemical Etching*, Society of Photo-Instrumentation Engineers Symposium, Los Angeles, January 1984
2. *Laser Deposition of Copper from the Vapor Phase*, Rank Prize Funds Symposium on Photolytic Deposition, Malvern, England, April 1984
3. *Mechanism of Laser Assisted Etching of Silicon*, Thin Film Gordon Conference, New Hampshire, July 1984
4. *Etching of Silicon by XeF₂, F and F₂*, Plasma Chemistry Gordon Conference, New Hampshire, August 1984
5. *Fundamental Mechanisms in Laser-Assisted Chemical Etching*, Materials Research Society Fall Meeting, Boston, November 1984
6. *Fundamental Processes in Laser-Surface Photochemistry*, IBM Europe Institute Seminar on Laser Science, Lech, Austria, July 1985
7. *Fundamental Aspects of Photon Assisted Processing*, Electrochemical Society National Meeting, Las Vegas, October 1985
8. *Heat and Light in Laser-Materials Interactions*, American Vacuum Society National Symposium, Houston, November 1985
9. *Surface Photoreactions Induced by Electronic Excitation in a Solid*, American Chemical Society National Meeting, New York, May 1986
10. *Surface Reactions in Laser Deposition and Etching*, American Chemical Society National Meeting, Anaheim, September 1986
11. *Coupling of Reaction and Desorption in Spontaneous and Laser-Induced Etching*, American Physical Society March Meeting, New York, March 1987
12. *Interdependence of Excitation and Reaction in Laser Deposition of Thin Films*, American Chemical Society National Meeting, New Orleans, September, 1987
13. *Mechanistic Studies of Etching of Silicon by XeF₂*, Dry Process Symposium, Electrochemical Society National Meeting, Honolulu, October 1987
14. *Photogenerated Charge Carriers and Laser Assisted Etching of Semiconductors*, American Vacuum Society National Symposium, Atlanta, October 1988
15. *Surface Reactions in Photochemical Film Growth from the Metal Hexacarbonyls*, American Chemical Society National Meeting, Miami, September 1989
16. *Mechanisms of Laser Photochemical Modification of Solid Surfaces*, Chemistry of Electronic Materials Gordon Research Conference, Ventura, CA, Feb 1990
17. *Connecting Optical Excitation and Film Properties in Laser-Induced Deposition*, 7th Interdisciplinary Laser Science Conference, Monterey, CA Sept 1991
18. *Fundamental Aspects of Laser Deposition of Thin Metal Films: Chemistry of Contamination*, K. A. Singmaster and F. A. Houle, Electrochemical Society National Symposium, Phoenix, October 1991
19. *Laser Assisted Chemical Vapor Deposition from the Metal Hexacarbonyls*, K. A. Singmaster and F. A. Houle, American Chemical Society National Meeting, San Francisco, April 1992
20. *Surface Chemistry of Laser-Assisted Film Growth*, 2nd International Conference on Laser Advanced Materials Processing, Nagaoka, Japan, June 1992
21. *Local Reactivity and Kinetic Control in Chemical Vapor Deposition*, Materials Research Society Fall Meeting, Boston, December 1992
22. *Stochastic simulation of CW and pulsed laser-induced chemical vapor deposition chemistry* OE/LASE '94, Los Angeles, January 1994
23. *Mechanistic Studies of Chemically Amplified Photoresists*, W. D. Hinsberg, G. M. Wallraff and F. A. Houle, American Chemical Society National Meeting, San Francisco, April 1997

24. *Modelling Chemical Vapor Deposition of Early Transition Metals*, F. A. Houle, K. A. Singmaster and W. D. Hinsberg, American Chemical Society National Meeting, San Francisco, April 1997
25. *Chemistry Controlling Nanoscale Pattern Formation by Deep UV Photolithography*, F. A. Houle, W. D. Hinsberg, M. Morrison, M. I. Sanchez, G. Wallraff, C. Larson and J. Hoffnagle, ACS Spring meeting, Anaheim, CA, March 1999
26. *Factors Controlling Pattern Formation in Chemically Amplified Resists at Sub-100 nm Dimensions*, W. Hinsberg, F. Houle, G. Wallraff, M. Sanchez, M. Morrison, J. Hoffnagle, H. Ito, C. Nguyen, C. Larson, 16th Conference of Photopolymer Science and Technology, Chiba, Japan, June 1999.
27. *Quantitative Description of the Postexposure Bake Process in a Chemically Amplified Resist Based on Spectroscopic Measurements*, W. Hinsberg, F. Houle, G. Wallraff, M. Morrison, M. Sanchez, C. Larson and J. Hoffnagle, IEEE Lithography Workshop, Anchorage, Alaska, August 1999.
28. *Factors Controlling Pattern Formation in Polymeric Resists at Nanoscale Dimensions*, W. Hinsberg, F. Houle, G. Wallraff, M. Sanchez, M. Morrison, J. Hoffnagle, H. Ito, C. Nguyen, C. Larson, P. Brock and G. Breyta, Materials Research Society Fall Meeting, Boston, MA, November 1999.
29. *Simulating Chemical Kinetics*, F. A. Houle and W. D. Hinsberg, ACS Spring Meeting, San Francisco, April 2000
30. *Chemistry and physics controlling nanoscale pattern formation in polymeric resists*, F. A. Houle, W. D. Hinsberg, M. I. Sanchez and J. A. Hoffnagle, Nanofabrication GRC July, 2000
31. *Physical Chemistry of Photolithography*, F. A. Houle and W. D. Hinsberg, ACS Spring meeting, San Diego, April 2001
32. *The influence of resist components on image blur in patterned positive tone chemically amplified photoresists*, F. A. Houle, W. D. Hinsberg, M. I. Sanchez and J. A. Hoffnagle, International Conf. On Electron, Ion and Photon Beams and Nanofabrication, Washington June 2001
33. PLENARY *Testing Limits of Photoresists with Interferometric Lithography*, John A. Hoffnagle, William D. Hinsberg, Frances A. Houle, Martha I. Sanchez, ICALEO 2001, Orlando, October 2001
34. *Basic Studies of Lithographic Materials Using Interferometry*, W. Hinsberg, S. Lee, J. Hoffnagle, M. Sanchez, F. Houle, T. Wallow, H. Ito and K. Kanazawa, 46th Annual International Conference on Electron, Ion and Photon Beams, Anaheim, CA (May 2002)
35. *Basic Studies of Lithographic Materials Using Interferometry*, W. Hinsberg, S. Lee, J. Hoffnagle, M. Sanchez, F. Houle, T. Wallow, H. Ito and K. Kanazawa, 19th Conference of Photopolymer Science and Technology, Chiba Japan, (June)
36. *Chemistry and physics of image formation in advanced chemically amplified photoresists*, F. A. Houle, W. D. Hinsberg, M. I. Sanchez and J.A. Hoffnagle, Inaugural meeting of the African Materials Research Society, Dakar, Senegal, December 2002
37. *Extendability of chemically amplified resists: another brick wall?* W. D. Hinsberg, F. A. Houle, M. I. Sanchez, J. A. Hoffnagle, G. M. Wallraff, D. R. Medeiros, J. L. Cobb, Advances in Resist Technology and Processing XX, SPIE , Santa Clara, CA March 2003
38. *Line Edge Roughness: Measurement Techniques*, M. Sanchez, W. Hinsberg, F. Houle, J. Hoffnagle, G. Gallatin, A. Mahorowala, D. Goldfarb, and S. Rasgon, 47th International Conference on Electron, Ion, and Photon Beam Technology and Nanofabrication, Tampa, FL, May 2003
39. *Use of interferometric lithography to characterize the spatial resolution of a photoresist film* J. A. Hoffnagle, W. D. Hinsberg, F. A. Houle and M. I. Sanchez, 20th Conference of Photopolymer Science and Technology, Chiba, Japan, June 2003

40. *Life on the frontier*, F. A. Houle, American Chemical Society National Meeting, New York NY, September 2003
41. *Reactive Dissolution Kinetics of Lithographic Copolymers* W. Hinsberg, F. A. Houle, H. Ito, ACS National Meeting, Anaheim, March 2004
42. *Sub-50 nm Half Pitch Imaging with a low Activation Energy Chemically Amplified Photoresist* Gregory M. Wallraff, David R. Medeiros, Carl E. Larson, Martha I. Sanchez, Karen E. Petrillo, Charles T. Rettner, Blake W. Davis, Linda K. Sundberg, Frances A. Houle, William D. Hinsberg, John A. Hoffnagle, Dario L. Goldfarb, Karen Temple, James J. Bucchignano, W. S. Huang, S. Wind, A. Fornoff, 9th International Conference on Electron, Ion and Photon Beam Technology and Nanofabrication, San Diego, CA June 2004
43. *Chemical kinetics of nanofabrication*, F. A. Houle and W. D. Hinsberg, ACS National Meeting, Washington DC, August 2005
44. *Characterization of Materials for Nanoscale Lithography*, W. Hinsberg, J. A. Hoffnagle, F. A. Houle, G. M. Wallraff, M. I. Sanchez, C. M. Jefferson, D. S. Bethune and C.E. Larson, American Physical Society March Meeting, Baltimore, MD, March 2006
45. *Materials for Step and Flash Nanoimprint Lithography*, H. Ito, F. A. Houle, M.W. Hart, R. A. DiPietro, E. Hagberg, K. Carter, ACS National Meeting, Atlanta GA March, 2006
46. *Kinetics of Ionization and Photoresist Dissolution* W. Hinsberg, F. Houle, S. Lee, K. Kanazawa, A. Rao, V. Prabhu and W-I Wu, Materials Research Society Spring Meeting, San Francisco CA, April 2006
47. *Numeric Analyses of the Roles of Gas Phase and Liquid Phase UV Photochemistry in Conventional and Immersion 193 nm Lithography*, W. Hinsberg and F. A. Houle, 23rd Conference on Photopolymer Science and Technology, Chiba, Japan, June 2006
48. *Material Design for Step and Flash Nanoimprint Lithography*, H. Ito, F. A. Houle, R. A. DiPietro, M. W. Hart, 17th IEEE Lithography Workshop, Prince Edward Island, Canada, August 2006
49. *Characterization of Materials for Nanoscale Lithography*, W. D. Hinsberg, J. A. Hoffnagle, F. A. Houle, G. M. Wallraff, M. I. Sanchez, C. M. Jefferson, D. S. Bethune, C. E. Larson, International Microprocesses and Nanotechnology Conference, Kamakura, Japan October 2006
50. *A discussion of professional ethics* DISTINGUISHED SPEAKER International Conference on Computer Aided Design '06, San Jose November 2006
51. *Nanoimprint Materials Systems*, KEYNOTE TALK 25th Conference on Photopolymer Science and Technology, Chiba, Japan, June 2008
52. *Debonding of UV cured nanoimprint resist-release layer systems*, D. L. Casher, F. A. Houle and D. C. Miller, SPIE Advanced Lithography Symposium, Alternative Lithographic Technologies, San Jose, February 2009
53. 2009 AVS JOHN A. THORNTON MEMORIAL AWARD AND LECTURE. *Nanofabrication Chemistry: the impact of solid surfaces*. AVS International Symposium, San Jose, CA, November 2009
54. *Energy Critical Elements*, 2011 World Materials Summit and Student Congress, Washington, D.C., October 2011
55. *Energy Critical Elements*, Poptech, Camden, ME, October 2011.
56. *Stochastic simulations to bridge experiment and theory of complex chemical processes: application to aerosol ageing* 2014 Mesilla Chemistry Workshop in memory of Sally Chapman on Studies of the Chemical Dynamics of Energy Transfer and Chemical Reaction, Mesilla, NM, Feb 1-4, 2014
57. *Solar Fuels Generation by Artificial Photosynthesis: Translation from Science to Prototypes* 23rd International Materials Research Congress, Cancun Mexico, August 2014