Syllabus

EE 508: Nano-Fabrication Lithography

Fall, 2017

Time: 2:00 - 3:20 pm MW

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Summary: Nano-fabrication is one of the enabling technologies of nano-device and nano-science researches. While it was mainly invented throughout the progress of the semiconductor industry, its applications have gone beyond semiconductor devices and circuits. Understanding the science and technology of nano-fabrication becomes an essential foundation of successful research in the frontier of electronics, photonics, and circuits.

EE 507 and EE 508 form a two-course sequence in micro/nano-fabrication, and the courses can be taken in either order. The goal of EE 508 is to:

1) Survey the landscape of state-of-the-art lithography technologies.
2) Understand the fundamental sciences behind nano-lithography.
3) Provide a starting point for nano-fabrication research.

Prerequisites: Graduate standing in Engineering, Physics, or Chemistry

Course text:

Handout for each class, and
"Fabrication Engineering at the Micro and Nanoscale", by Stephen A. Campbell

Grading:

10% homework, 20% oral presentation, 30% mid-term exam, 40% final exam

Weekly topics:

1. Introduction and overview of lithography technologies
   Pease, R.F. and S.Y. Chou, *Lithography and other patterning techniques for future electronics*. Proceedings of the Ieee, 2008. 96(2): p. 248-270.
2. Overview of lithography technologies and overview of pattern transfer
   Smith, H.I., *A Review of Submicron Lithography. Superlattices and Microstructures*, 1986. 2(2): p. 129-142.
   Smith, H.I. and D.C. Flanders, *X-Ray-Lithography - a Review and Assessment of Future Applications.* Journal of Vacuum Science & Technology, 1980. 17(1): p. 533-535.
3. Photolithography fundamentals (first homework)
   Rothschild, M. and D.J. Ehrlich, *A Review of Excimer Laser Projection Lithography*. Journal of Vacuum Science & Technology B, 1988. 6(1): p. 1-17.
   Bates, A.K., M. Rothschild, T.M. Bloomstein, T.H. Fedynyshyn, R.R. Kunz, V. Liberman, and M. Switkes, *Review of technology for 157-nm lithography*. Ibm Journal of Research and Development, 2001. 45(5): p. 605-614.
4. Resolution enhancement technologies: immersion, off-axis illumination
   ITRS roadmap 2010 update, 2010
   Riviere-Cazaux, L., K. Lucas, and J. Fitch, *Integration of Design For Manufacturability (DFM) practices in design flows*. 6th International Symposium on Quality Electronic Design, Proceedings, 2005: p. 102-106.
5. Resolution enhancement technologies: phase-shift mask, optical proximity correction, double processes (second homework)
   Pang, L.Y., D.P. Peng, L. He, D.X. Chen, and V. Tolani, *Computational Lithography & Inspection (CLI) and its Applications in Mask Inspection, Metrology, Review, and Repair*. Photomask Technology 2010, 2010. 7823.
6. Wrap-up photolithography, EUV lithography (system, light sources)
   Wua, B.Q. and A. Kumar, *Extreme ultraviolet lithography: A review*. Journal of Vacuum Science & Technology B, 2007. 25(6): p. 1743-1761.
7. EUV lithography (optics, mask, resist and challenges), other photon-based lithographies: interference lithography (third homework)
   Hector, S. and P. Mangat, *Review of progress in extreme ultraviolet lithography masks.* Journal of Vacuum Science & Technology B, 2001. 19(6): p. 2612-2616.
   Blaikie, R.J., D.O.S. Melville, and M.M. Alkaisi, Super-resolution near-field lithography using planar silver lenses: A review of recent developments. Microelectronic Engineering, 2006. 83(4-9): p. 723-729.
8. Other photon-based lithographies: phase-mask lithography, maskless lithography, double- photon lithography (fourth homework)
   Kasko, A.M. and D.Y. Wong, *Two-photon lithography in the future of cell-based therapeutics and regenerative medicine: a review of techniques for hydrogel patterning and controlled release.* Future Medicinal Chemistry, 2010. 2(11): p. 1669-1680.

9. Mid-term exam, Electron-beam lithography and SEM
   Liddle, J.A. and G.M. Gallatin, *Lithography, metrology and nanomanufacturing. Nanoscale,* 2011. 3(7): p. 2679-2688.
10. Electron-beam lithography and SEM (fifth home work)
    Petric, P., C. Bevis, M. McCord, A. Carroll, A. Brodie, U. Ummethala, L. Grella, A. Cheung, and R. Freed, *Reflective electron beam lithography: A maskless ebeam direct write lithography approach using the reflective electron beam lithography concept.* Journal of Vacuum Science & Technology B, 2010. 28(6): p. C6c6-C6c13.
11. Focused-ion-beam lithography, Helium-ion-beam lithography (sixth homework)
    Winston, D., B.M. Cord, B. Ming, D.C. Bell, W.F. DiNatale, L.A. Stern, A.E. Vladar, M.T. Postek, M.K. Mondol, J.K.W. Yang, and K.K. Berggren. *Scanning-helium-ion-beam lithography with hydrogen silsesquioxane resist.* 2009: AVS.
    Baglin, J.E.E., Ion beam nanoscale fabrication and lithography-A review. Applied Surface Science, 2012. 258(9): p. 4103-4111.
12. Tip-based lithographies
    Tseng, A.A., A. Notargiacomo, and T.P. Chen, *Nanofabrication by scanning probe microscope lithography: A review.* Journal of Vacuum Science & Technology B, 2005. 23(3): p. 877-894.
13. Nanoimprint lithography and soft lithography (seventh homework)
    Malloy, M. and L.C. Litt, *Technology review and assessment of nanoimprint lithography for semiconductor and patterned media manufacturing*. Journal of Micro-Nanolithography Mems and Moems, 2011. 10(3).
    Schift, H., *Nanoimprint lithography: An old story in modern times? A review*. Journal of Vacuum Science & Technology B, 2008. 26(2): p. 458-480.
    Kim, P., K.W. Kwon, M.C. Park, S.H. Lee, S.M. Kim, and K.Y. Suh, *Soft lithography for microfluidics: a review.* Biochip Journal, 2008. 2(1): p. 1-11.
14. Directed self-assembly, lithography with superlattices
    Orilall, M.C. and U. Wiesner, *Block copolymer based composition and morphology control in nanostructured hybrid materials for energy conversion and storage: solar cells, batteries, and fuel cells.* Chemical Society Reviews, 2011. 40(2): p. 520-535.
15. Student presentations

Reading materials are assigned after every class.

Statement for Students with Disabilities
Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

Statement on Academic Integrity

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. *Scampus*, the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/ publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.