

University of California, Berkeley
Department of Mechanical Engineering

ME 290R – Topics in Manufacturing, Fall 2014: Lithography

Class meetings: TuTh 3.30–5pm in 1165 Etcheverry

Tentative class schedule (last updated September 18)

Class #	Date		Lecture topic	Papers that will be discussed in class	Assignment due
1	Th	August 28	Introduction to ME290R. Overview of current and emerging lithography technologies and challenges. Future lithography requirements (with reference to the International Technology Roadmap for Semiconductors). Requirements for integration of lithography with other process steps.		
2	Tu	September 2	Performance metrics for lithography techniques (ways to evaluate a lithography process). Resolution; line edge roughness; overlay capability; throughput; cost of ownership; capital cost; energy consumption and environmental impact (e.g. solvent usage; material wastage); pattern dependencies.		
3	Th	September 4	Nanoimprint lithography (NIL), part 1: process physics. Contact mechanics of stamp-wafer interactions. Resist deformation models. Sources of defects.		Reading 1 response by 11.59pm
4	Tu	September 9	Nanoimprint lithography, part 2: imprintable materials. Thermal vs UV-curing resist materials. Temperature-viscosity relationships of thermoplastic resists. Shear thinning. Photocrosslinking and thermal crosslinking reactions. Oxygen inhibition. Use of surfactants and release layers.	Reading 1: NIL capabilities and challenges	

Class #	Date		Lecture topic	Papers that will be discussed in class	Assignment due
5	Th	September 11	Nanoimprint lithography, part 3: stamp fabrication technologies. Materials (quartz, silicon, metallic, polymeric). Intermediate stamp replication strategies. Pattern-writing processes (e-beam, directed self-assembly). Seamless rollers for roller-based patterning. Defect inspection approaches.		Reading 2 response by 11.59pm
6	Tu	September 16	Introduction to simulation assignment. Demonstration of NIL simulation software. Example: investigation of nanoimprint-friendly “dummy fill”. Presentation of task. Q&A.	Reading 2: NIL defectivity, throughput and stamp lifetime considerations	
7	Th	September 18	Nanoimprint lithography, part 4: machine design. Step-and-flash vs whole-wafer patterning. Roll-to-roll and roll-to-plate configurations. Resist dispensing methods: droplet, spin-on, doctor blade. Load application: flexure; stamp-bowing mechanism; air cushion press. Managing defect sources.		Reading 3 response by 11.59pm
8	Tu	September 23	Nanoimprint lithography, part 5: applications. Photonic crystal LEDs. Dual damascene dielectric imprinting. Bit-patterned data storage. Flash memory. Novel memory structures (e.g. by “topolithography”). Surface nanoengineering (e.g. superhydrophobicity; “printing color” using plasmonics).	Reading 3: NIL applications (bit-patterned media; Flash memory)	
9	Th	September 25	Nanoimprint lithography, part 6: stamp compliance optimization and large-area patterning. Segmented, layered, and monolithic stamps. Micro-gravure. “Self-Aligned Imprint Lithography”.		
10	Tu	September 30	Guest lecture: Prof. Vivek Subramanian, Berkeley EECS. Microgravure		
11	Th	October 2	Microcontact printing. Ink transfer processes. Design of stamps and sources of defects – collapse, buckling, etc. Metal film peel-off patterning via rate-dependent adhesion. Application example, e.g. printing transparent conductive patterns.		Simulation assignment preparatory questions due 11.59pm

Class #	Date		Lecture topic	Paper(s) that will be discussed in class	Assignment due
12	Tu	October 7	Lithography for MEMS and microfluidics. LIGA (very high-aspect-ratio patterning); hot embossing; soft lithography. Examples in microfluidics manufacturing.		
13	Th	October 9	Photolithography. Factors determining resolution (numerical aperture, k , wavelength). Illumination technology. Alignment methods (fiducial, moiré). Resist technology (positive, negative, image reversal, contrast concepts). <i>Resolution-enhancing innovations</i> . Double- and triple-patterning. Coloring algorithms. Line cutting. Immersion lithography. Source-mask optimization. Phase masks. Computational lithography (optical proximity correction).		Expressions of interest in pitching project ideas on 10/16 also due by 11.59pm
14	Tu	October 14	Project idea pitches and team networking		Simulation assignment due 11.59pm.
15	Th	October 16	Extreme ultraviolet lithography. Issues: source power, mask infrastructure, economics.		Reading 4 response by 11.59pm
16	Tu	October 21	Scanning-beam lithographic methods. Electron-beam lithography: resolution-limiting factors. Salty development. Grayscale and reflow techniques. Proximity correction. Ion and proton beam techniques.	Reading 4: Photolithography/EUV innovations	
17	Th	October 23	Quiz. 75 minutes, open book/notes.		Reading 5 response and project teams compositions (3–5 people per team) due by 11.59pm

Class #	Date		Lecture topic	Paper(s) that will be discussed in class	Assignment due
18	Tu	October 28	Directed self-assembly. Block copolymers. Scalable approaches. DNA-based self-assembly.	Reading 5: multiple e-beam and directed self-assembly	
19	Th	October 30	X-ray/zone-plate array lithography; near-field methods		
20	Tu	November 4	Guest lecture/visit		
21	Th	November 6	Interim project presentations		
	Tu	November 11	No class: Veterans' Day		
22	Th	November 13	Guest lecture: Christoph Peroz, Director of Nanofabrication and Optical Devices, Abeam Inc., based at the LBNL Molecular Foundry.		
23	Tu	November 18	Panel discussion: <i>The Future of Lithography.</i>		
24	Th	November 20	Emerging/specialist lithography techniques. Interference lithography. "Nanoskiving". Edge-based lithography. 3D lithography techniques (stereolithography, including two-photon processes; holographic lithography).		
25	Tu	November 25	Project presentations, part 1 (approx. 4 groups, each with 12 minutes presentation plus 5 minutes Q&A and 3 minutes changeover time)		
	Th	November 27	No class: Thanksgiving		
26	Tu	December 2	Project presentations, part 2 (another ~4 groups)		
27	Th	December 4	Project presentations, part 3 (another ~4 groups)		

- Final project reports due via bCourses by Friday December 12 at 5pm
- For literature readings 1–5, written responses will be required to one paper per set of readings. The papers will be available on bCourses at least one week before the response is due. The papers will be briefly introduced in class one week before the due

date (e.g. for Reading 1, whose response is due on September 4, the papers will be introduced on August 28). During the in-class introduction, some potential points for discussion will be raised.