Microfabrication and Microfluidics, BioE 599M & N
Winter Quarter 2007

Dr. Paul Yager
Foege N530J, 206-543-6126, yagerp@u.washington.edu
Monday and Wednesday 1:30 PM to 2:50 PM PAA A110

Optional Laboratory BioE 599N
Lisa LaFleur, TA, llafleur@u.washington.edu
Monday and Wednesday, 3:30 to 4:20 PM HST T360A, and in Fluke Microfabrication Laboratory

This course is aimed at preparing students to use 2- and 3-dimensional structures with features between 1 mm and 0.1 μm in their research with biomaterials, cells, and complex liquids. It may be taken by also be taken by upper-level undergraduates with advance permission of the instructor.) This course focuses on those aspects of microfabrication that are best suited to micropatterning of surfaces, and microfluidic chemical analytical systems. Initial material reviews fabrication techniques, microfluidic chemical analytical systems, and "soft lithography" through lectures and discussion of current literature. Additional material covering utilization of such techniques in devices for use in point-of-care diagnostics for use in the developed and developing worlds has recently been added. The 3-credit lecture course is open. The companion 2-credit companion laboratory course project is limited to 9 students. The purpose of the laboratory course is to learn (hands on!) how to prepare devices that will be immediately useful in the student's research. In the lab students will make thin or thick photoresist structures, then use these to prepare polydimethylsiloxane replicas for use in micropatterning, micromolding or microfluidics.

Meetings:
The first of the meetings each week will generally be a formal introductory lecture by the main or guest lecturer. The second meetings will be broken into two approximately equal parts as follows:

1. Lecture.
2. Breaking up of the students into groups of 4 or 5 to informally discuss readings assigned in the previous lecture (see syllabus). Professor to float between groups to ensure that the discussions progress.

Readings:
The “text” for this course will be the set of PowerPoint-based lecture notes by the professor except as noted below. A preliminary version of these notes will be placed in PDF form on the course WWW site at the beginning of the class. All notes on the WWW site more than 1 week before class are to be considered tentative. These may be updated a day or two before that day’s lecture, so it is wise not to download the full set. The URL for the class WWW xxxxxxxxxxxxxxx There is a separate section of the www site for the laboratory class..

For those of you in need of a “real” text, I strongly recommend the following:

1. Fundamentals of Microfabrication, by Marc Madou, CRC Press, Boca Raton, 1997
2. Micromachined Transducers Sourcebook, by Gregory T. A. Kovacs, McGraw-Hill, Boston, 1998

In addition, there are three review articles on microfluidics that should be read before the final exam:

1. Darwin R. Reyes, Dimitri Iossifidis, Pierre-Alain Auroux, and Andreas Manz, Micro total analysis systems. 1. Introduction, theory, and technology. Analytical Chemistry, 2002. 74: p. X.

2. Pierre-Alain Auroux, Dimitri Iossifidis, Darwin R. Reyes, and Andreas Manz, Micro total analysis systems. 2. Analytical standard operations and applications, Analytical Chemistry, 2002. 74: p. X.
3. Elisabeth Verpoorte, Microfluidic chips for clinical and forensic analysis. Electrophoresis, 2002. 23: p. 677-712.

Student Participation:
Students will be expected to perform three sets of tasks during the course:
I. The first is active and informed participation in the Discussion sections. The reading material assigned during the previous class will be the topic for discussion, along with the relevant lecture materials. Failure to participate or to have read the material beforehand will result in the loss of credit.

II. Second, the research paper or papers assigned, then subsequently discussed in the Discussion section will be the topic of a 3 page (single spaced 12 point Times or equivalent) critique due about one week after the discussion section (see syllabus). These critiques are to be sent to Yager electronically as Microsoft Word files as enclosures in e-mail, and are due electronically at 5 PM on the date shown on the syllabus. They should be sent to Yager *and* the TA for the class. All e-mail to Yager and the TA should have the header Microfab Class. Discussion among students preparing these critiques *is strongly encouraged*, but the actual writing of each critique must be in the student's own words. Late critiques will be graded down by 50%, and critiques more than one week overdue will not be accepted without prior approval of the instructor. Papers *longer* than 3 pages will be graded down by 50%. The critiques must address at least the following questions (unless the assignment states otherwise):

1. A brief summary of the content of the paper(s) in your own words—how does the device or system work?
2. Do the authors adequately address the problems inherent in the device of system described?
3. Do the authors cover *all* the relevant literature up to the time of publication? (requires a literature search!)
4. What applications could be foreseen for the device or system (if not already mentioned in the paper(s))?
5. If there are more than one paper, compare and contrast the two approaches.

Writing must be in good formal (not colloquial) English, with attention paid to punctuation, grammar, etc. A bibliography (not www sites) with appropriate in-text citations are mandatory[*]. The weighting will be the following:

English writing and proofreading	2
Understanding of the paper(s)	2
Depth of research and coverage	2
Originality of ideas in interpretation	1

Note that some of these assignments may (at the instructor's discretion) take the form of short design projects, for which the grading key will be the following:

English writing and proofreading	2
Understanding of the paper(s)	1
Depth of research and coverage	1

[*] Students are fully responsible for understanding the strictest interpretation of plagiarism. A demonstrated instance of plagiarism on any document submitted for a grade in this course will result in a grade of 0.0 for the entire course and an explanatory letter being placed in the student's permanent file.

Soundness of design	2
Originality of ideas in design	1

There is a free lunch; the two lowest scores on the weekly write-ups will be revised up to full points. This will be true even if the lowest scores are zeros (if, for example, the student chooses to skip those papers).

III. Third, there will be a take-home final examination. It has generally taken the form of a design project. The exam will be handed out at the conclusion of the last class. It is due at 5 PM on the date shown in the syllabus below. Discussion or collaboration of the final examination among students is not permitted.

Grading:

In Class Participation:	8 x (1 points) = 8 points
Written Critiques:	8 x (7 points) = 56 points
Final Examination:	36 points
	TOTAL= 100 points

The laboratory component of the class is separately graded pass/no pass. Laboratories will be held in several locations, including the Fluke Hall Microfabrication Laboratory. Only students taking the lecture course for a grade will be allowed to take the laboratory. For entry codes please contact Cassie Giles at 543-8958.

SYLLABUS

Week	Date	Lecture Topic	Project Assigned	In-Class Discussion	Project Due	Laboratory
1	Wednesday January 3	Organization, Introduction Introduction to MEMS and photolithography	Intro. Reading by Xia 1, 2			Project Definition, materials limitations, HST T360A
2	Monday January 8	Photolithography and soft lithography techniques	Paper Set 1			
2	Wednesday January 10	Soft lithography applications	Paper Set 2	Paper Set 1		Present sketches, discuss feasibility, begin xfer to AutoCAD, Computer Lab
3	Monday January 15	Holiday				
3	Wednesday January 17	Classic Si micromachining		Paper Set 2	Paper 1	Present and finalize mask design, Computer lab
4	Monday January 23	Si micromachined devices	Paper Set 3			
4	Wednesday January 24	Microfab with materials other than Si		Paper Set 3	Paper 2	Lab Safety Lecture HST T360A, collect masks files
5	Monday January 29	Laminate fabrication	Paper Set 4			
5	Wednesday January 31	Fluidics		Paper Set 4	Paper 3	Check mask, HST T360A Spin to prebake SU8, Fab Lab
6	Monday February 5	Microfluidics, including lift effects	Paper Set 5			
6	Wednesday February 7	Connectors and valves		Paper Set 5	Paper 4	Expose, develop SU8, Microfab Lab
7	Monday February 12	Pumps and pumping	Paper Set 6			
7	Wednesday February 14	Measuring flow; Microfluidic mixing, electrokinetics		Paper Set 6	Paper 5	Characterize wafers, cast PDMS, Microfab Lab
8	Monday February 19	Holiday Capillary electrophoresis on a chip, FFF, DEP	Paper Set 7			
8	Wednesday February 21	Flow cytometry, post arrays for particle manipulation	Paper Set 8	Paper Set 7	Paper 6	Remove PDMS and physically characterize, Yager Lab
9	Monday February 26	Out of town.				
9	Wednesday February 28	Transverse diffusion-based technologies		Paper Set 8	Paper 7	Test and characterize device performance
10	Monday March 5	Transverse electrokinetic phenomena				
10	Wednesday March 7	Recent updates from Yager lab, class evaluation	Take Home Exam		Paper 8	Presentation of student projects, HST T360A
11	Wednesday				Take Home	

	March 14				Exam Due 5 PM	

Paper Set	Paper(s)
1	Kenis, P.J., R.F. Ismagilov, and G.M. Whitesides, *Microfabrication inside capillaries using multiphase laminar flow patterning.* Science, 1999. **285**(5424): p. 83-85.
2	Lin, L. and A.P. Pisano, *Silicon-Processed Microneedles.* Journal of Microelectromechanical Systems, 1999. **8(1)**(March): p. 78-84. (see also Henry, S., D. V. McAllister, et al. (1999). "Microfabricated microneedles: a novel approach to transdermal drug delivery." Journal of Pharmaceutical Sciences **87(8)**(August): 922-925)
3	Beebe, D.J., J.S. Moore, Q. Yu, R.H. Liu, M.L. Kraft, B.-H. Jo, and C. Devadoss, *Microfluidic tectonics: A comprehensive construction platform for microfluidic systems.* Proceedings of the National Academy of Sciences USA, 2000. **97(25)**: p. 13488-13493.
4	Handique, K., D.T. Burke, C.H. Mastrangelo, and M.A. Burns, *On-chip thermopneumatic pressure for discrete drop pumping.* Analytical Chemistry, 2001. **on www**(xx): p. XX.
5	Kwok, Y.C., N.T. Jeffery, and A. Manz, *Velocity measurement of particles flowing in a microfluidic chip using Shah convolution Fourier transform detection.* Analytical Chemistry, 2001. **on www**(XX): p. XX.
6	Paegel, B.M., L.D. Hutt, P.C. Simpson, and R.A. Mathies, *Turn geometry for minimizing band broadening in microfabricated capillary electrophoresis channels.* Analytical Chemistry, 2000. **72**: p. 3030-3037..
7	Wong, S.H., M.C.L. Ward, and C.W. Wharton, *Micro T-mixer as a rapid mixing micromixer*. Sensors and Actuators B-chemical, 2004. **100(3)**(MAY 15 2004): p. 359-379.
8	Costin, C.D., McBrady, A.D., McDonnell, M.S., and Synovec, R.E., *Theoretical modeling and experimental evaluation of a microscale molecular mass sensor*. Analytical Chemistry, 2004. **76**: p. 2725-2733.