Work in Progress - BioMEMS and Lab-on-a-Chip Course Education at West Virginia University

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***Abstract* - A course in BioMEMS and Lab-on-a-Chip (LOC) is taught in Spring 2010 at the junior/senior undergraduate and graduate level in the Department of Computer Science and Electrical Engineering at West Virginia University. The course focuses on the basic principles and applications of BioMEMS and LOC technology applied in the area of biology and biomedicine. The students are from Electrical Engineering, Mechanical Engineering, and Chemistry. Research review articles are used as supplement lecture materials in this course. Quizzes and homeworks are used to test understanding of concepts. The paper provides an overview of the course and some development.**

Index Terms – BioMEMS, Graduate, Lab-on-a-Chip, microfluidics, Undergraduate

1 INTRODUCTION

The application of microelectromechanical systems (MEMS) to life sciences and medicine, or Biological or Biomedical MEMS, is a rapidly growing field. BioMEMS and Lab-on-a-Chip (LOC) technologies have dramatically altered biomedical, pharmaceutical, and environmental research. Accordingly, demand for skilled and educated workers and researchers in this field is rapidly expanding and universities need to develop educational plans to address the specialized needs in the BioMEMS and LOC areas. At West Virginia University, state-of-the-art biomedical research is successfully integrated within Engineering Departments and the Health Science Center. However, BioMEMS and LOC, as the most advanced technologies, have not yet to be successfully transferred to the biological and biomedical research. One of the reasons is that there is no completely established curriculum for both undergraduate and graduate students study. Another reason for this is the multidisciplinary nature of BioMEMS. General MEMS curriculum development relies heavily on traditional material science, electrical engineering, and mechanical engineering coursework, furthermore, BioMEMS curriculum requires additional background in biology and chemistry.

At West Virginia University, the College of Engineering and Mineral Resources is working to develop a series of courses in Biomedical Engineering and some of them have been taught for a few years. Figure 1 shows the titles and course numbers of these classes at well as their relationship to each other. Each of these courses in the sequence is focused on the topic area and provides significant depth in both theoretical and practical topics. Some courses include labs and laboratory exercise. These courses are designed for both undergraduate and graduate students and provides an in depth education in Biomedical Engineering and BioMEMS.

To help undergraduate juniors and seniors and graduate students to the emerging area of BioMEMS, a new course EE 493/EE591: BioMEMS and Lab-on-a-Chip is developed at West Virginia University. The course is the first course focused on applications of BioMEMS and microscale biosensors in biology, medicine, and environmental engineering, and provides a deeper coverage of the most advanced BioMEMS and LOC topics, such as BioMEMS materials, conventional MEMS fabrication and non-conventional soft lithography fabrication, biosensors and biochips, microarray technology, microfluidic and its applications in cells and tissue engineering, drug delivery and implant devices, bionanotechnologies. In the course offerings, enrollment has spread beyond the initial target audience of Electrical Engineering, and now includes students from mechanical engineering and chemistry. We are working on the effective use of research articles to supplement lecture materials and providing students with a real world perspective. Reading assignments, discussions of research papers, and short quizzes at the beginning of lectures are currently used to test understanding of concepts. This is also done to ensure that students are not overwhelmed by the multidisciplinary material or the pace of the course. Each student will choose a research topic in the field of BioMEMs and LOC to present at the end of the course. They will learn the skills of literature searching, research article reading and comprehesion, scientific research presenting and research paper writing (required for graduates). Additionally, four lab sections are arranged to help students have some hands-on experience about device fabrication. We envision the course, which can provide a strong fundamental base in biomedical microsystems to the students who participated in the class.

2 COURSE DESCRIPTION

The course was designed to be a 16-week long, three credit-hour course consisting of twenty two 75 min lectures including two guest lectures. As both a 400 and 500-level course, it is dual-level; intended for the undergraduate

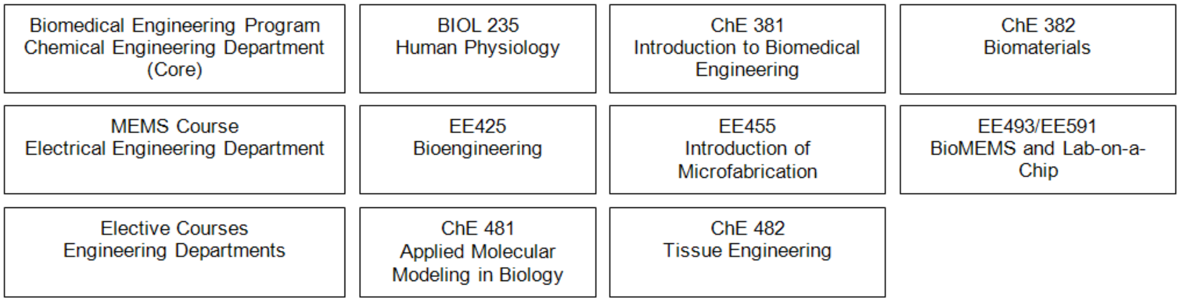

Figure 1. Biomedical engineering and MEMS courses offered at West Virginia University

Seniors and graduate students in the Engineering Departments. The course had no prerequisites other than Junior class standing. Further, no background in microfabrication, MEMS, biomedical instrumentation, or any other specialized area is assumed or required. This permitted a diverse class makeup but presented some instructional challenges. The topics and their sequence are given in Table 1.

There are handouts and journal review articles related to each topic covered in class. The instructor's teaching media included a combination of PowerPoint slides and whiteboard, which permitted a lot of colorful schematic diagrams and illustrations, offering multiple representations of the same material. Research on learning also shows that using multiple representations is more conducive to teaching an audience with diverse backgrounds, as students tend to work with their preferred representation [1][2].

The topic sequence was selected with three criteria in mind. The first was to introduce students to fundamentals of MEMS and BioMEMS fabrication. Thus, the first 3 weeks of the course focused on introducing the key concepts (such as conventional MEMS materials, various lithography methods, etching, and film deposition), then, followed the lectures about BioMEMS nonconventional fabrication technologies (soft lithography, hot embossing, and injection molding, etc.) with focus on biomedical applications. After the introduction of all necessary microfabrication technologies, the students were arranged for lab sections in a class 100 and 1000 Cleanroom for tour and photolithography demonstration. In those 3 weeks, students are familiar with some fundamental structures and techniques. The theories and concepts will be revisited later in the course when discussing any related devices, such as stress cantilever biosensors and their biomedical applications. Again after introduction of microfluidic theories, important parameters, and components (like valves and pumps), another two lab sections will be arranged for students to make microfluidic channels in lab and test the device to emphasize the concepts learned in the course. The discussion of MEMS and BioMEMS fabrication, and specifically the four lab sections will provide students with a common starting point for any biological and biomedical related systems and devices later on.

Table 1. Topics covered in the "BioMEMS and Lab-on-a-Chip"course

Week	Topics
1	Introduction and overview of BioMEMS and Lab-on-a-Chip
2	MEMS fabrication
3	BioMEMS fabrication
4	Cleanroom tour and lithography demonstration
5	Cell, DNA, and Protein Basics
6	Biosensor and Biochips
7	Microarray and Middle Exam
8	Microfluidics and components
9	Microfluidics labs
10	Drug delivery and implant devices
11	Microtechnology and cells
12	Microtechnology and tissue
13	Bionanotechnology
14	Students presentation
15	Students presentation
16	Final

The second criterion was not to overwhelm the engineering students by the breadth of the interdisciplinary topics encompassed in BioMEMS and LOC. Although most of the students have been involved in research and show interest in biotechnology, the students have few courses outside their own department. Thus, the fundamental knowledge and important concepts commonly used in cell biology and biosensors are introduced earlier in the course, such as DNA to protein, DNA and protein structures, based built units, DNA hybridization, polymerase chain reaction for DNA amplification, and biolink using DNA and proteins. In addition, based on students' engineering background, the sequence of lectures guides them in the directions of the more engineering and biologically intense nature of BioMEMS and LOC towards the end of the course. Based on this criterion, mechanical sensors are discussed in the beginning of the course, and cell and tissue engineering toward the end.

The third and final criterion was to give students equal exposure to the theoretical principles and their biomedical applications. For example, after introducing fundamentals of microfluidics, application to microfluidics devices will be discussed. This theme of "from theory to application" will be carried out throughout the course. In addition, research topics are assigned for guiding the students with their term project. The topics, for example, are microtechnology and pathogen detection, microfluidic based blood and analysis system, monitoring metabolic activity on chip, electronic noses for medical diagnosis, stem cells and microtechnology, cancer detection and microtechnology, and Microtechnology and nanomaterials toxicity, etc.

3. TEXTBOOK AND ADDITIONAL BIBLIOGRAPHY

The list of textbooks for a class in BioMEMS and LOC is currently quite short, and none can completely cover major advanced topics in this area. Some possible reasons for the shortage of textbooks are due to the fast development in BioMEMS and LOC research and applications, and also because the different background of authors makes them emphasizing topics quite differently. Two books were chosen as reference books and reserved in our Evansdale Engineering Library. The books are Microsystem Technology in Chemistry and Life Sciences [3] and Microsystem Engineering of Lab-on-a-chip Devices [4]. The review journal papers are posted in class website after each lecture. There will be an average of two review and important papers in each selected topic given to students for further reading.

4 DISCUSSION

The main objective of the course, in addition to the normal educational objectives, is to rapidly prepare and train students at West Virginia University to perform basic research in the area of BioMEMS, LOC, and microfluidics, so there are certain demands for this course. The course is designed to give each student a broad background in this area and an understanding of the core issues in currently most advanced applications related to microfluidics, LOC and BioMEMS. The course, currently in its first offering, there is significant room for improvement. Current feedback is that the interested faculty and their students responses favorabe. The course enrollment is 14, including 2 undergraduate students and 12 graduate students. This is a good start and a healthy number.

Many students want to be able to physically perform some of the experiments and fabrication procedures discussed in the class. Thus, the lab components are added; the practical training of the students is invaluable to both them and their research advisors.

The research projects are selected either from instructor provided lists or based on students intent that would be able to fit in directly with their ongoing research efforts. The project topics cover the full range of the course lectures and involve most advanced and hot topics in BioMEMS and LOC.

5 FUTURE PLAN

Our course objectives and plans are 1) to gain background knowledge about MEMS techniques for understanding the fabrication, design and function of BioMEMS; 2) Be able to select materials depending on desired properties and applications; 3) To become familiar with microminiaturization concepts, such as microfluidics, biosensors, biochips, and LOC; 4) To learn how to do an effective literature search and monitor BioMEMS journals for interesting articles; 5) To research the state of the art of a selected BioMEMS topic, present key results, formulate open questions, and define a research direction or application of the particular technology. The course will be taught again in Spring 2011, any recommendations and inquiries are welcome.

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