ENGR 1282.02H

Fundamentals of Engineering for Honors II

Microfluidics Project Description

Microfluidics – Big Lab on a Tiny Chip Research & Design Project Description and Specifications

It is assumed that all students enrolled in the 1282.02H course have read and understood this document. It is up to the student to clarify any points that may seem unclear.

Project Overview:

As part of a research group studying microfluidics, you and your exceptional team of scientists are seeking to answer questions about yeast cell adhesion in a microfluidics channel. One of your research team's heroes, Dr. Muriel Mercier-Bonin, began working in this field over a decade ago and you are seeking to build off of her research.

After developing your research question and experimental methodology, you will design, build, and conduct experiments with a lab-on-a-chip (LOC) device. You will then write a journal article for submission to the Journal of Fluidics and Extremely-small Hydrodynamics (FEH): Microfluidics. The submission deadline is at the end of the term and specified in the DAL for APP N26-1: Micro Report – Final Journal Article.

In preparation for submission to this journal, your Principal Investigators (or PIs), Paul Clingan, Kelly Kolotka, and Dr. Deb Grzybowski, want to track your progress throughout the semester. The following submissions will be required throughout the semester:

1. Outline
2. Part 1 Draft
3. Part 2 Draft and Abstract
4. Final Draft

Each of these submissions should include all information that your team has available at the time of submission.

The specific requirements for each submission are detailed on the course's Carmen page.

A journal template will be provided. Students must use this template for Part 1, Part 2 and Abstract, and Final Draft submissions. For most journals, it is important to follow the formatting guidelines to increase chances of acceptance to the journal.

Experimental Microfluidics

For the experimental microfluidics project, your team will design, build and conduct experiments with a lab-on-a-chip (LOC) device to test a hypothesis regarding cell attachment to surfaces. The semester long design/build/research project will offer the team working knowledge of biomedical devices based on nanotechnology, microfluidics, and microscale engineering. Along with the hands-on activities at the microscale, various readings, videos, and in-class presentations from student teams will introduce the techniques necessary to develop technology at the micro and nanoscale. The challenge for this project is to produce a design for an experimental microfluidic device, manufacture that design in a biocompatible material, and study the effect of a specific, experimental variable treatment on cell attachment.

Project Objectives:

1. Exposure to various fields of engineering
2. Experience in essential time management, task scheduling, and project management skills
3. Experience in following a complete design cycle from brainstorming, idea inception, and drawings to manufacturing and testing of a prototype
4. Exposure to an interdisciplinary team-based work environment
5. Exposure to the developing fields of microfluidics and nanotechnology

Lab-on-a-chip General Device Requirement:

You are to construct a microfluidics device to be used in a research study. Cell attachment to material surfaces can play an important role in many flow systems that may contain biological materials, such as orthopedic and vascular implants, biosensors, biological filtration systems, along with many other medical, biological, and environmental flow systems. You are to construct a device that will contain several flow channels which will allow testing for specific treatment variables. The device must generate a well-defined flow in each channel. To do so, thin rectangular channels will be used. Computer simulation will be used to calculate the velocity profile and shear stress distribution in the channel. Each channel will be seeded with yeast cells, and various flow rates will be applied to the channel until the increasing shear force experienced by the yeast cells causes them to detach from the surface. Attached cell counts will be observed visually under a microscope and recorded for each flow rate applied to the channel in order to determine detachment caused by the shear forces. Each team will compare a set of control data to a treatment of their choosing in order to investigate how this treatment affects yeast cell adhesion.

The design project progress will be recorded in both a Project Portfolio (using the u.osu.edu website platform) and a lab notebook. At the conclusion of the project, the team must submit their findings to the Journal of Fluidics and Extremely-small Hydrodynamics (FEH): Microfluidics as well as present to the class near the end of the term at a date specified in the DAL for APP N21-1: Micro Oral Presentation.

Specific On-Chip Requirements:

1. Student teams will design a microfluidics device to be produced using polydimethylsiloxane (PDMS) on an acrylic mold. The mold will be produced using computer controlled milling machines on a 2” (5.08 cm) diameter acrylic wafer. Hence the entire layout of the chip must fit within a 5.08 cm diameter circle. In order to carry out the experiments, the chip must contain the following features:

a. At least 4 channels wide enough (300-400 μm) to generate a well-defined flow field and deep enough (120-150 μm) to contain a monolayer of yeast cells while allowing for flow over the top of the cells.
b. Inlet (feed) wells for initiating pressure driven flow through each channel.
c. Outlet wells for continuous flow in each channel.
d. Markers that indicate the beginning and end of a defined "testing region" within a channel.
e. Labels indicating the team number and year for identification purposes (e.g. X1-16)

2. The analysis will require you to decide upon a specific, well-controlled treatment to apply to the channel. Since engineering disciplines apply theoretical research to solve real-world problems, it is imperative that your team considers any practical applications that your chosen treatment may have an impact upon. Comparison between the control procedure and the variable treatment procedure will be based on the threshold shear stress required for the detachment of a significant number of cells from the channel (i.e. > 50% of initial adhered cells), as defined by the team. While any experiment can be proposed, some pre-approved treatments include:

    a. Varying between a smooth channel base and a base with micro-patterned features
    b. Varying incubation time of the yeast in the beaker
    c. Varying incubation time of the yeast in the channels (seed time)
    d. Varying the geometry of the channels
    e. Varying temperature of water used in incubating yeast
    f. Varying ionic strength (concentration of salt) of the water used in incubating yeast
    g. Varying yeast concentration in incubation
    h. Varying type of yeast

3. Each chip will be constructed of two pieces: a chip bottom and a chip top. The chip top will contain the flow channels. Without the chip bottom attached, these flow channels will have walls on three sides and be open on the fourth.

4. The chip top will be secured to the chip bottom using a chip holder designed and prepared for manufacture by each student team.

5. Student teams will produce one chip top design which must function properly with their chip holder. If, after a number of experimental trials, it is found that the designed chip does not function properly, a standard chip will be used for cell adhesion experiments.

6. Because of the method used to produce the acrylic mold, the depth of **all** features in the chip must be at the same depth (between 120 - 150 μm).

    a. The test channel width will be determined by simulating the flow profile and choosing dimensions that minimize entrance and exit effects.
    b. Chip holder designs must account for the need to access inlet and outlet ports on the chip.

c. The length of the channels, including the inlet and outlet ports, must not come within 5mm of the edge of the chip to ensure a good seal.

Research Study with Lab-on-a-Chip Devices:

The following tasks will be completed:

1. Calibrate flow rate vs. pressure head through each channel in the chip.
2. Write a computer program to determine velocity profile, average velocity, wall shear stress, and other relevant variables from experimental flow rate measurements.
3. Perform a computational fluid dynamics simulation to create 3D velocity and shear profiles of the regions of interest within the channels.
4. Determine flow and shear rates necessary to remove (detach) a significant percentage of the yeast cells from the bottom surface of each channel. The “significant percentage” will be selected by your project team and defined in the experimental design.
    a. Use experimental design techniques to plan the order of experiments.
    b. Create a detailed research plan that clearly describes the experimental procedure and methods involved in shearing cells from the channel surface.
    c. Obtain enough data to determine a statistical average for each channel.
        i. Collect data from a minimum of five “complete shearing runs” for the control (generic) procedure.
        ii. Collect data from a minimum of five “complete shearing runs” for the chosen treatment variable procedure.
        iii. Remember that your experiments will go through intermediate stages of increasing shear before getting to the point of “complete shear.” So, you will have intermediate data points from each “run” which can be compared between surface types as well. The number of intermediate data points is, of course, completely up to you since you will have designed the experiments.
    d. Perform a statistical test (t-test or chi-squared analysis) on data collected from your experiments. This will determine whether the treatment results in a statistically significant effect.
5. Document and present your results from the LOC design project and experiments:
6. Prepare a documentation set consisting of Lab Notebook, Project Portfolio, and Journal Article.

Materials:

All materials necessary for producing the acrylic molds, PDMS chips, and chip holders will be provided. Student teams will each be assigned a box that will contain most of the equipment required to conduct their microfluidics experiment. These will be kept in a cabinet at the back of the room for safe storage.

Other required materials will be provided by the instructional team. The student teams must return the standard acrylic wafer molds to the instructional team at the end of the project for future use. The PDMS chips and chip holders designed by your team may be taken with you at the end of the semester.

Detection of cell detachment will be determined using an optical microscope and captured via a photograph of your fluid channel and cells (generally accomplished using a cell phone camera). Microscopes will be made available as shared resources within the classroom, and microscope training will be provided. Because of this arrangement, as well as the time constraints of the classroom lab time, it will likely be necessary for teams to perform experiments during supplemental lab hours.

NOTE: All tools and materials assigned to a team must be returned and formally accounted for at the end of the semester. Failure to return any object will result in a grade of incomplete for the **entire team** until the object is found or replaced.

Supplemental Lab Hours:

The instructional team will schedule supplemental "open lab" hours during the weeks when experiments are being performed to ensure that each team has adequate laboratory and microscope time to collect the necessary experimental data. If a team wishes to utilize the supplemental hours, they must sign up at least 24 hours in advance by emailing the appropriate instructional team member(s) for the available time slots. These open lab hours will begin sometime after spring break. More details will be provided later in the semester.