Activity 1 - Microfluidics
Instructor Guide

Notes to Instructor

This is the first of three activities for the film MEMS: Making Micro Machines, an overview of microelectromechanical systems, produced and directed by Ruth Carranza of Silicon Run Production. This activity should be completed after viewing the first part of the film entitled: Microfluidics.

This activity is a general knowledge crossword puzzle that challenges the participants on terminology and processes associated with microsystems applications and fabrication specifically in the area of microfluidics. There are several Post-Activity Questions that challenge the participant's comprehension, applications and analysis of the information.

You many choose to assign all or part of this activity before and/or after the participants have viewed the first part of the film. The film script is provided as a supplement to this learning module.

This activity is part of the MEMS: Making Micro Machines Learning Module. Below are the contents of this learning module:

- Knowledge Probe – Pre-assessment
- **Activity 1 – Microfluidics**
- Activity 2 – Optical MEMS
- Activity 3 – Sensors
- Supplement – Film Script
- Final Assessment

Description and Estimated Time to Complete

This is the first of three activities for the film MEMS: Making Micro Machines, an overview of microelectromechanical systems, produced and directed by Ruth Carranza of Silicon Run Production. A DVD can be ordered through the SCME website while supply lasts (http://scme-nm.org) or you can purchase it or access it online via Silicon Run (http://siliconrun.com/our-films/mems/). This activity should be completed after viewing the first part of the film: Microfluidics.

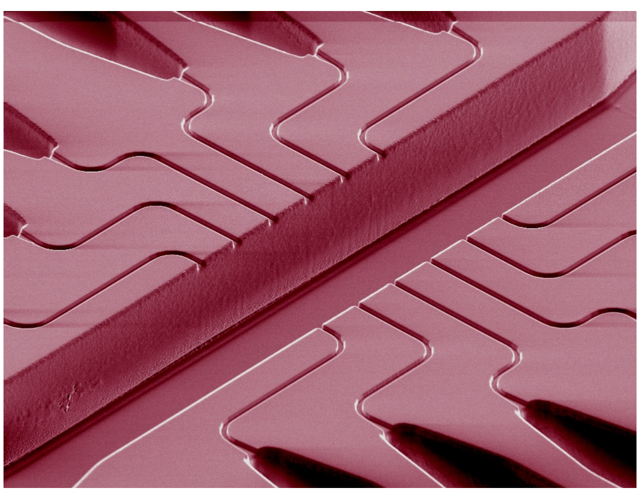
This activity consists of two parts:

- A **crossword puzzle** that tests your knowledge of the terminology and acronyms associated with MEMS applications and microfluidics, and
- **Post-activity questions** that ask you to demonstrate your understanding of microfluidics and microfluidics fabrication.

Estimated Time to Complete
Allow at least 30 minutes to complete this activity.

Introduction

Microfluidics is a multidisciplinary field that deals with the behavior of fluids in the microliter and smaller volume range. As volume decreases, the ratio of surface area to volume increases. As a result, the surface properties of fluids become dominant as one deals with smaller and smaller volumes. Therefore, the interaction of the fluid with the walls of micro chamber and channel surfaces dominates fluid behavior. The surface area to volume ratio of a 100µm per side cube is $0.06cm^{-1}$ and that of a 10µm per side cube is $0.6cm^{-1}$, ten times larger! Therefore, a fluid will cool or heat much faster in a smaller chamber.



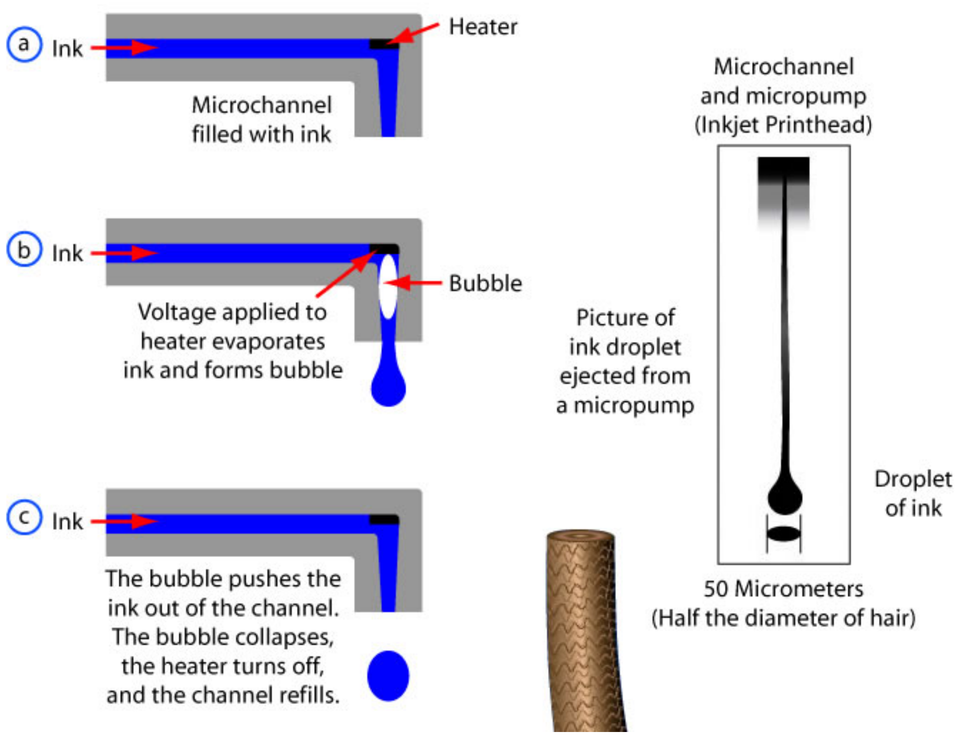
This image is of an array of microfluidic channels and reservoirs created at the University of California, Berkeley. The width of the reservoirs are smaller than the diameter of a strain of hair (60 to 100 µm). Think about how small the microchannels are! *[C. Ionescu-Zanetti, R. M. Shaw, J. Seo, Y. Jan, L. Y. Jan, and L. P. Lee (PNAS, 2005). Printed with permission by Luke Lee, Dept. of Bioengineering, UC-Berkeley)*

Fluid flow is enhanced as channels decrease in size due to surface tension effects, called capillary action. The microfluidics field includes the science of these behaviors as well as the technology used to incorporate and leverage the small-scale behavior of fluids. Microfluidic systems are found in many application areas such as biomedical, molecular biology, consumer products, filtration and purification systems, environmental testing and micropumps.

The film MEMS: Making Micro Machines discusses the fabrication of a microfluidic device called a thermal inkjet printhead, also referred to as a bubblejet printhead. This printhead is a microfluidic device that uses the capillary effect of a fluid in a microchannel as well as the rapid heating of a fluid (due to high surface area to volume ratio) to produce a fast, high resolution printhead.

A thermal inkjet printhead is a non-mechanical micropump, meaning it has no moving parts. In this pump, heat is applied locally to a microchamber filled with ink. Very quickly (0.0001 seconds) the ink evaporates forming a bubble. The bubble forces a tiny droplet of ink out through the micro nozzle and onto the paper. When the heat is removed, the bubble collapses bringing more ink into the chamber through capillary action. Surface tension prevents the ink from flowing out of the nozzle once the chamber is full.[1]

Let's take a more detailed look at how this thermal inkjet printhead works. The process of pumping a droplet of ink from an inkjet printhead (micropump) is a multiple stage process. (Refer to the diagram and film as you follow this process.)



1. The microchannel fills with ink. Because the microchannel's dimensions are so small (approximately a micrometer in diameter) the liquid automatically fills the microchannel due to capillary action.

2. An electrical voltage is applied to the heater (a resistive element). Current through the heater creates enough heat energy to evaporate the ink in less than 0.0001 seconds.

3. Evaporation of the ink forms a bubble.

4. As the bubble forms it forces the ink through the nozzle and out of the channel.

5. The ink is sprayed onto the paper below.

6. The voltage is removed, the heater turns off, and the bubble collapses.

7. The microchannel automatically refills due to capillary action.

To make an inkjet printhead, "hundreds of these microscopic MEMS devices are typically fabricated in pairs of columns that surround an ink supply manifold."[2] Some of the newest printers produce droplets as small as 5 picoliters and can print up to 9 pages per minute in full color (14 pages in black and white).[3] The first part of the film MEMS: Making Micro Machines covers the fabrication of these inkjet printheads.

Activity Objectives and Outcomes

Activity Objectives

- Identify the related terms or acronyms associated with definitions related to MEMS, MEMS applications, microfluidics and microfluidics fabrication.
- Demonstrate your understanding of microfluidics and microfluidics fabrication by correctly answering the Post-Activity questions.

Resources

- MEMS: Making Micro Machines, an overview of microelectromechanical systems, produced and directed by Ruth Carranza of Silicon Run Production. 2009.
- "MEMS Applications". Southwest Center for Microsystems Education (SCME). 2009.
- "Photolithograpy". Southwest Center for Microsystems Education (SCME). 2009.
- "Deposition". Southwest Center for Microsystems Education (SCME). 2009.

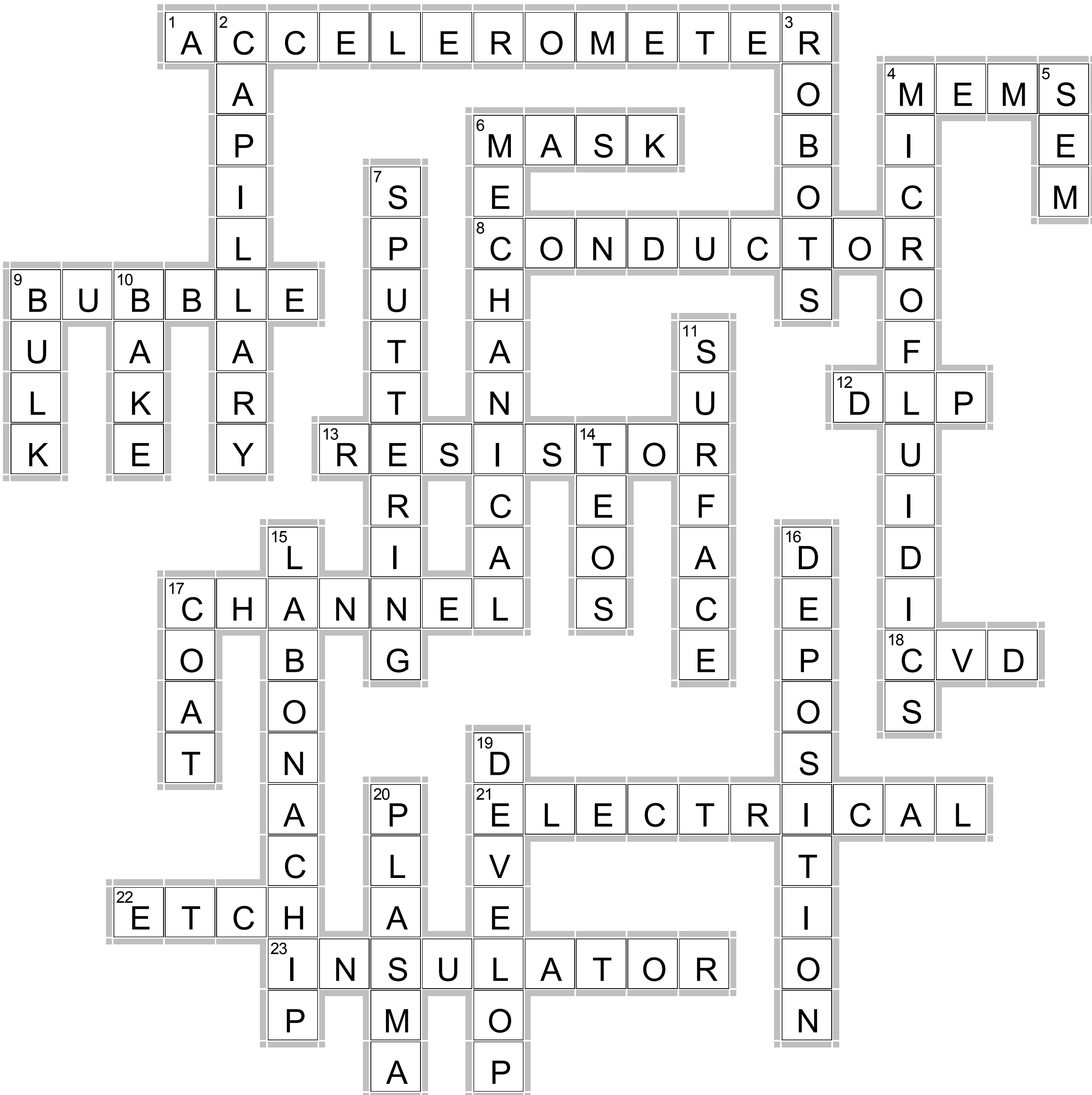
Documentation

1. Completed Crossword Puzzle
2. Questions and Answers to the Post-Activity Questions

Activity 1: Microfluidics Crossword Puzzle

Complete the crossword puzzle using the clues on the following page.

Answer Key to Crossword Puzzle – Microfluidics



EclipseCrossword.com

Answers / Clues

Across

1. **ACCELEROMETER**—MEMS used to stabilize the image of a camcorder or the effect of impact on a football helmet.
4. **MEMS**—Acronym for Microelectromechanical Systems.
6. **MASK**—A quartz plate that contains a pattern and is used for the exposed step in photolithography.
8. **CONDUCTOR**—In CMOS fabrication the metal layer is used as a(n) __________.
9. **BUBBLE**—In a thermal inkjet print head, the heater vaporizes ink to form a _______.
12. **DLP**—Acronym for the optical MEMS that consists of an array of millions of digital micromirrors.
13. **RESISTOR**—The thermo component that is used as a heater in an inkjet printhead.
17. **CHANNEL**—A micro-_________________ is a trench between two rows of nozzles in an inkjet printhead.
18. **CVD**—Acronym for chemical vapor deposition.
21. **ELECTRICAL**—In a MEMS, the type of components that convert information to and from digital.
22. **ETCH**—The fabrication process that removes select material from the surface layer. Process can be wet or dry.
23. **INSULATOR**—In CMOS manufacturing the silicon dioxide layer can be used as a(n) ___________.

Down

2. **CAPILLARY**—In an inkjet printhead, ____________ action is the property of microfluids that refills the microchannels.
3. **ROBOTS**—Common term for equipment that moves objects such as wafers from one place to another or one stage of the process to another (pick and place).
4. **MICROFLUIDICS**—The study of the behavior of small volume fluids.
5. **SEM**—Acronym for scanning electron microscope.
6. **MECHANICAL**—In MEMS, the type of component that "moves" something.
7. **SPUTTERING**—A fabrication process that deposits metal layers using a plasma and ion bombardment.
9. **BULK**—A micromachining process that etches into the substrate (bulk, surface or LIGA).
10. **BAKE**—A soft ______ evaporates solvents from the photoresist.
11. **SURFACE**—Micromachining process that etches layers of thin films (bulk, surface or LIGA).
14. **TEOS**—The CVD process that deposits a silicon dioxide thin film using a vaporized liquid that contains silicate is called __________.
15. **LABONACHIP**—A MEMS device that moves clinical lab testing out of the laboratory and into the field.
16. **DEPOSITION**—A fabrication process that deposits a thin film on the wafer's surface.
17. **COAT**—Photolithography step that spins resist onto the wafer.
19. **DEVELOP**—Photolithography process that removes the exposed resist.
20. **PLASMA**—A ____________ of ionized chlorine based gases and inert gases is used to etch metal.

Post-Activity Questions / Answers

1. What is microfluidics?

   Answer: The study of fluid behaviors in small (less than milliliter) volumes.

2. Name three applications of microfluidics.

   Answer: Biomedical, molecular biology, consumer products, filtration and purification systems, environmental testing, inkjet printers, lab-on-a-chip, and micropumps.

3. Briefly discuss two challenges that engineers might face in the design and fabrication of microfluidic devices. In your answer, include some of the information presented in the film.

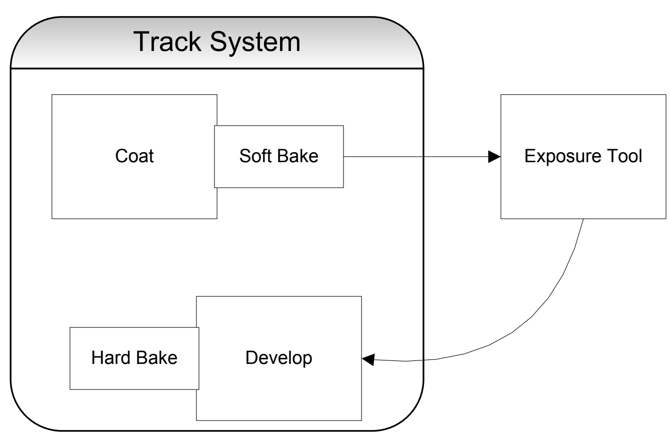
   Answers will vary, but should demonstrate an understanding the material:

   e.g., In small volumes, the behaviors of fluids, such as surface tension and energy dissipation, can be different than in larger volumes. Therefore, microdevices such as micropumps, cannot always use the same design and fabrication methods of larger devices. In the micro scale, surface effects, and effects due to large surface area to volume ratios, dominate. When fabricating these microfluidic devices, the engineer must consider the forces or reactions that can cause problems in the micro, nano, and even smaller scales. For example, the resistors of the thermal inkjet pump must have three layers between the resistors and the ink. These layers provide electrical (insulator), chemical (protects from corrosive chemical attack from ink) and mechanical (protects from force of bursting bubble) protection. The microchannel must be constructed such that the capillary effect can refill the microchamber with ink once the bubble has burst and the heaters are off.

4. Create a diagram or illustration of the photolithography process showing the various steps as presented in the MEMS film.

   Answer: The participant's diagram or illustration should include these basic steps:

   - ***Coat (spin on photoresist)***
     - ***Edge bead removal (occurs at the end of the coat spin)***
   - ***Bake (a soft bake that removes most of the solvent in the resist)***
   - ***Expose (not seen is the alignment of the mask to wafer prior to expose)***
   - ***Develop***
   - ***Bake (a hard bake to or curing of the resist)***



5. Sketch and describe how an inkjet microsystem works.

   Answer: The answer should include the following elements:

   Microfluidic channels deliver ink from the reservoir to the chamber.

   A small resistive heater is turned on, forming a bubble. The bubble provides the pressure to force a small droplet of ink through and out the nozzle. Surface tension at the nozzle tip keeps the ink from both dripping out as well as being sucked back in as the bubble collapses. The heater is turned off and the microchannel refills.

Summary

Microfluidics is a multidisciplinary field that deals with the behavior of fluids in the micro, nano and even picoliter scales. The behavior of fluids in these scales can differ from those of larger volumes. The design and fabrication of microfluidic devices must address these differences and create effective solutions. The manufacturing of an inkjet print head is an excellent example of how fluid behavior at these small scales is applied through microsystems fabrication technology in creating a highly effective consumer product.

References

1. "Micropumps Overview". Southwest Center for Microsystems Education. 2009.
2. MEMS: Making Micro Machines, an overview of microelectromechanical systems, produced and directed by Ruth Carranza of Silicon Run Production.
3. Canon Bubblejet S520. High speed, high quality printer for the office.

Support for this work was provided by the National Science Foundation's Advanced Technological Education (ATE) Program through Grants. For more learning modules related to microtechnology, visit the SCME website (http://scme-nm.org).