MEMS Micromachining Terminology Activity
Instructor Guide

Notes to Instructor

This activity provides the participants an opportunity to better understand the terminology associated with MEMS (microelectromechanical systems) micromachining processes. Participants should read the MEMS Micromachining Overview PK SCO before doing this activity in order to get an understanding of micromachining terminology.

This activity is part of the *MEMS Micromachining Overview Learning Module*:

- Knowledge Probe (KP)
- MEMS Micromachining Overview PK
- **Terminology Activity**
- Research Activity
- LIGA Activities (4) – These activities can be found in the LIGA Micromachining Activities Module. A SCME kit is required for 2 of these activities*.
- Final Assessment

**The LIGA Micromachining kit can be ordered though the SCME website (http://scme-nm.org) while supply lasts and center is funded.*

This companion Instructor Guide (IG) contains all of the information in the PG as well as answers to the Post-Activity questions.

Description and Estimated Time to Complete

In this activity you demonstrate your knowledge of MEMS (microelectromechanical systems) micromachining terminology. This activity consists of two parts:

- A **crossword puzzle** that tests your knowledge of the terminology and acronyms associated with three micromachining processes, and
- **Post-activity questions** that ask you to demonstrate a better understanding of micromachining and how each type applies to MEMS devices.

If you have not reviewed the unit *MEMS Micromachining Overview*, you should do so before completing this activity.

Estimated Time to Complete

Allow at least 30 minutes to complete this activity.

Introduction

Many of MEMS fabrication processes use batch fabrication techniques where more than one wafer is processed at a time, as well as tools and infrastructure similar to that used in the manufacturing of integrated circuits (IC) or computer chips. By incorporating this existing technology, MEMS fabrication (also called micromachining) has allowed for the manufacturing of micro and nano-sized devices at lower cost and increased reliability when compared to macro-sized equivalent components. This is especially true for sensors and actuators.[1] These microdevices also tend to be quite rugged. They respond quickly while consuming little power and they occupy very small volumes.[2]

MEMS micromachining techniques allow for the construction of three-dimensional (3D) micro-sized structures, components, and various elements on or within a substrate (usually silicon). In some cases, micromachining is the utilization of modified IC manufacturing processes in conjunction with other processes such as deep bulk etching, laser assisted chemical vapor deposition, electroplating, and molding techniques.

Three widely used MEMS fabrication methods are
- surface micromachining,
- bulk micromachining, and
- LIGA (Lithography, Galvanoformung (electroforming), and Abformung (molding).

When working in the microtechnology field, it is important that you understanding the terminology associated with these three processes. This activity allows you to test your understanding.

Activity Objectives

- Identify the correct terms used for several definitions or statements related to MEMS micromachining.
- Describe the micromachining processes required to fabricate various MEMS devices.

Resources

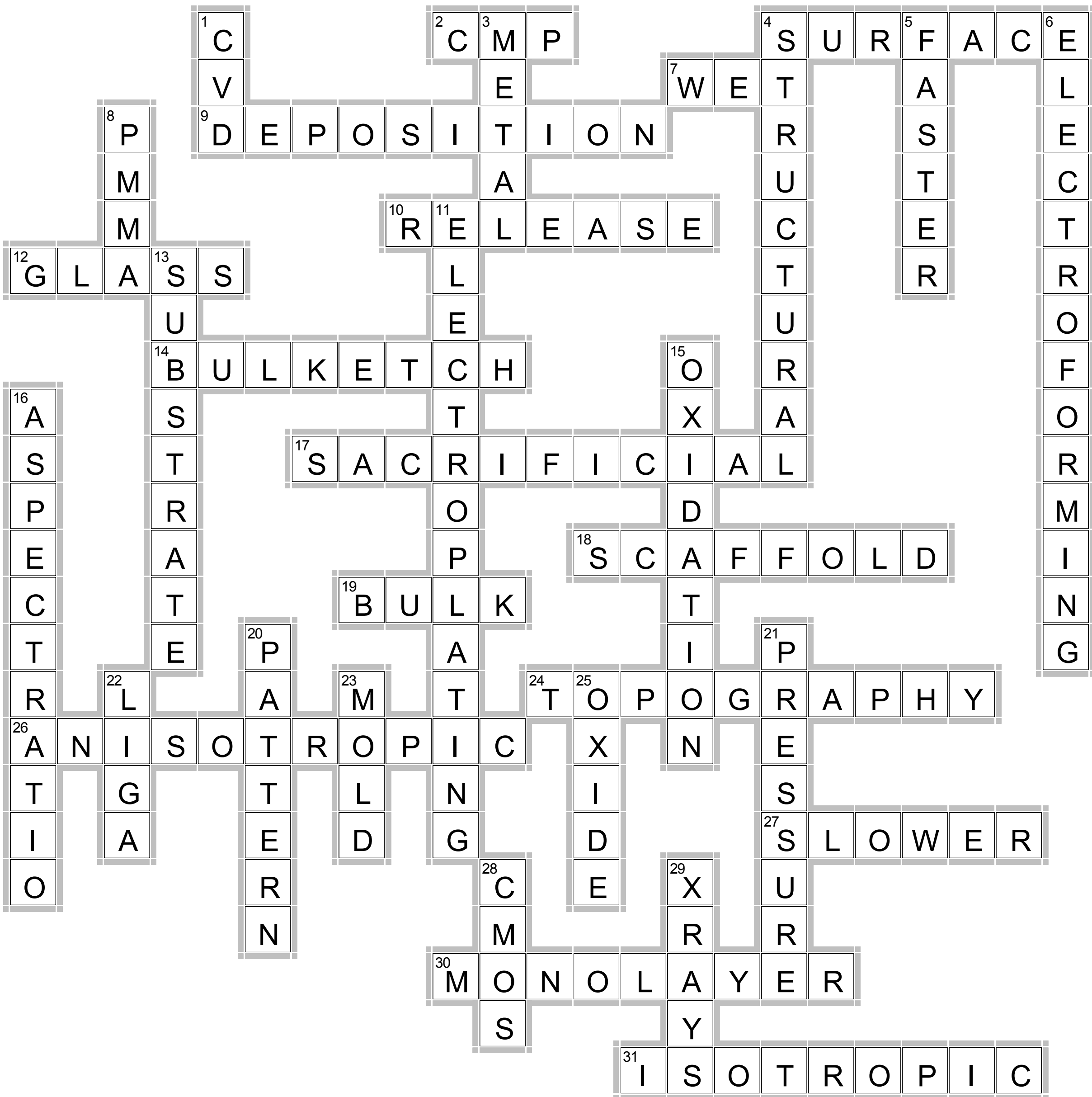
SCME's *MEMS Micromachining Overview Primary Knowledge Unit*

Documentation

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

Activity: MEMS Micromachining Terminology – Key to Crossword Puzzle

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



EclipseCrossword.com

ACROSS

Question	Answer
2. A process used to flatten the topography of the wafer's surface as new layers are deposited (acronym)	**CMP**
4. A micromachining process that uses layers of thin films deposited on the surface of a substrate to construct structural components for MEMS	**surface**
7. The type of etch used to remove sacrificial layers	**wet**
9. A process that deposits a thin film or material onto a surface	**deposition**
10. The purpose of removing the sacrificial layer from underneath the structural layer is to __________ the object so it can move	**release**
12. LIGA allows for the mass production of micro-devices made of metal, polymers and ________	**glass**
14. A subtractive process in which the silicon substrate is selectively removed (2 words)	**bulk etch**
17. Layer deposited between structural layers for mechanical separation and isolation	**sacrificial**
18. The sacrificial layer is to the structural layer as a __________ is to a bridge	**scaffold**
19. A micromachining process that defines structures by selectively removing or etching inside a substrate.	**bulk**
24. In surface micromachining as layers are deposited and etched, the ___________________ of the surface becomes uneven	**topography**
26. An etch profile with straight wall geometries	**anisotropic**
27. In a bulk etch, the (111) plane etches about 400 times ____________ than the (100) plane	**slower**
30. SAM or a self-assembled ___________ is deposited to make the surface hydrophobic and to reduce friction	**monolayer**
31. An etch profile created by chemical reaction between the etchant and underlying layer	**isotropic**

DOWN

Questions	Answers
1. Deposition process used to deposit many of the different types of layers used in surface micromachining (acronym)	**CVD**
3. Conductive layers are normally thin films of ___________	**metal**
4. Layer having the mechanical and electrical properties needed for the component being constructed	**structural**
5. In a KOH etch, the (100) plane of the substrate etches _________ than the (111) plane	**faster**
6. The LIGA step used to coat an object with a metal or metal alloy	**electroforming**
8. A photosensitive material known as acrylic glass or Plexiglas used in LIGA (acronym)	**PMMA**
11. The process of using electrical current to coat faucets and door knobs with a layer of chrome	**electroplating**
13. A cliff face is to cliff dwellings as the ______________ is to a bulk etch	**substrate**
15. Process used to grow a uniform, high quality layer of silicon dioxide on the surface of a silicon substrate	**oxidation**
16. The representation of the height of an etched feature to its width (2 words)	**aspect ratio**
20. Photolithography is used to transfer a _________________ from a mask to resist	**pattern**
21. A MEMS _______________ sensor uses a silicon nitride membrane over a bulk etched chamber	**pressure**
22. A long involved German acronym or lithography, electroforming and molding	**LIGA**
23. LIGA can be used to create a ____________ for the mass production of a plastic micro-component	**mold**
25. In surface micromachining, _____________ is commonly used as a sacrificial layer and hard mask	**oxide**
28. Surface micromachining uses many of the same processes and tools as _____________ fabrication (acronym)	**CMOS**
29. In LIGA synchrotron radiation produces ___________ to "expose" sensitive materials	**xrays**

Post-Activity Questions / Answers

1. Inkjet printers use microchambers and channels to store and pump ink to the print heads. What type of micromachining process is best for creating these chambers and channels?
   Answer: *Bulk Micromachining*

2. Explain why surface micromachining is used for MEMS such as gear trains, combdrives, switches and gyroscopes.
   Answer: *Surface micromachining produces low aspect ratio devices such as gear trains, combdrives, switches and gyroscopes. Surface micromachining is a process in which structural layers and sacrificial layers are constructed on top of each other as many times as needed to erect multilayered gear trains or to fabricate objects that can move laterally, vertically or obliquely above the substrate surface. Sacrificial layers are deposited between structural layers. At the end of the process the sacrificial layers are removed "releasing" the structural components.*

3. Describe the LIGA process step(s) that yields high aspect ratio cavities.
   Answer: *LIGA uses the collimated x-rays produced by synchrotron radiation to illuminate thick x-ray sensitive materials such as PMMA (polymethylmethacrylate), also known as acrylic glass or Plexiglas. As with a basic photolithography process, the PMMA layer is patterned under a lithographic mask using an x-ray exposure. The PMMA pattern is developed (like photoresist) leaving tall, thin or deep structures or cavities.*

4. What are three types or characteristics of MEMS devices fabricated using LIGA?
   Answer*:* *Micro-size components that are*
   - *free-standing,*
   - *possibly high aspect ratio,*
   - *attached to the substrate, or*
   - *metal inserts for injection molding.*

   Examples: Probes, pin, electrodes, gears, waveguides, and molds

5. Why is chemical mechanical polishing used in surface micromachining?
   Answer: *In surface micromachining the topography on the surface of the wafer becomes uneven and bumpy as layers are deposited, patterned, and etched. This unevenness can affect subsequent processes such as deposition and photolithography, but it can also affect the movement of components upon release. CMP is used to remove the "bumpiness" of the top surface prior to the deposition of the corresponding sacrificial layer.*

6. Bulk etch is called a subtractive process and LIGA is called an additive process. Explain.
   Answer: *Bulk is a subtractive process because it "removes" bulk material from the substrate. LIGA is an additive process because it allows for multi-layer processing and construction through bonding and other processes.*

Summary

MEMS fabrication (also called micromachining) allows for the manufacturing of micro-sized devices at lower cost and increased reliability when compared to macro-sized equivalent components. Such devices can be fabrication on top of substrates, within substrates, or molded and bonded depending on the micromachining processes used. Three widely used micromachining processes are

- surface micromachining
- bulk micromachining, and
- LIGA (Lithography, Galvanoformung, and Abformung).

References

1. Fabricating MEMS and Nanotechnology. MEMS Exchange. 2009. http://www.memsnet.org/mems/fabrication.html
2. A Tutorial of MEMS. Micro Fabrication Techniques. Trimmer.net™, William Trimmer, Ph.D. President of Belle Mead Research, specializing in MEMS. 2009. http://home.earthlink.net/~trimmerw/mems/index.html

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