Final Assessment
Instructor Guide

Notes to Instructor

This Final Assessment (FA) supports the film MEMS: Making Micro Machines, an overview of microelectromechanical systems, produced and directed by Ruth Carranza of Silicon Run Production. This FA was designed to assess the participants' knowledge of MEMS, MEMS applications, fabrication, packaging, and design after viewing the film and completing the activities. You may choose to use this FA and/or the Knowledge Probe to assess the participants before and after viewing the film and completing the activities. This would allow you to better determine the knowledge gained from this learning module.

This final assessment 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**

Introduction

The purpose of this assessment is to determine your understanding of MEMS, MEMS applications, fabrications, packaging and design after viewing the film MEMS: Making Micro Machines and completing its three related activities. This assessment consists of several fill-in-the-blank and short answer questions.

There are twenty (20) assessment questions.

1. What are Microelectromechanical systems (MEMS)?

   Answer: MEMS are micro-sized machines that have both mechanical and electrical components either integrated on one chip or separated into two chips (electrical chip, mechanical chip).

2. A ________________________ is an inertial sensor that senses rotational motion.

   Answer: gyroscope

3. MEMS components that move other MEMS components by forces such as electrostatic or mechanical are called _____________________.

   Answer: Actuators

4. Briefly describe two different types of MEMS.

   Answers will vary. Participants may choose to be general (i.e., sensors, optical devices) or specific (i.e., pressure sensors, DMDs, inkjet printhead) Here are some examples.

   a. Sensors – MEMS sensors sense a change in the input and produce an output (usually electrical) that represents that change.

   b. Optical MEMS – The objective of optical MEMS is to use the electromechanical components of MEMS to manipulate optical signals. Optical MEMS are used in data communication networks to transmit data over long distances and in imaging devices such as digital light processors, cameras, and televisions.

   c. Thermal Inkjet printhead – A MEMS thermal inkjet printhead consists of an array of microchannels, each containing a nozzle and heater (thermoresistor). All of the microchannels connect to the main ink reservoir. When the heaters turn on, a bubble forms in the nozzle forcing the ink below it out onto the paper. The bubble collapses, the heater turns off. Capillary action of liquids in a microchannel allows ink from the reservoir to refill the microchannels.

   d. Other devices discussed in this learning module are inertial sensors (accelerometers and gyroscopes), pressure sensors, digital mirror devices (DMD)

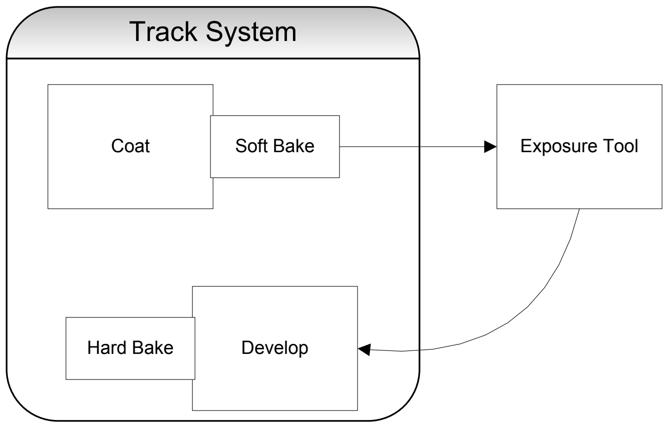
5. What type of MEMS is used in airbag deployment systems in automobiles?

   Answer: Accelerometer (or inertial sensor)

6. Name three applications of MEMS pressure sensors.

Answer: to measure tire pressures, intake manifold pressures in cars, blood pressure, intracranial pressures, pressure at the bottom of the ocean, barometric pressures, pressures due to seismic activities, etc.

7. What fabrication process is illustrated in the following diagram? ______________________



Answer: Photolithography

8. Refer to the diagram in the previous question. Which block (step) of this process uses UV light and a patterned mask? ________________________________

Answer: Exposure Tool

9. Refer to the above diagram. What is the light sensitive material that is applied to the wafer during the coat process? ______________________________

Answer: Photoresist

10. In a digital mirror display (DMD), each micromirror reflects a ____________ of light during operation.

Answer: pixel

11. In a digital mirror display (DMD), the mirrors move to an ON position when __________________ is applied to the electrodes fabricated below the mirrors.

Answer: voltage

12. In the fabrication of a DMD array, silicon dioxide (oxide) layers are used as a __________ __________ to protect the sections of the yoke during fabrication and to provide a patterned layer for etching the aluminum layer that forms the mirrors.

Answer: Hard mask

13. In the fabrication of DMDs, layers of photoresist are applied above and below the aluminum layer that forms the mirrors and posts. These photoresist layers are later removed in the packaging process. What are the purposes of these photoresist layers?
    a. The resist layer below the aluminum is ______________________________________

    ____

    b. The resist layer above the aluminum is ______________________________________

    ____

Answer:
The resist layer below the aluminum is a sacrificial layer used as a spacer to raise the mirrors above the yoke layer and "release" the mirrors once the resist layer is removed.
The resist layer above the aluminum is a protective layer that protects the mirrors when shipped to various locations for packaging.

14. During packaging of DMDs, ___________________ is applied around the edges of the DMD dies as a glue to connect DMD chips to the protective windows. The glued wafer and windows are then transfer to the ___________________ chamber which hermetically seals the MEMS structures.

Answers: epoxy and bonding

15. A wet anisotropic etch process using KOH (potassium hydroxide) is used to etch the crystalline silicon substrate to form the microchannels used in inkjet print heads. A removal process that etches into the silicon crystal or substrate is called a ___________ etch process.

Answers: bulk

16. The deep reactive ion etch (DRIE) process uses the Bosch process to develop tall structures and deep trench with high _____________ ratios.

Answer: aspect

17. Mechanical designers determine the limitation of the mechanical _____________________, the components that convert motion into an electrical signal.

Answer: transducers

18. State two tasks that could be performed during the partitioning and model generation step of the design process?

Answers will vary. Here are some steps performed.

a. ***Components are partitioned into blocks that represent the physics of the mechanical and electrical chips.***
b. ***Develop the code for each block. Code development is used to enhance the model's details and set the operational parameters.***
c. ***Can predict proof mass motion (referencing the accelerometer model used in the film). In other words, this step writes various code (or equations) to predict and test hypotheses.***
d. ***A transducer model is developed that helps the designers determine the effect of packaging on the performance of the chip.***
e. ***The MEMS device is partitioned into working blocks with appropriate code that is tested by the ASIC designer and the systems engineer prior to the analysis phase.***

19. The steps of the design process are repeated over and over again before an acceptable model is developed.
    a. True
    b. False

    Answer: a. True

20. Now that you have learned about MEMS, MEMS applications, fabrication, packaging and design, what excites you? What part of the process do you find most interesting and why?

Answer: There is no right or wrong answer (except for no answer at all)

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