



## Activity 2 – Optical MEMS

### Participant Guide

#### Description and Estimated Time to Complete

*MEMS: Making Micro Machines Learning Module supports the film of the same name produced and directed by Ruth Carranza of Silicon Run Production. The film introduces MEMS (microelectromechanical systems), applications, fabrication, and design. This learning module provides activities to encourage you to delve deeper into the topics introduced in the film and to demonstrate your understanding of the terminology and general concepts of MEMS.*

This is the second of three activities in the learning module. This activity is designed to be completed after viewing the second part of the film: Optical MEMS.

This activity consists of two parts:

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

#### Estimated Time to Complete

Allow at least 30 minutes to complete this activity.

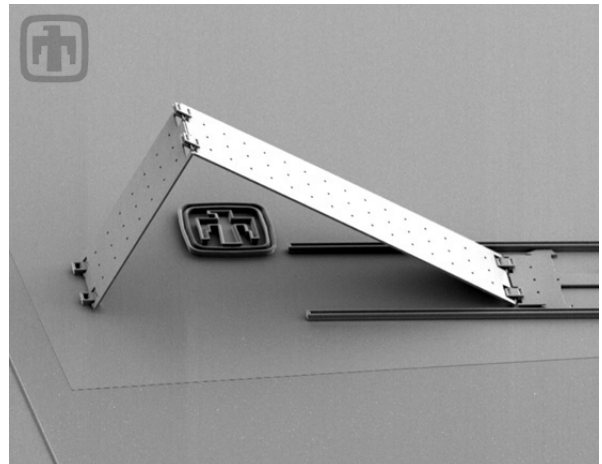
## Introduction

The objective for optical MEMS is to integrate optical, mechanical and electronic functions into one device. Optical MEMS usually consist of moveable micromirrors, lenses, diffraction elements for modulating light. Actuators for moving these elements, sensors and electronics for receiving, processing, and transmitting signals as well as providing the inputs for the actuators.

MEMS micromirror arrays are often the key components used in spatial light modulators or SLM's. These devices are used in high definition display systems as well as optical switching networks. Optical micromirror arrays transmit optical information without going through the timely and costly signal conversion process of optical to electronic and back to optical. The micromirrors can act as switches that direct light from a fiber optic to another fiber optic or to a specific output port by moving up and down, left to right or swiveling to a desired position. This requires the individual mirrors to be actuated, supported on a movable mount or stage, and integrated into a digital network.

The scanning electron microscope image to the right shows a popped-up micromirror. Notice the hinge allowing for the different angles needed to direct light in different directions. Also notice the track that assists in positioning the mirror at the correct angle.

*MEMS Pop-up mirror for optical applications  
[Image Courtesy of Sandia National Laboratories  
SUMMIT<sup>TM</sup> Technologies, [www.mems.sandia.gov](http://www.mems.sandia.gov)]*



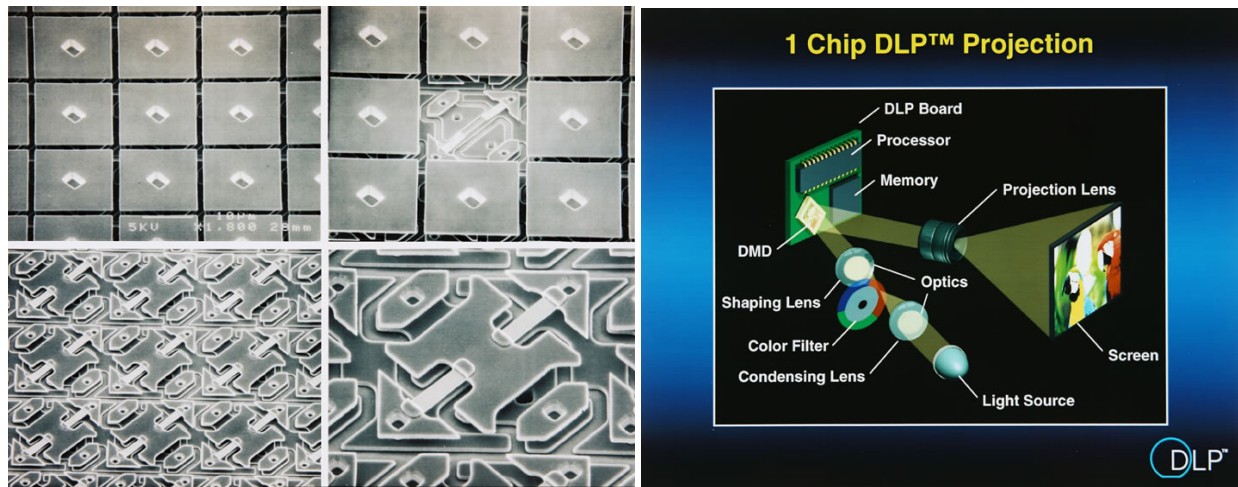
Applications of optical MEMS include the following:

- Projection displays (GLV's and DMD's)
- Tunable lasers and filters
- Spatial Light Modulators (SLMs)
- Variable optical attenuators
- Optical Spectrometers
- Bar code readers
- Maskless lithography

Optical MEMS have already been quite successful in display technologies. This success is rapidly growing with the innovations of high definition (HD) displays.

Texas Instrument's Digital Mirror Devices (DMD) have been used for several years in a variety of projection systems including film projection and digital cinema. The technology is called digital light processing or DLP™, a trademark owned by Texas Instruments, Inc. A DMD is an array of micromirrors (*see figure of DMD array below and left*). Each micromirror (between 5µm and 20µm per side) is designed to tilt into (ON) or away from (OFF) a light source. The mirror tilts when a digital signal energizes an electrode beneath the mirror. The applied actuator voltage causes the mirror corner to be attracted to the actuator pad resulting in the tilt of the mirror. When the digital signal is removed, the mirror returns to the "home" position. In the ON position, the mirror reflects light towards the output lens. In the OFF position, the light is reflected away from the output optics to a light absorber within the projection system housing. One mirror can be turned OFF and ON over 30,000 times per second.

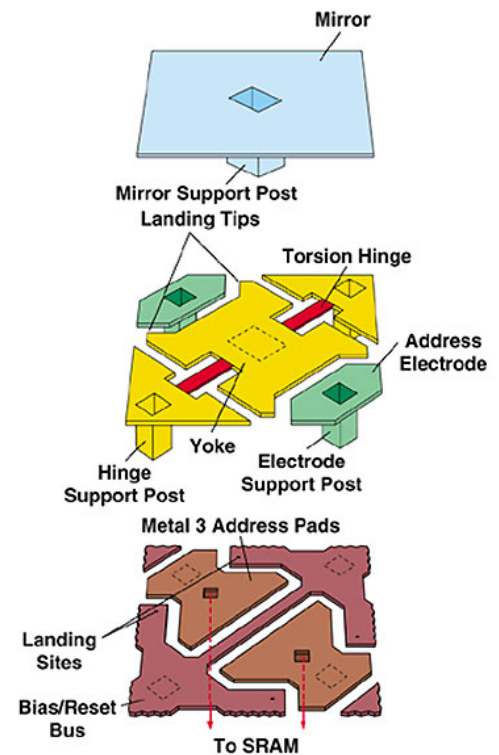
There can be over 2 million mirrors in an array with less than 1 µm spacing between each mirror. The DLP 1080p technology delivers more than 2 million pixels for true 1920x1080p resolution.<sup>(1,2)</sup> The diagram below right illustrates how the DLP projection system works. The left set of images are scanning electron microscope images of the DMD mirrors and underlying hinge system.



*Levels of a DMD Array (left) and How a DLP system works (right).  
[Images Courtesy of Texas Instruments]*

The illustration below breaks down a digital mirror of a DMD into three levels. It shows the mirror, support post, hinge, yoke and electrodes discussed in the film. The film MEMS: Making Micro Machines discusses the fabrication, packaging and testing of this DMD. You should recognize some of the components mentioned in the film (e.g., mirror, torsion hinge, yoke). To learn more about the operation of a digital light projector (DLP), visit Texas Instruments webpage How DLP Technology Works.

<http://www.dlp.com/technology/how-dlp-works/default.aspx>



*[Images Courtesy of Texas Instruments]*

## Activity Objectives and Outcomes

### Activity Objectives

- Identify terms or acronyms associated with definitions related to MEMS, optical MEMS, optical MEMS fabrication, packaging and testing.
- Demonstrate your understanding of digital MEMS and DLP fabrication, packaging and testing by correctly answering the Post-Activity questions.

### Resources

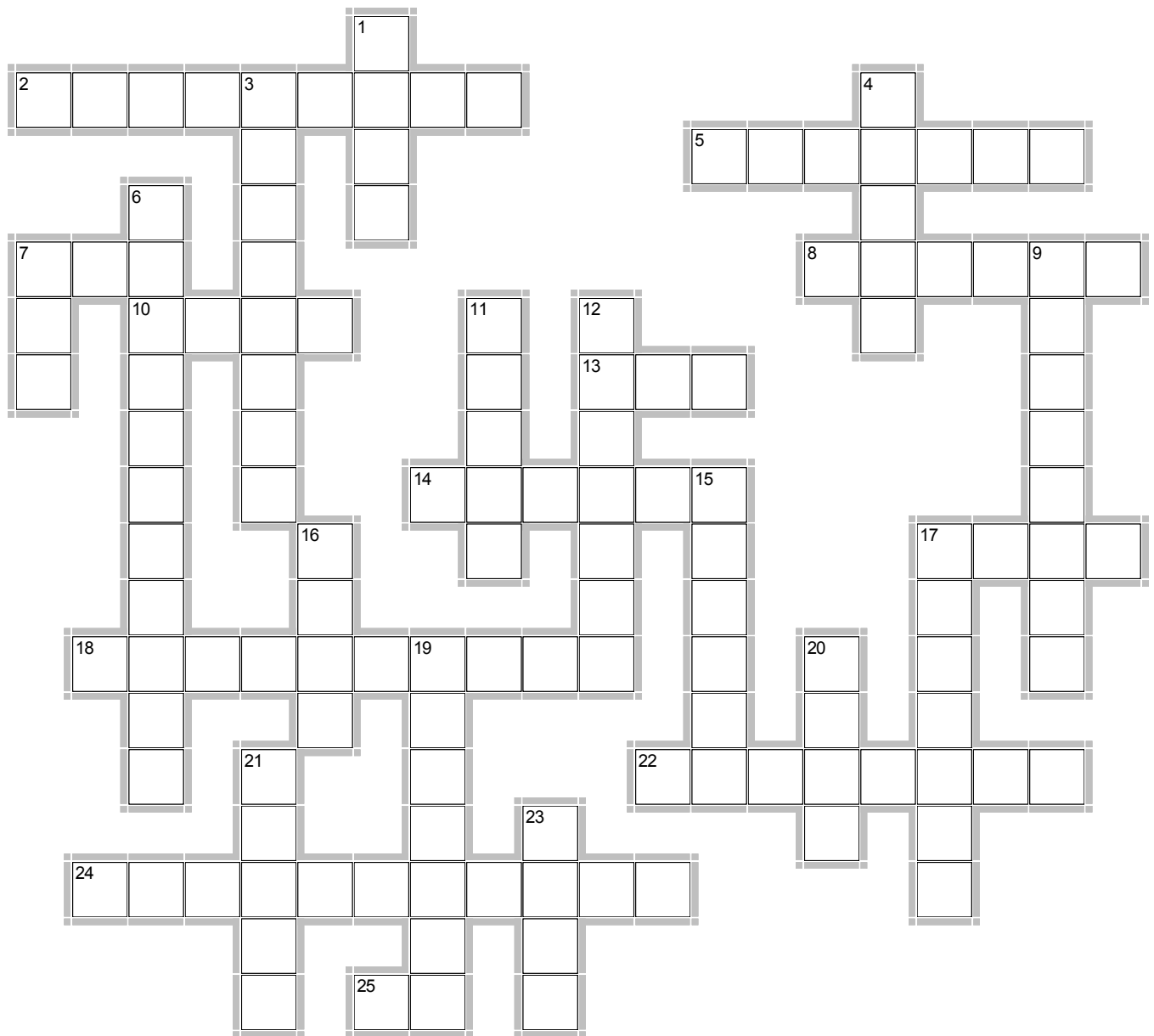
- MEMS: Making Micro Machines, an overview of microelectromechanical systems, produced and directed by Ruth Carranza of Silicon Run Production.
- "MEMS Applications". Southwest Center for Microsystems Education (SCME). 2009.
- "Photolithography". Southwest Center for Microsystems Education (SCME). 2009.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

### Documentation

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

## Activity 2: Optical MEMS Crossword Puzzle

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



EclipseCrossword.com

## Across

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2. MEMS components that move mirrors or other MEMS devices are called \_\_\_\_\_.
5. Three or more colored \_\_\_\_\_ are contained in the color wheel of a DLP system to provide a colored output from the DMD array.
7. The acronym for digital light processing.
8. After fabrication a DMD goes through a series of tests, most of which are electrical. The final test is a \_\_\_\_\_ test.
10. To electrically \_\_\_\_\_ a DMD array, the mirrors are turned ON and OFF for 2 to 24 hours inside a burn-in furnace.
13. When a DMD mirror is not reflecting light it is said to be \_\_\_\_\_.
14. A \_\_\_\_\_ strip is placed on DMD windows for the purpose of absorbing moisture.
17. To \_\_\_\_\_ is to join two or more components together.
18. An anti- \_\_\_\_\_ coating that enhances the transmission of light is applied to the protective windows in a DMD.
22. The tendency for surface forces to cause small structures to stick.
24. In MEMS fabrication a \_\_\_\_\_ layer provides spacing between two or more components by first being deposited then removed.
25. When a micromirror is reflecting light it is said to be \_\_\_\_\_.

## Down

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1. The component of a DMD micromirror that supports the mirror's support post.
3. Small spring tips are constructed on the yoke of a DMD mirror to overcome \_\_\_\_\_, the tendency of a micromirror to stay ON with voltage removed.
4. The fabrication process used to remove the protective resist layer after the develop process step is called a plasma \_\_\_\_\_.
6. A microsystems device that integrates optical, mechanical and electrical.
7. The acronym for digital mirror device.
9. The material used to construct the post, hinge and yoke of a DMD micromirror.
11. In a DMD, one micromirror is one \_\_\_\_\_.
12. A \_\_\_\_\_ is applied to the electrode of a micromirror to turn the mirror ON.
15. The thin film used as a sacrificial layer that provides spacing and protection for the micromirrors.
16. A(n) \_\_\_\_\_ is used to harden epoxy.
17. A \_\_\_\_\_ process uses UV light, heat and pressure to connect the windows of the DMD to the CMOS wafer.
19. In a DMD the hinge that is fabricated to overcome stiction is called the \_\_\_\_\_ hinge.
20. The fabrication process that removes unwanted material from a layer.
21. Hundreds and even thousands of micromirrors on a chip is called a(n) \_\_\_\_\_.
23. The fabricated channels that provide access to the CMOS circuitry.

## Post-Activity Questions

1. What is the objective of optical MEMS?
2. For the transmission of data optical information, optical mirrors may be faster and cheaper because they eliminate the conversion process of \_\_\_\_\_.
3. Micromirrors need to move. What MEMS components are required to move micromirrors?
4. What company developed DMDs?
5. In your own words, briefly explain how a DMD works.
6. How is the resolution of DLP devices increased?
7. Once the DMD array is fabricated, how is it protected during shipping to the packaging location?
8. In the fabrication of a micromirror, photo resist is used as a sacrificial layer. What is the purpose of this sacrificial layer?
9. How is mirror movement tested?
10. The output of a DMD is black and white. How is this black and white image converted to color?

## Summary

Optical MEMS integrate optical, mechanical and electronic functions into one device. Micromirror arrays are used for data transmission and for optical image production in DLP projection systems. There may be hundreds of thousands and even millions of mirrors in an array, fabricated on a single chip. Surface micromachining fabrication methods similar to those used in making computer chips are the primary fabrication technology used to make these devices. In the final tests, all of the mirrors must work in order for the chip to be used in a DLP device. This creates a special challenge in the fabrication and packaging of micromirror arrays.

## References

- <sup>1</sup> "How DLP sets work." Tracy V. Wilson and Ryan Johnson. HowStuffWorks. <http://electronics.howstuffworks.com/dlp1.htm>
- <sup>2</sup> "How DLP Technology Works". DLP Texas Instruments. <http://www.dlp.com/tech/what.aspx>
- <sup>3</sup> MEMS: Making Micro Machines, an overview of microelectromechanical systems, produced and directed by Ruth Carranza of Silicon Run Production.

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