What Do You Know About Deposition? Activity
Instructor Guide

Notes to Instructor

This activity provides the participants an opportunity to better understand the terminology and applications of deposition processes as well as the processes themselves. Participants should read the PK unit before doing this activity in order to get an understanding of deposition.

The *Deposition Overview for Microsystem Learning Module* consists of the following.

- Knowledge Probe (KP) - pretest
- Deposition Overview for Microsystems PK
- Deposition Terminology Activity
- Science of Thin Films Activity (Supporting SCME Kit available)
- **Activity – What Do You Know About Deposition?**
- Final Assessment

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 deposition for microsystems, by explaining at least two deposition processes, identifying the applications of microsystems in which these processes would be used and studying recent advances and improvements of these processes for microsystems fabrication.

If you have not reviewed the unit *Deposition Overview for Microsystems*, you should do so before completing this activity.

<u>Estimated Time to Complete</u>
Allow at least 1.5 hours to complete this activity.

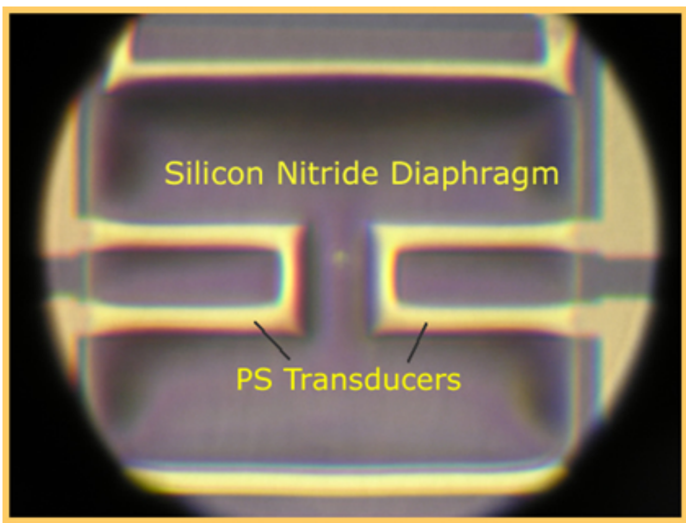
Introduction

Microsystems (or MEMS) are fabricated using many of the same processes found in the manufacture of integrated circuits. Such processes include photolithography, wet and dry etch, oxidation, diffusion, planarization, and deposition.

The deposition process, which is the focus of this activity, provides the ability to deposit different types of thin film layers as thick as 100 micrometers or as thin as a few nanometers.[1] Such films are used for

- mechanical components (i.e., cantilevers and diaphragms),
- electrical components (i.e., insulators and conductors), and
- sensor coatings (i.e., gas sensors and biomolecular sensors).

The figure below shows a thin film of silicon nitride being used as the diaphragm for a MEMS pressure sensor.



MEMS Pressure Sensor close-up
(Electrical transducers in yellow, Silicon nitride diaphragm in gray)
[Image courtesy of the MTTC at the University of New Mexico]

Because thin films for microsystems have different thicknesses, purposes, and make-up (metals, insulators, semiconductors), different deposition processes are used. The deposition processes used for microsystems include the following:

- Spin-on film
- Thermal Oxidation (oxide growth)
- Chemical vapor deposition (CVD)
- Physical vapor deposition (PVD)
- Electroplating

Activity Objective

- Identify the type of deposition process associated with different aspects of microsystems fabrication.
- Describe three deposition processes used in microsystems fabrication.
- Discuss at recent research and improvements in at least one of these deposition processes.

Resources

SCME's Deposition Overview for Microsystems PK

Documentation

Present a written paper to your instructor that includes the questions and answers to the following questions as well the information requested on the various deposition processes.

Activity: What Do You Know About Deposition?

Answer each of the following questions and write a brief response for research requests.

1. Why is CVD the most widely used deposition method for most thin films?
2. Write the chemical formulas for the following processes and a brief explanation of each formula.
    a. Wet oxidation process
    b. Dry oxidation process
3. For each of the deposition processes below,
    a. outline the fabrication process,
    b. the types of films deposited, and
    c. at least two microsystem applications for the deposited films. These applications can be current applications as well as applications being researched.

Thermal Oxidation	a.
	b.
	c.
Chemical Vapor Deposition	a.
	b.
	c.
Evaporation	a.
	b.
	c.

4. Which deposition process(es) would be used for the following applications?
    a. conductive layer for RF switches - _____________________________
    b. structural layer for cantilever sensors - _________________________
    c. sacrificial layer between the substrate and the first structural layer - _______________
    d. fill in the cavity of a LIGA mold - __________________________
    e. a strain gauge on a microcantilever - ___________________________
    f. a silicon nitride hard mask - ____________________________
    g. sacrificial layer between two structural layers - _____________________________
    h. masking layer for photolithography expose - _______________________________

Activity: What Do You Know About Deposition?/ Answers

1. Why is CVD the most widely used deposition method?

   Answer: CVD is more versatile in that it can be used to deposit a variety of thin films over a large range of thickness.

2. Write the chemical formulas for the
   a. Wet oxidation process

      Si (solid) + $2H_2O$ (vapor) → SiO_2 (solid) + $2H_2$ (gas)

   b. Dry oxidation process

      Si (solid) + O_2 (gas) → SiO_2 (solid)

3. For each of the deposition processes below,
   a. outline the fabrication process,
   b. the types of films deposited, and
   c. microsystem applications for the deposited films.

Thermal Oxidation	*a. In thermal oxidation the wafer is placed in a heated vacuum chamber (typically 900 – 1200 degrees C). A source of oxygen (gas or vapor) is pumped into the chamber. The oxygen molecules react with the silicon substrate forming a surface layer of silicon dioxide.*
	b. Primarily silicon dioxide (SiO_2) also referred to as oxide.
	c. Oxide is used as a sacrificial layer, electrical insulator and a hard mask layer.
Chemical Vapor Deposition	*a. The films deposited during CVD are a result of the chemical reaction between the reactive gas(es) (homogeneous) and between the reactive gases and the atoms on the substrate surface (heterogeneous) CVD processes typically use a low pressure reaction chamber. In LPCVD reactants and inert gases enter a heated chamber,*

	encounter the substrate surface, and react with each other and with the molecules on the wafer (substrate) surface. These reactions form a solid thin film adsorbed onto the surface. *In PECVD a plasma is used to provide energy to the reactant gas molecules. This enhances the rate of deposition.* *In high density PECVD (HDPECVD), a magnetic field is used to increase the density of the plasma.*
	b. LPCVD is used exclusively when a film is needed on both sides of the wafers. *Other films deposited using CVD include phosphosilicate glass (PSG), polysilicon, silicon nitride*
	c. All three of these films can be used as a structural layer. *Polysilicon is also used as a piezoresistive layer in sensors.* *Nitride is used for electrical and environmental isolation, protective layer and masking layer.* *PSG can also be used as a sacrificial layer.*
Evaporation	*a. Evaporation uses a vacuum chamber and energy source to evaporate a source metal. As the source metal evaporates, the individual particles (atoms or molecules) travel in a straight-line path through the vacuum until condensing on a surface.. This in turn coats the surfaces of the chamber as well as the surfaces of the wafers within the chamber. The atoms or molecules condense on all of the surfaces that they come in contact with.*
	b. Used for depositing thin metals and metal alloys (Al, Au, Ag, AlCu, Cr)
	c. Metals and metal alloys are used for conductive layers and components such as electrodes, and for reflective material for optical devices. They are also used in the construction of RF

	switches, coated cantilevers (chemical sensor arrays are coated with gold).

4. Which deposition process(es) would be used for the following applications?
   a. conductive layer for RF switches – ***PVD (evaporation or sputtering)***
   b. structural layer for cantilever sensors - ***CVD***
   c. sacrificial layer between the substrate and the first structural layer – ***Thermal oxidation***
   d. fill in the cavity of a LIGA mold - ***electroplating***
   e. a strain gauge on a microcantilever – ***PVD (evaporation or sputtering)***
   f. a silicon nitride hard mask - ***CVD***
   g. sacrificial oxide layer between two structural layers - ***CVD***
   h. masking layer for photolithography expose – ***spin-on***

Summary

Deposition is any process that deposits a thin film of material onto a substrate. A thin film can range from greater than 100 micrometers to only a few nanometers thick. Some gate oxides used in integrated circuits are even thinner, on the order of tens of microns. Microsystems technology uses a variety of deposition processes. The type of process used depends on the thin film material, its thickness, and the structure (stochiometry) being fabricated.

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