MTTC Pressure Sensor Process
Cleanroom Activity
Participant Guide

Description and Estimated Time to Complete

The Manufacturing Technology Training Center (MTTC) is a process cleanroom at the University of New Mexico (UNM). The MTTC is used for hands-on activities relative to microsystems fabrication. This unit introduces and provides a brief overview of the processes involved in building the MTTC micro-pressure sensor.

This activity should be completed in conjunction with the Primary Knowledge unit on the MTTC Pressure Sensor Process. This activity requires a cleanroom or fabrication facility with the proper equipment and supplies. Information for each step of the process is presented and discussed prior to executing the step in the cleanroom. If you don't have a cleanroom, you should still go through this process and then complete the Process Model Activity.

The SCME Pressure Sensor Process Model Activity and the SCME Matching Activity Kit also support this step-by-step process, but do not require a cleanroom. If a cleanroom is not available, it is recommended that you complete the Model Activity followed by the Matching Activity.

The following topics and process steps will be briefly discussed:

- The Pressure Sensor Membrane
- Pressure Sensor Circuitry
- How Does a Pressure Sensor Work?
- The Making of a Pressure Sensor

1. Bare Silicon
2. Silicon Nitride Deposition
3. Backside Photolithography
    a. Frontside and Backside Photolithography - Coat
    b. Backside Photolithography - Expose
    c. Backside Photolithography – Develop
4. Backside Etch – RIE
5. Frontside and Backside Photoresist Strip
6. Frontside Photolithography
    a. Frontside Photolithography – Coat
    b. Frontside Photolithography - Expose
    c. Frontside Photolithography – Develop
7. Metal Deposition

8. Metal Lift-off
9. LOR Strip
10. KOH Etch

- Testing and Probing

Estimated Time to Complete
Allow approximately 12 hours of processing time

Facilities

The MTTC pressure sensor process is designed to be performed in the Manufacturing Technology Training Center (MTTC) at the University of New Mexico. The equipment and process steps described here are for use in this facility.

Safety

The MTTC pressure sensor process involves working with dangerous equipment and chemicals. It is important to read and understand the Material Safety Data Sheets (MSDS) for each chemical involved. It is also a requirement of the MTTC that every person working in the cleanroom must go through specific safety training for the facility, as well as pass a safety test.

The MTTC is a cleanroom, so proper attire is required. It is important to always wear long pants, closed toe shoes, and it is preferred that short sleeved shirts be worn. A smock, hair bouffant, mouth cover, latex or nitrile gloves, safety glasses, and shoe covers are also required.

It is also important that contact lenses and make-up are not worn as they can absorb some of the chemical vapors.

Teamwork

The MTTC pressure sensor process requires that you work in teams. Under most circumstances, the teams should not consist of more than six people.

Equipment, Supplies, and Materials

Each step of the process requires the use of specific equipment, supplies and materials. It is very important for each of the steps to be aware of the chemicals used to ensure proper personal protective equipment (PPE). The equipment, chemicals, supplies, and materials are listed for each process step.

Introduction

MTTC Pressure Sensor

Instructors at the UNM MTTC and Central New Mexico Community College (CNM) have jointly developed a process to fabricate a micro-pressure sensor to measure changes in pressure applied to a thin membrane or diaphragm. The MTTC design incorporates a Wheatstone Bridge configuration as an electronic sensing circuit. A thin membrane of silicon nitride deflects when the pressures on opposite sides of this membrane are different. The amount of deflection is sensed by variable components of the Wheatstone Bridge.

The pressure sensor fabrication process consists of several steps. The process starts with a silicon wafer pre-deposited with silicon nitride, and ends with a wafer of approximately 800 micro-pressure sensors.

The pressure sensor fabrication process was designed at the University of New Mexico's MTTC. The Southwest Center for Microsystems Education (SCME) offers a five day workshop for instructors and students to learn about this process and actually fabricate a wafer of micro-pressure sensors. The workshop is approximately five days and includes instruction on the process, fabrication time, and testing and probing the final product.

The purpose of this activity is to present the process steps and parameters necessary to create the MTTC micropressure sensor.

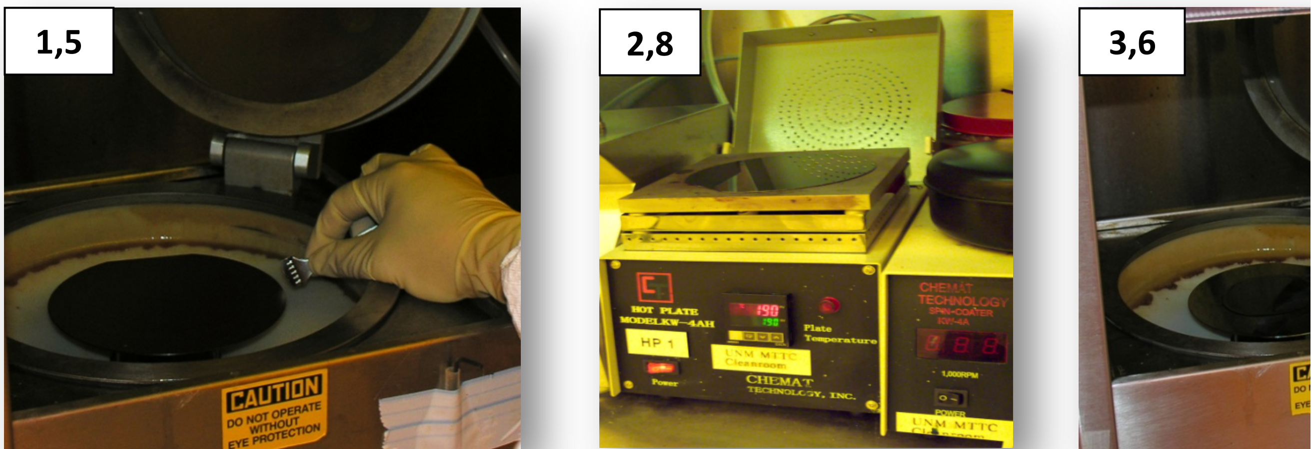
Objectives

- Outline the process of building the MTTC Pressure sensor.
- Describe the basic steps involved in building a MEMS device.

Backside Photolithography – Step 3

After the bare silicon wafers have been coated on both sides with a 1 µm film of silicon nitride, the next process step is backside photolithography. The wafer used is a bare silicon wafer, pre-deposited with silicon nitride. The deposition of the silicon nitride is not performed at the MTTC. The wafers are purchased with a 1 µm low stress silicon nitride layer. Steps 1 and 2 are bare silicon, and silicon nitride deposition, respectively, which again, are not performed at the MTTC.

Backside Photolithography – Coat (Step 3a)



Backside Coat

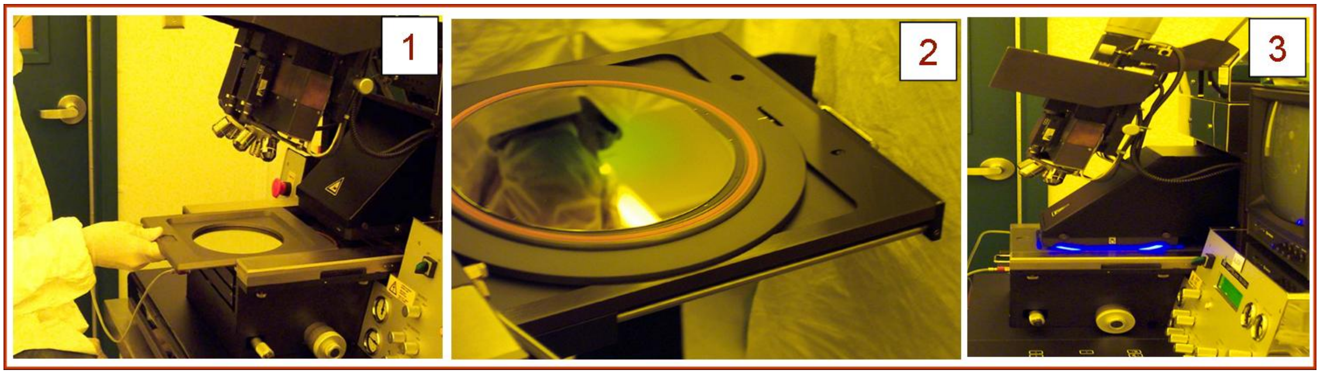
Equipment, Materials, and Supplies
The equipment used in this step is a spin coater which is shown on the left and a hotplate, shown on the right. The HMDS and the photoresist are applied manually with a pipette.

Chemicals Used: HMDS, photoresist (AZ9260)

Coat Parameters

1. Frontside coat - Carefully align and center wafer on vacuum chuck – Visually check for misalignment
2. Bake wafer for 2 minutes at 110ºC / Cool wafer on metal table to bring wafer back to room temp
3. Dispense HMDS w/pipette/Spin (HMDS is a primer to allow photoresist to stick to the wafer)
4. Dispense photoresist (AZ9260) w/pipette/Spin
5. Backside coat - Carefully align and center wafer on vacuum chuck – Visually check for misalignment
6. Dispense HMDS w/pipette/Spin
7. Dispense photoresist (AZ9260) w/pipette/Spin
8. Bake wafer for **2 minutes at 110ºC** to cure and remove solvents / Cool wafer on metal table to bring wafer back to room temp

Backside Photolithography – Expose (Step 3b)



Backside Expose

Equipment, Materials, and Supplies
The equipment used in this step is the Carl Zeiss contact aligner.

Expose Parameters

1. Load Mask into holding tray and slide the tray into the Carl Zeiss alignment system
2. Load wafer into Carl Zeiss contact aligner
3. Expose the wafer to UV light for approximately 300 seconds

Backside Photolithography – Develop (Step 3c)

Backside Develop

Equipment, Materials, and Supplies

The develop step is performed at the caustic bench. A quick dump rinser (QDR) is used as well as a SRD. A microscope station is also used for inspection after the develop is completed.

Chemicals Used: KOH (1:3 solution of deionized water to KOH)

Develop Parameters

1. Place exposed wafer in last slot of white Teflon boat (closest to H bar)
2. Pour develop solution (1:3 concentration of deionized water to KOH) into container and insert boat so entire wafer is submerged
3. Allow wafers to develop for 15 minutes
4. Remove boat at a 45° angle from develop solution to allow excess develop to drip off
5. Place in QDR (Quick Dump Rinse) and rinse 5 times
6. Remove at 45° angle to allow for run-off
7. Place entire boat into SRD (Spin Rinse Dryer) (H-bar in first). Run SRD until water resistivity readout indicates 15MΩ
8. Do a microscopic inspection to check for defects.

Backside Etch – Reactive Ion Etch (RIE) – Step 4

Reactive Ion Etcher

<u>Equipment, Materials, and Supplies</u>
A Reactive Ion Etcher (RIE) etcher is used in this process step.

<u>RIE Parameters</u>

1. Place wafer in the RIE for 300 seconds. You will be using a pre-programmed recipe so you will not need to set any other parameters.
2. Turn off RIE and vent to atmospheric pressure
3. Open RIE and turn wafer 180º. Etch for another 300 seconds
4. Turn off RIE and vent to atmospheric pressure
5. Remove wafer

Backside Etch Strip – Step 5

Backside Etch Strip

Equipment, Materials, and Supplies
The backside etch strip will be performed at the acid wet bench. The SRD is also used.

Chemicals Used: H_2SO_4/ H_2O_2

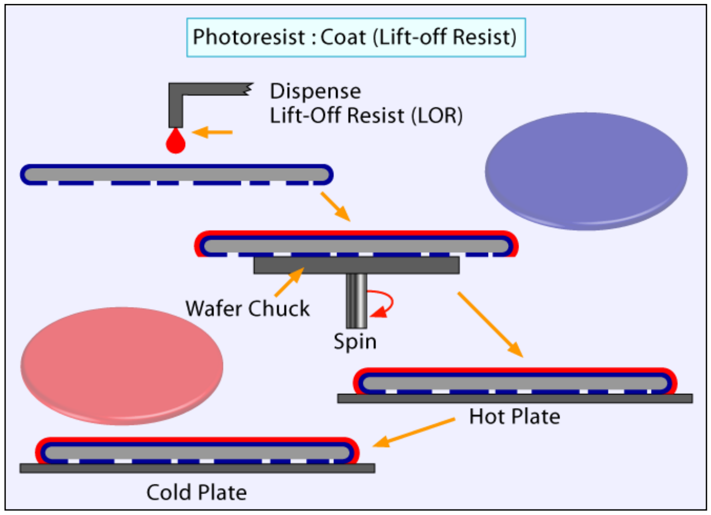
Backside Photoresist Strip Parameters (USE ACID GEAR)

1. Pour 4.5 gallons of sulfuric acid into the acid wet bench.
2. Add 200mL hydrogen peroxide
3. Heat to 100ºC
4. Set wafers in for 15 minutes
5. Place SRD using program 1 (about 6 minutes)

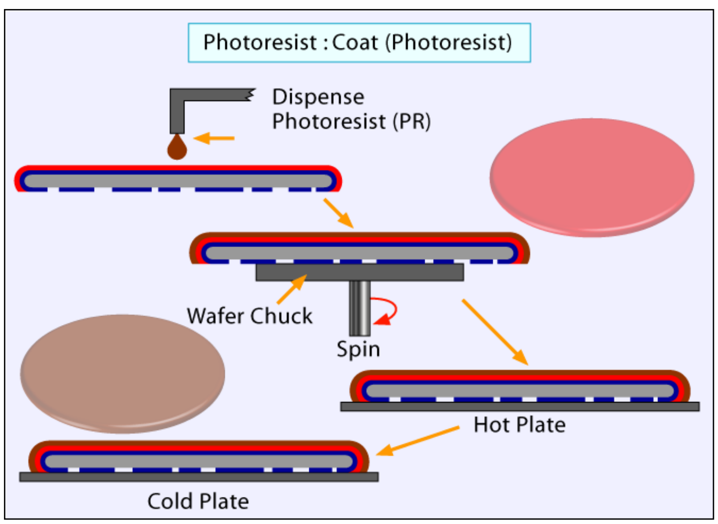
Process Time: 15 minutes

Frontside Photolithography – Step 6

The next step in the process is to pattern the frontside of the wafer with the Wheatstone Bridge pattern. In this step, a lift-off resist is also applied in order to create a desired undercutting during the develop process.



Frontside Coat (LOR)

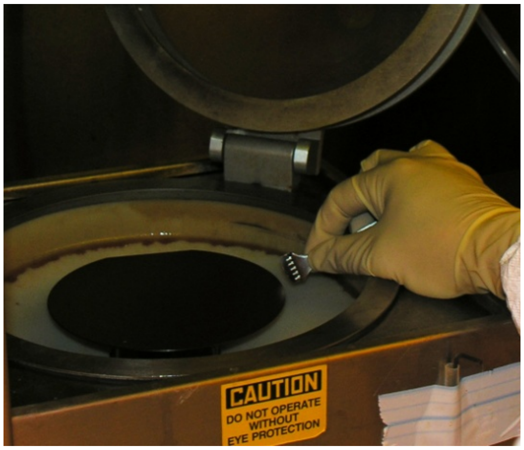


Frontside Coat (Photoresist)

Frontside Photolithography – Coat (Step 6a)

Equipment, Materials, and Supplies

The equipment used in this step is a spin coater which is shown on the left and a hotplate, shown on the right. The HMDS and the photoresist are applied manually with a pipette.

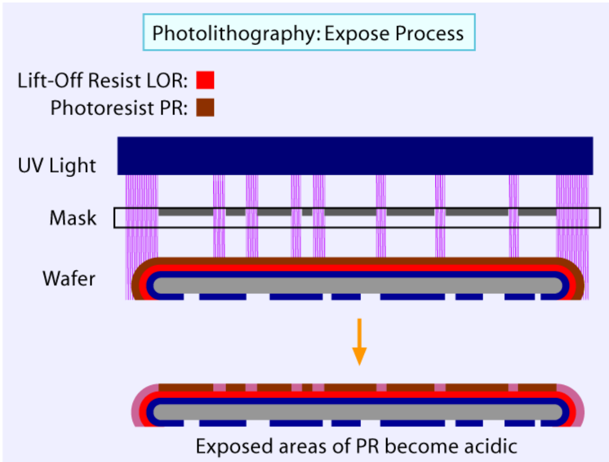


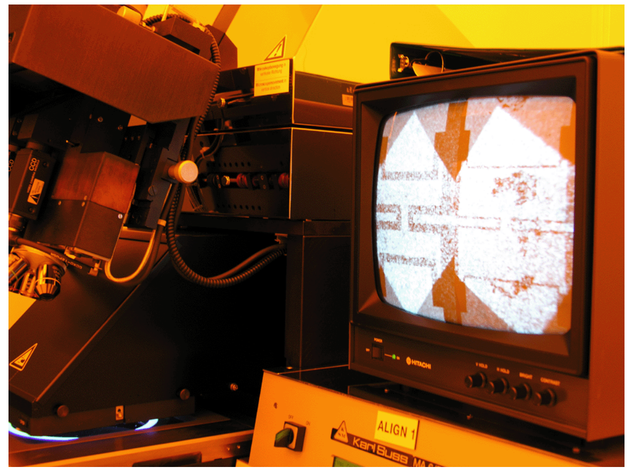
Chemicals Used: LOR, HMDS, Photoresist

Frontside Coat Parameters

1. Carefully align and center wafer on vacuum chuck – Visually check for misalignment
2. Dispense Lift off Resist (LOR) with pipette. Spin
3. Bake wafer for 2 minutes at 190ºC to remove solvents
4. Cool wafer on metal table to bring wafer back to room temp
5. Carefully align and center wafer on vacuum chuck – Visually check for misalignment
6. Dispense photoresist (AZ5214) with pipette.
7. Bake wafer for 2 minutes at 100ºC to remove solvents
8. Cool wafer on metal table

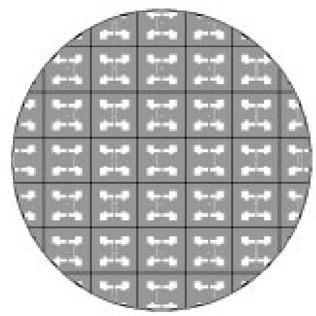
Frontside Photolithography – Expose (Step 6b)





Frontside Expose

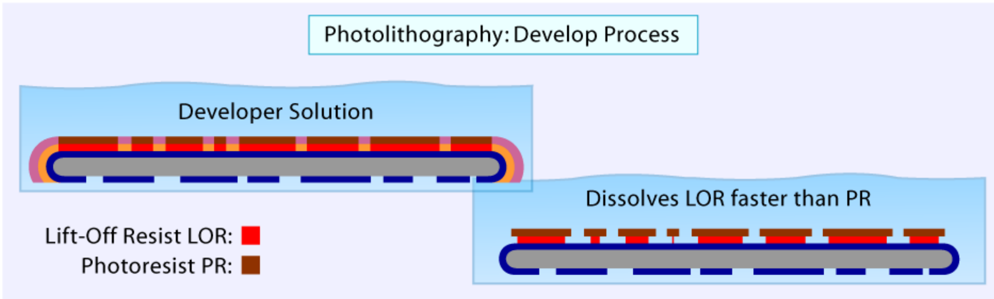
Equipment, Materials, and Supplies
The equipment used in this step is the Carl Zeiss contact aligner. The image on the right is the mask pattern used for this step.



Frontside Expose Parameters

1. Load mask into holding tray and slide the tray into the Carl Zeiss alignment system
2. Load wafer into Carl Zeiss Contact Aligner
3. Align wafer using alignment system
4. Expose wafer to UV light for 40 seconds

Frontside Photolithography – Develop (Step 6c)



Frontside Develop

Equipment, Materials, and Supplies

The develop step is performed at the caustic bench. A quick dump rinser (QDR) is used as well as a SRD. A microscope station is also used for inspection after the develop is completed.

Chemicals Used: KOH (1:5 solution)

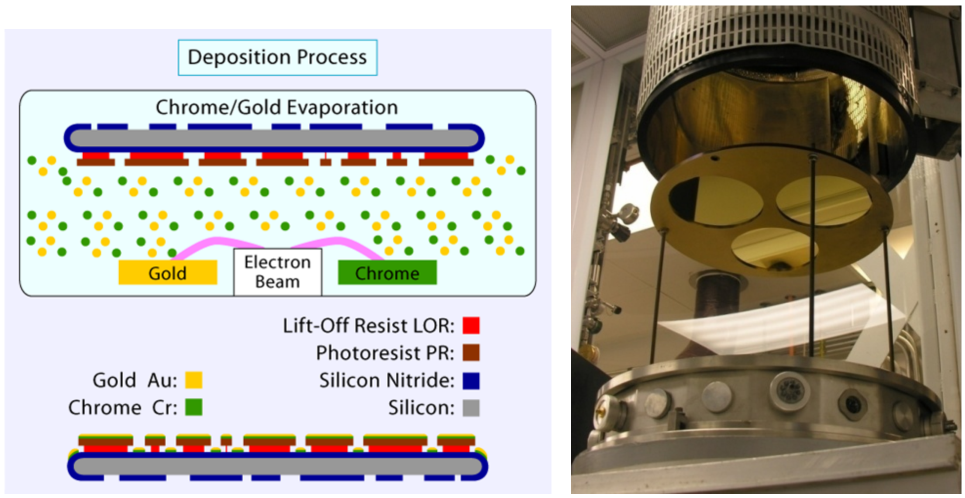
Frontside Develop Parameters: Performed at Caustic Wet Bench, USE ACID GEAR

1. Place exposed wafer in last slot of white Teflon boat (closest to H bar)
2. Pour develop solution (1:5 concentration of KOH) into container. Insert boat so entire wafer is submerged
3. Allow wafers to develop for 60 seconds
4. Remove boat at a 45° angle from develop solution to allow excess mixture to drip off
5. Place in QDR (Quick Dump Rinse) and Rinse 5 times
6. Remove at 45° angle to allow for run-off
7. Place entire boat into SRD (Spin Rinse Dryer) (H-bar in first). Run SRD until water resistivity readout indicates until unit reaches 15MΩ
8. Do a microscopic inspection to check for defects

Bad LOR

Metal Deposition – Step 7

The purpose of this step is to deposit the metal conductive material used for the resistor bridges in the Wheatstone Bridge.



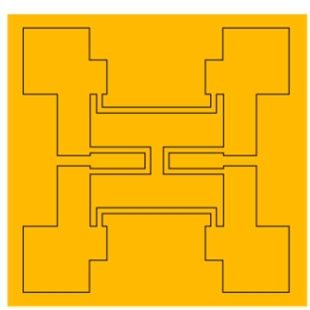
Chrome/Gold Deposition

<u>Equipment and Materials</u>
This process step is performed in a bell jar vacuum evaporator.

<u>Supplies</u>: Chrome pellets, gold pellets

<u>Chrome/Gold Process Parameters</u>

1. Place wafer into the vacuum evaporator
2. Deposit 100 Angstroms of chrome onto the wafer – Process Time: 90 seconds
3. Deposit 4000 Angstroms of gold over the chrome – Process Time: 5 minutes

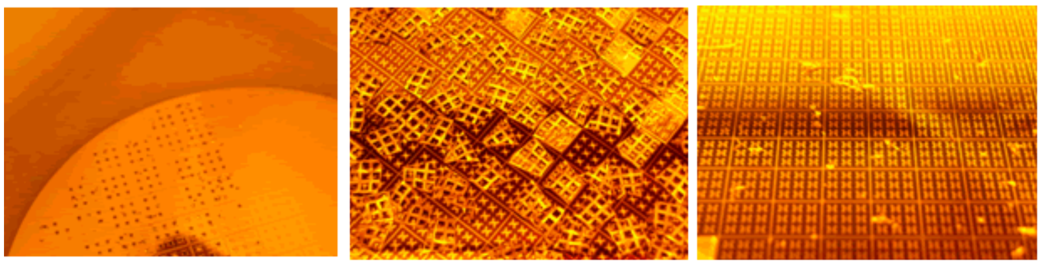


Wheatstone Bridge Pattern after Chrome/Gold Deposition

Metal Lift-off – Step 8

The purpose of this step to remove the excess chrome and gold deposited, leaving only the chrome and gold in the Wheatstone bridge pattern.

Once the excess metal has lifted off, the remaining LOR is removed using KOH. Finally, the exposed silicon nitride on the backside of the wafer is etched by the KOH leaving a thin silicon nitride membrane.



Stage 1: Chrome/Gold beginning to liftoff

Stage 2: Wheatstone bridge structures beginning to be revealed

Stage 3: Chrome/Gold liftoff complete

Metal Lift-off Process

Equipment, Materials, and Supplies
The lift-off step is performed at the solvent bench. Deionized (DI) water and a SRD are also used.

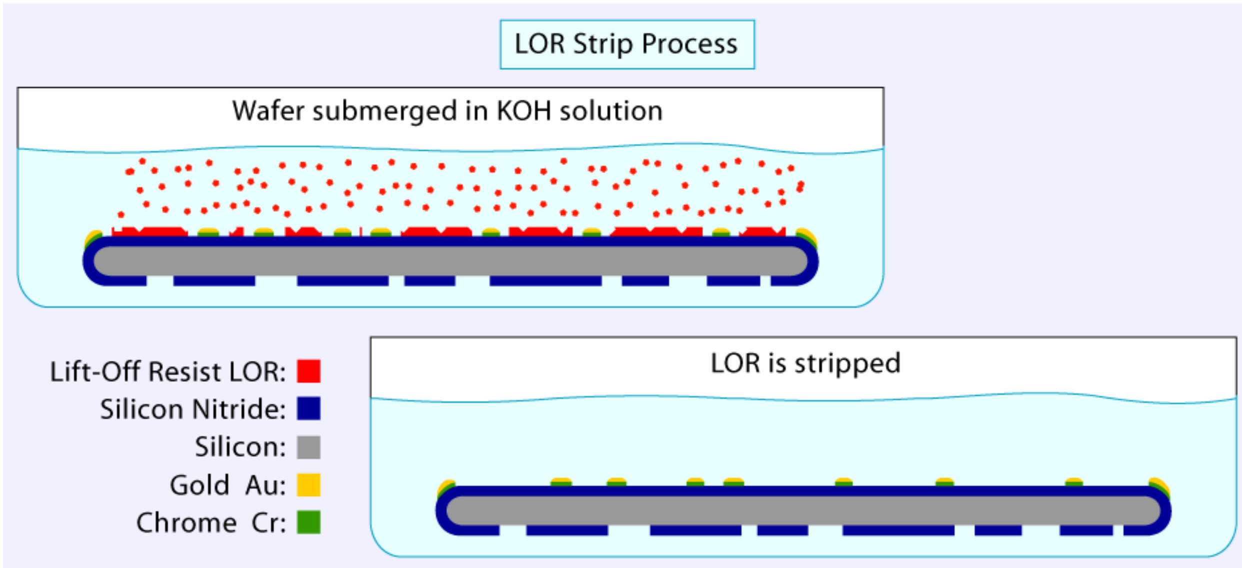
Chemicals Used: Acetone

Metal Lift-off Parameters

1. Carefully place the wafer face up in the acetone
2. Let the wafer process in the acetone for 30 minutes
3. Remove wafer from the acetone
4. Rinse with deionized (DI) water
5. Place entire boat into SRD (Spin Rinse Dryer) (H-bar in first). Run SRD until water resistivity readout indicates until unit reaches 15MΩ
6. The lift-off is complete

Microscope Photo of Wheatstone Bridge after Lift-off

LOR Strip – Step 9



LOR Strip

Equipment, Materials, and Supplies
The LOR strip is performed at the caustic bench.

Chemicals Used: KOH at room temperature

LOR Strip Parameters
For the LOR strip, wafers are submerged in a room temperature KOH bath. This to removes the remaining LOR.

1.Carefully place the wafer, face up in the KOH bath 2.Allow a process time of approximately 2 minutes

KOH Etch – Step 10

KOH Etch

Equipment, Materials, and Supplies

The KOH etch is performed at the caustic bench. A nitrogen blow gun is also used.

Chemicals Used: KOH, Isopropyl Alcohol (IPA), nitrogen

KOH Etch Parameters

The KOH etch process takes several hours. There are three stages during the process where temperature and time are changed:

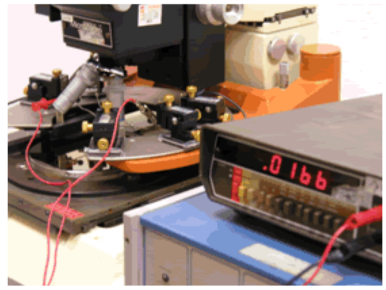
Stage 1: 105ºC for 2 hours
Stage 2: 95ºC for 90 minutes
Stage 3: 80ºC for approximately 45 minutes, or until etch is complete

1. Place wafers in a Teflon boat. Very gently, place the boat into a KOH bath heated to 105ºC. Process for 2 hours
2. Reduce the temperature to 95ºC. Leave for 90 minutes
3. Reduce the temperature to 80ºC. Leave for approximately 45 minutes, or until etch is complete
4. Place boat of wafers in QDR
5. Rinse with Isopropyl Alcohol (IPA) and carefully blow with nitrogen

Total Process Time: Approximately 4 1/2 hours

Testing and Probing

Pressure Sensor wafer on probing station



Probing station and power supply

Probe on the Wheatstone Bridge

Testing and Probing

Equipment, Materials, and Supplies

The testing is performed at a probing station containing micromanipulators with probing needles. A power source and digital volt meter are also used.

Testing and Probing Description

Next it is time for the testing and probing of the final pressure sensor product. A probing station with a microscope is used to observe the deflection of the silicon nitride membrane of the pressure sensor when it is subjected to a power source. This pumping action of the membrane when subjected to the applied voltage illustrates another application of the pressure sensor: a micropump!

1. Place the wafer on the probing station
2. Connect the wafer to a power supply
3. Apply less than a volt
4. Through the microscope observe the membrane moving in a pumping action when subjected to the applied voltage

Summary

The MTTC pressure sensor process produces a pressure sensor with a Wheatstone bridge configuration on a silicon nitride membrane. This activity illustrates the process sequence used commercially to produce MEMS pressure sensors. It also provides a basic understanding of photolithography, plasma etch, metal deposition, metal lift-off, and KOH etch.

References

MTTC Pressure Sensor.doc, Harold Madsen, Albuquerque UNM.
MTTC KOH Flow.xls, Harold Madsen, Albuquerque UNM.
Lift-Off.ppt Fabian Lopez, Albuquerque CNMCC.

Disclaimer

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