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# Surface Micromachining: Lift-Off Process Activity

## Instructor Guide

### Notes to Instructor

The Surface Micromachining: Lift-Off Process Activity is an activity in the *MTTC Pressure Sensor Process Learning Module*. This activity should be assigned after the primary knowledge unit on the MTTC Pressure Sensor Process. This activity does require the use of Acetone; therefore, it should be performed in a well-ventilated environment and all safety requirements should be followed.

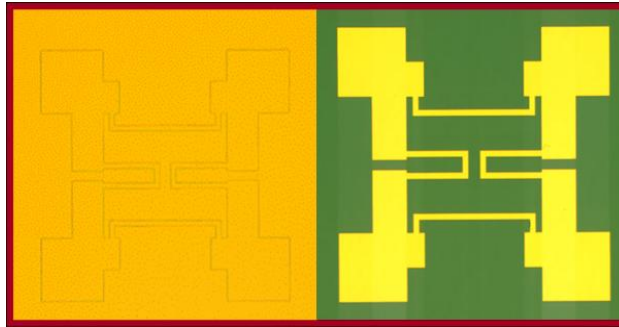
The *MTTC Pressure Sensor Process Learning Module* consists of the following:

- Knowledge Probe (KP) or Pre-quiz
- MTTC Pressure Sensor Process Primary Knowledge
- MTTC Pressure Sensor Process Activity (Requires cleanroom or fabrication facility)
- A MEMS Process Model Activity
- Micro Pressure Sensor Process Activity\*
- **Surface Micromachining: Lift-Off Process Activity\***
- Bulk Micromachining: An Etch Process Activity\*
- Final Assessment

\*Kit available through [scme-nm.org](http://scme-nm.org) while supply lasts

This activity requires the SCME Surface Micromachining: Lift-off Process Kit. To learn more about this kit, click here for “[kit description](http://bit.ly/1p32b5B)” (<http://bit.ly/1p32b5B>). To order this kit, go straight to the SCME Kit store. (<http://bit.ly/2wnHSFJ>)

## Introduction



*Wheatstone bridge Pattern Before and After Lift-Off*

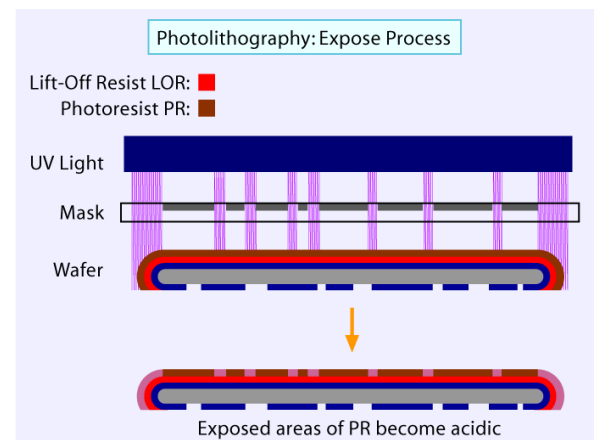
This activity demonstrates the lift-off process, a process used in surface micromachining. Lift-off is the 8<sup>th</sup> step in a 10 step process\* for making a micro-pressure sensor. The pressure sensor design used in this process incorporates a Wheatstone bridge configuration on a silicon nitride membrane.

The purpose of this activity is to lift-off an excess of two pre-deposited metal layers: 4000 Angstroms of gold on top of 100 Angstroms of chrome. After lift-off, what remains is the chrome and gold in a Wheatstone bridge pattern. This process uses acetone to dissolve a pre-applied photoresist underneath the two metals. As the photoresist dissolves, the chrome and gold layers on top of the photoresist lift-off.

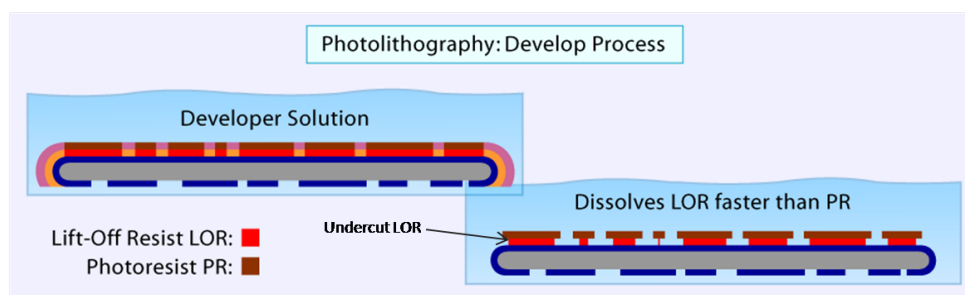
Let's review some of the preceding steps to Lift-off.

The steps preceding lift-off include coating the wafer with a lift-off resist (LOR) followed by a photoresist (PR) coat. The PR is then patterned with a Wheatstone bridge circuit using a mask and UV light (shown in the graphic).

*\*The MTTC Pressure Sensor Process*



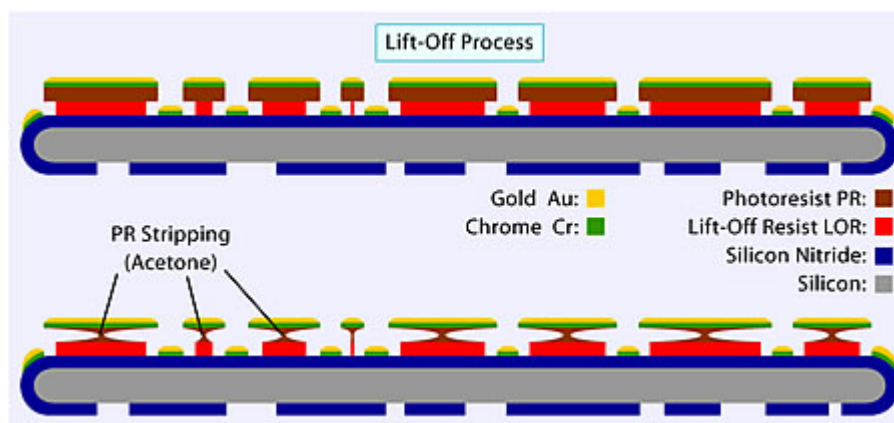
The photoresist is developed, removing the exposed photoresist and dissolving the LOR beneath the openings in the PR. As seen in the graphic below, the LOR dissolves faster than the exposed PR. This creates an undercutting beneath the top photoresist layer (PR). This step is essential to subsequent process steps. If the LOR did not undercut the photoresist, the metal layer deposited in the next process step would be completely removed during the following lift-off step of the metal layer.



## Metal Lift-off Description and Parameters

After the PR develop, an evaporator is used to deposit a 100 angstroms layer of chrome followed by 4000 angstroms layer of gold. The graphic below shows the pre-processed wafer with the chrome and gold layers (top graphic) and the lift-off process (bottom graphic).

In this activity a single die from a pre-processed wafer is soaked in acetone. Once the die has soaked in the acetone for a few minutes, the photoresist layer dissolves and the chrome and gold deposited on the photoresist lift-off. The Wheatstone bridge circuitry and LOR (lift-off resist) is left behind. During this process the die must stay wet or the released metal could stick to the die surface.



Process Time: Approximately 15 minutes

Chemicals Used: Acetone

\*The 10 step process was developed jointly by the University of New Mexico (UNM) and Central New Mexico Community College (CNMCC)

## **Activity Objectives and Outcomes**

### Activity Objectives

- Describe the process of removing excess gold and chrome to leave a desired geometry.
- Safely and successfully execute the lift-off process.

### Activity Outcomes

Upon examination, the desired Wheatstone bridge pattern should be revealed.

### **Safety**

This activity uses 100% acetone. It is important to follow safe chemical handling and safety procedures when performing this activity. This activity must be performed in a well-ventilated area.

The following personal protective equipment (PPE) is required when performing this activity:

- Latex or nitrile gloves
- Safety goggles

## Supplies/Equipment

**This activity requires the SCME Surface Micromachining: Lift-off Process Kit. To learn more about this kit, click here for “[kit description](http://bit.ly/1p32b5B)” (<http://bit.ly/1p32b5B>). To order this kit, go straight to the SCME Kit store. (<http://bit.ly/2wnHSFJ>)** Kits are available only while supply lasts and the center is funded.

### Supplies provided by instructor

- 75 ml Acetone (a small can of Acetone can be purchased from a home improvement center)
- DI or distilled water for rinsing
- Spouted measuring cup (metric) or Small plastic funnel
- Microscope or magnifying glass
- Compressed air
- Timer
- Table covering
- Paper and pencil
- Safety goggles
- Nitrile gloves (large) or any chemically resistant gloves

### Kit supplies

- 1 - 125 ml flask
- 6 - Pre-processed lift-off chip
- 1 - 6 in Teflon tubing with a pre-processed lift-off chip
- Plastic syringe
- 1 MTTC Pressure Sensor Process Learning Module – Instructor Guide
- 1 MTTC Pressure Sensor Process Learning Module – Participant Guide

## Facility

This activity can be performed in any well-ventilated classroom.

## Preparation/setup

Before performing this activity, put on your latex or nitrile gloves and your safety goggles.

## Activity: Lift-Off

**Description:** Using acetone, lift-off off the excessive metal from a pre-processed chip to expose the Wheatstone bridge circuit.

### Material Safety Data Sheet (MSDS)

1. From the Internet, download the MSDS for acetone. Study the MSDS and answer the following questions.
2. Answer the following question before proceeding with this procedure.
  - a. Why is it important to ensure that all heat sources and ignition sources are removed before working with Acetone?

*Answer: Acetone is extremely flammable in both liquid and vapor form. Therefore, just the vapors from the acetone can ignite.*

- b. What are the health hazards of acetone?

*Answer: Can cause moderate to severe eye irritation, moderately irritating to the skin, inhalation of high concentrations may lead to central nervous system effects (e.g., drowsiness, nausea, headache), may be harmful or fatal if swallowed.*

- c. What personal protective equipment should you wear when working with acetone in a well-ventilated area?

*Answer: Safety goggles, chemically resistant gloves*

**NOTE:** Anytime you work with chemicals, it is your responsibility to know the chemical you are working with, know the necessary precautions, and follow ALL safety procedures (i.e., handling, personal protective clothing, first aid measures, disposal) when working with the chemical.

**Note to Instructor:** *Because this activity deals with a hazardous chemical (sodium hydroxide), be sure to follow the safety requirements of your institution.*

## Lift-Off Procedure

1. Fill beaker with acetone.

Measure 75 ml of acetone with the spouted measuring cup and pour into the 125 ml flask. The spouted measuring cup should prevent spilling. If a spouted measuring cup is not available, use a funnel.

2. Place die in holder

Observe chip with microscope or magnifying glass before placing in tubing. Describe what you see.

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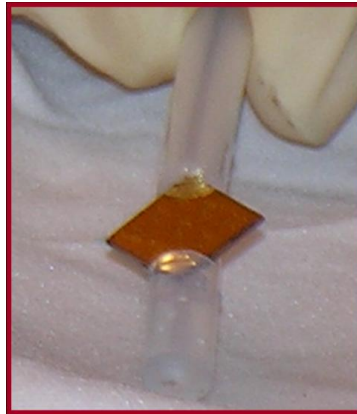
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Place the pressure sensor die in the Teflon tubing holder.



*Pressure Sensor Die in Teflon Tubing Holder*

3. Place Teflon die holder with die in acetone

Place the Teflon tubing holder with the die in the acetone.



*Pressure Sensor Die in Beaker with Acetone*

4. Set a timer

Set a timer for 15 minutes.

Observe the changes. Discuss what is happening. Record your observations below.

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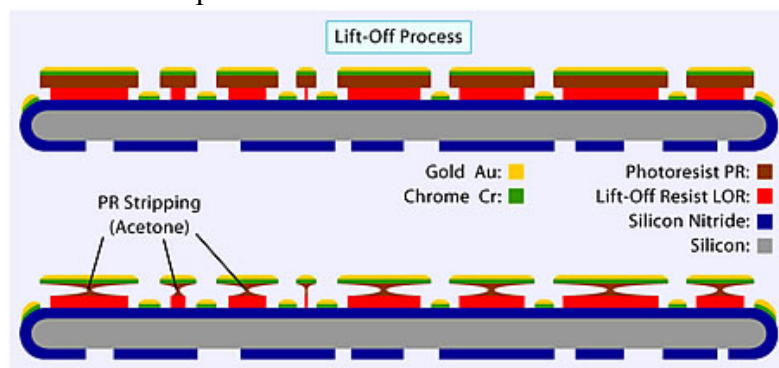
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Starting with the frontside lithography step, draw the cross section of the layers and indicate which layers are dissolved in the lift-off process.

*Answer:*





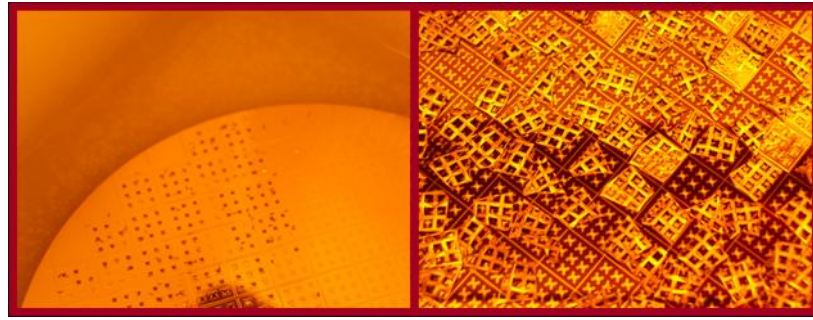
5. Observe the emerging pattern

Carefully observe the gold pattern as the photoresist under the gold film is removed.

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*Chrome/Gold layers being removed on a pressure sensor wafer.*

6. During the 15 minutes, shake the tubing holder

During the 15 minutes, occasionally agitate the tubing holder such that the chip remains submerged. This will help the gold come off the die. By the end of the 15 minutes, there should be a Wheatstone bridge pattern remaining, if there is still some gold remaining that is not part of the pattern, fill the syringe with acetone and aim the stream from the syringe on the unwanted gold to remove. Repeat this process until all of the unwanted gold is removed.

Note: You may start seeing the gold lift-off after a couple of minutes, and for some, the process could be complete after about 5 minutes. However, it may take longer for some for the gold between the resistors to be completely removed. The die must stay wet or the metal may stick randomly to the die surface.

7. Rinse the die holder with DI water

When all the excess chrome/gold has completely come off, fill the measuring cup with DI or distilled water. Rinse the die in the water.

8. Blow dry

Gently blow dry the die with compressed air.

9. Examine die under a microscope

Gently remove the die from the Teflon tubing. Make sure you are wearing safety gloves since the die is very sharp. Place the die under a microscope or use a magnifying glass to look at the gold pattern on the die.

There will be a line where the LOR (lift-off resist) has not been removed. It will outline the gold pattern.

Explain what you see.

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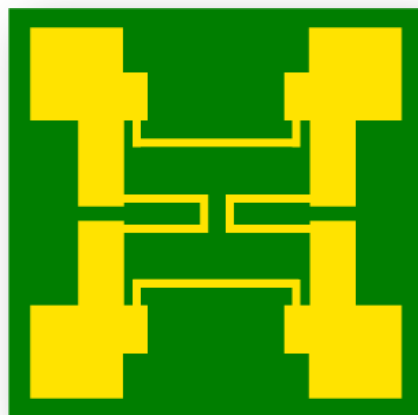
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10. Draw the gold pattern

Below, draw the pattern made by the remaining gold layer

*Answer:*



### Post Activity Questions

1. What is the purpose of the lift-off process in the fabrication of a micropressure sensor?
2. The original die was covered completely in gold over chrome. What allowed for selectively in the lift-off process?
3. What would be the result of the lift-off process if LOR were omitted?
4. Why is it more difficult for the gold between the resistors to be removed?
5. Explain why “lift-off” is considered a surface micromachining process.

### Post Activity Questions / Answers

1. What is the purpose of the lift-off process in the fabrication of a micropressure sensor?  
*Answer: To selectively remove the unwanted gold/chrome layers, leaving only the gold/chrome layers that form the Wheatstone bridge circuit.*
2. The original die was covered completely in gold over chrome. What allowed for selectively in the lift-off process?  
*Answer: The pre-depositing of photoresist on top of a lift-off resist (LOR). The LOR is "harder" allowing it to etch slower in the acetone. Therefore, when submerged in acetone, only the photoresist is removed along with the gold/chrome layers on top of it. The gold/chrome layers between the LOR deposits remain.*
3. What would be the result of the lift-off process if LOR were omitted?  
*Answer: All of the gold/chrome layers would come off the wafer during the process.*
4. Why is it more difficult for the gold between the resistors to be removed?  
*Answer: The small space between resistors makes it more difficult for the acetone to access the photoresist between the resistors.*
5. Explain why “lift-off” is considered a surface micromachining process.  
*Answer: Because it takes place on the surface of the wafer and involves “surface” thin films.*

*Support for this work was provided by the National Science Foundation's Advanced Technological Education (ATE) Program through Grants. For more learning modules related to microtechnology, visit the SCME website (<http://scme-nm.org>).*