Bulk Micromachining: An Etch Process Activity

Instructor Guide

Notes to Instructor

The Bulk Micromachining: An Etch Process activity is an activity in the *Etch Overview Learning Module* and the *MTTC Pressure Process Learning Module*. This activity demonstrates the bulk etch process used to selectively remove substrate material. This activity should be assigned after the primary knowledge (PK) unit on the MTTC Pressure Sensor Process or after *the Etch Overview for Microsystems PK.*

The *Etch Overview for Microsystems Learning Module* consists of the following:

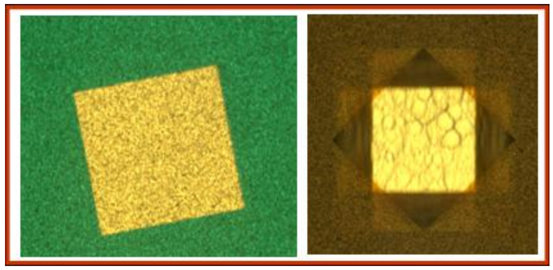
- Knowledge Probe (KP) or pre-test
- Etch Overview for Microsystems PK
- Etch Terminology Activity
- Science of Thin Films Activity (SCME Kit available @ http://scme-nm.org)
- **Bulk Micromachining: An Etch Process Activity** (SCME Kit available @ http://scme-nm.org)
- Final Assessment

This activity requires the SCME Bulk Micromachining: An Etch Process Kit. To learn more about this kit, click here for "kit description". You can order this kit through the SCME website while supply lasts and the center is funded.

This companion Instructor Guide (IG) contains all of the information in the PG as well as answers to the Post-Activity questions.

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).

Introduction



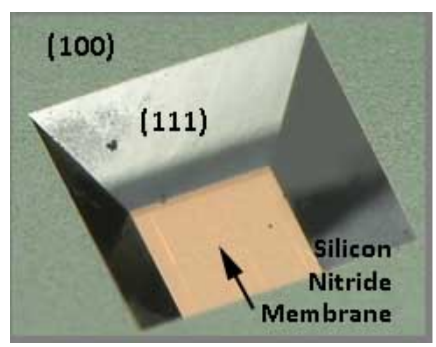
Backside of Pressure Sensor before and After Anisotropic Etch

This activity demonstrates the anisotropic etch process, which is considered a bulk micromachining process because it removes a select bulk of silicon wafer. It is the last step in a 10 step process* for making a micro pressure sensor. The micro pressure sensor design used in this process incorporates a Wheatstone bridge configuration on a silicon nitride membrane on the frontside of the chip. The backside of the chip is etched to remove a bulk of the silicon from beneath the membrane, forming a cavity. This cavity or chamber is used by the micro pressure sensor as the reference pressure chamber.

The micro pressure sensor process used at the Manufacturing Technology Training Center (MTTC) at the University of New Mexico uses KOH (potassium hydroxide) as the etchant. This activity uses a high concentration drain cleaner (sodium hydroxide), as a substitute for KOH. In this etch process wafers are submerged in a heated bath of a drain cleaner mixture. The drain cleaner is used because, like KOH, it produces an anisotropic etch with silicon by etching along the planes of the silicon.

Silicon nitride on the non-metal side (backside) of the chip acts as a hard mask on the chip. This mask leaves select areas of the silicon exposed to the drain cleaner. The exposed silicon is etched anisotropically by the drain cleaner. The etch continues until all of the exposed silicon is removed and the silicon nitride membrane on the front side of the chip is reached. KOH cannot etch silicon nitride; therefore, the etch stops when the silicon nitride layer is reached.

The image shows a backside etch. The brown indicates the silicon nitride membrane on the frontside of the chip. As you can see the backside (or silicon) has been etched to create an opening or chamber beneath the membrane. The top of the wafer is the (100) plane whiles the etched sides of the chamber are formed by the (111) plane of the silicon.



Drain Cleaner Description and Parameters
In this activity a single die from a processed wafer is submerged in drain cleaner to anisotropically etch the exposed silicon. It is very important to purchase the right kind of drain cleaner. It is highly recommended that you use 100% Sodium Hydroxide (lye) crystal drain cleaner as the etchant. The drain cleaner will be diluted during the experiment with de-ionized (DI) or distilled water. Many drain cleaners have concentrations of sodium hydroxide that are less than 100% and they contain other additives. These drain cleaners should be avoided.

It is also very important to note that this etchant will be heated and will emit toxic fumes. It will also emit hydrogen gas.

Therefore, you MUST perform this experiment under a fume hood. There should be no exceptions.

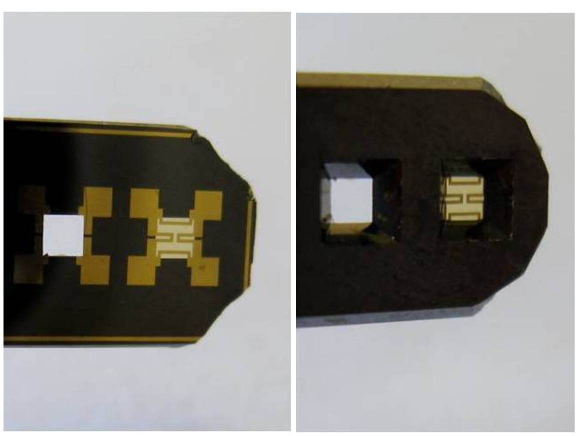
Experiment Preparation: Approximately 30 minutes
Process Time: Approximately 2.5 to 3.5 hours
Chemicals Used: 100% Sodium Hydroxide (NaOH) in crystal form

*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 wet anisotropic etch of silicon.
- Identify the safety requirements when performing the wet anisotropic etch process.

Activity Outcomes
Upon examination, the exposed silicon is etched anisotropically leaving a thin silicon nitride membrane on the front side of the wafer. The images below are what you should see upon completion of the etch process.



Frontside of an Individual Chip after Processing is Complete (far left)
Backside of an Individual Chip after Processing is Complete (right image)

Safety
This activity uses sodium hydroxide drain cleaner. It is important to study the Material Safety Data Sheet (MSDS) prior to performing this activity and to follow safe chemical handling procedures when performing this activity. All participants should wear impervious protective clothing

including shoes, gloves, and lab coat / apron. Safety goggles and/or a full face shield are required. This experiment should be performed in an area with an eye wash station and safety rinse area.

This experiment must be performed in a laboratory with a fume hood.

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 kit called Bulk Micromachining: An Etch Process.

Supplies provided by instructor

- Crystal Drain Cleaner – 100% Sodium Hydroxide (NaOH) or lye (can be purchased from a home improvement center)
- DI (de-ionized) or Distilled water (a gallon of distilled water can be obtained from a grocery store)
- Paper cup
- Plastic spoon
- Plastic glass
- Hotplate with thermocouple control and ceramic top (if possible)*
- Microscope
- Latex or nitrile gloves
- Safety goggles

*Sodium hydroxide does react with certain metals.

Kit supplies

- 1 Liter beaker
- 6 Pre-processed etch chip
- 1 - 6 in Teflon tubing with additional chip
- 1 Weighing Scale (with 100g weight for calibrating)
- 1 Etch Overview for Microsystems Learning Module - Instructor Guide
- 1 Etch Overview for Microsystems Learning Module – Participant Guide

Preparation/setup

Before performing this activity, put on your latex or nitrile gloves and your safety goggles. Make sure you work under a fume hood and that the work surface is well protected in case of spills.

Facility

This activity MUST be performed under a working fume hood and in a facility with an eye wash station and rinse area (e.g., safety shower).

Activity: Anisotropic Etch of Silicon

Description: Perform a wet anisotropic etch of silicon using sodium hydroxide to create a cavity on the backside of a silicon chip.

Safety Data Sheet (SDS / MSDS)

1. From the Internet, download the SDS for sodium hydroxide. Study the SDS and answer the following questions. (Note: Material Safety Data sheets (MSDS) are now called Safety Data Sheets (SDS))

2. Answer the following question before proceeding with this procedure.
   a. Why is it important to wear goggles, gloves and protective clothing when working with sodium hydroxide?

      Answer: Sodium hydroxide is a corrosive and can cause severe burns on contact with the skin and can result in corneal damage or blindness with eye contact.

   b. Why is it important to perform this activity under a fume hood?

      Answer: When mixed with water, sodium hydroxide forms hydrogen gas that can be explosive and should not be inhaled.

   c. What measures should you take if sodium hydroxide comes in contact with your skin?

      Answer: Get medical aid immediately. Flush skin with plenty of water for at least 15 minutes while removing contaminated clothing / shoes. Wash clothing before reuse.

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.*

Anisotropic Etch Procedure

1. Set the hot plate to 105ºC. It takes some time for the hotplate to reach this temperature.

2. While the hotplate is heating, place the pressure sensor die in the Teflon holder. Ensure that the die is placed with the corner in the holder and the backside facing out *(as shown below)*.

Pressure Sensor Die in Teflon Tubing Holder

3. Measure 600 mL of DI or distilled water into the 1 Liter beaker.

4. Place the paper cup on the scale. The scale might need to be calibrated. If so, use the instructions included with the scale to calibrate the scale.

5. Scoop enough crystal drain cleaner (NaOH) into the paper cup to measure 100 g.

6. VERY slowly add the 100 g of NaOH to the water in the 1 Liter beaker.

    - Remember, **Always Add Acid (AAA)** to water, and never the reverse. NaOH is a very strong base, but it should be treated as an acid. When NaOH is mixed with water, the reaction is highly exothermic. A large amount of heat is released. If you add water to NaOH, you initially form an extremely concentrated solution. Before you can completely add all of the water, the released heat from the NaOH and H_2O causes the solution to boil very violently, splashing concentrated NaOH out of the container! If you add the NaOH to water, the initial solution is very dilute and the small amount of heat released is not enough to vaporize and spatter it. AAA allows the heat to be released and to dissipate, preventing a violent reaction. This is the same reaction that can occur for acids and water; therefore, treat NaOH as an acid. Remember – it's also highly corrosive.

7. Once all of the NaOH has been added to the water, place the Teflon tube with die side down into the NaOH solution.

8. Swirl the Teflon tube in the solution to further dissolve the NaOH crystals.

9. Place the beaker with the solution and the Teflon tube with the die on the hotplate.

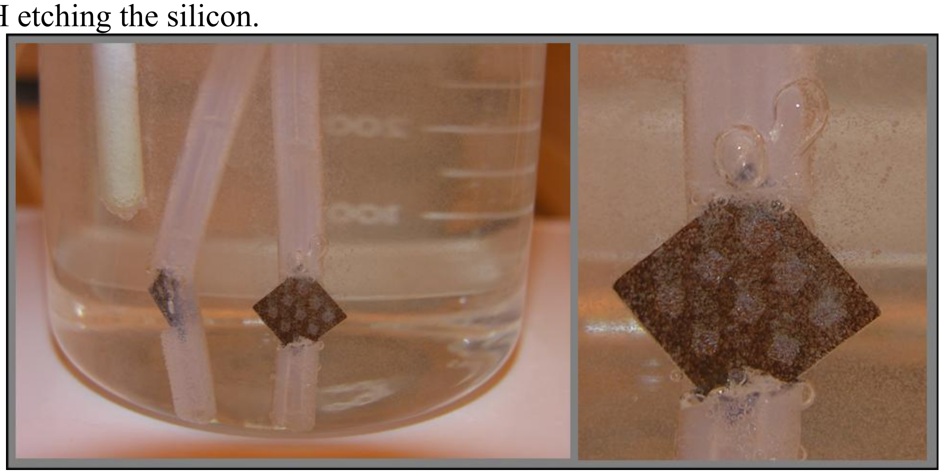
10. Insert the hotplate's thermocouple into the flask.

11. Monitor the temperature and allow the solution to come to 105ºC.

    - Even though the solution should already be hot due to the exothermic reaction between the NaOH crystals and the water, it may take some time for the solution to reach 105ºC.

12. The temperature should be monitored and should maintained at 105ºC.

13. Notice the bubbles forming as the silicon is being etched. (See image below). This is the NaOH etching the silicon.



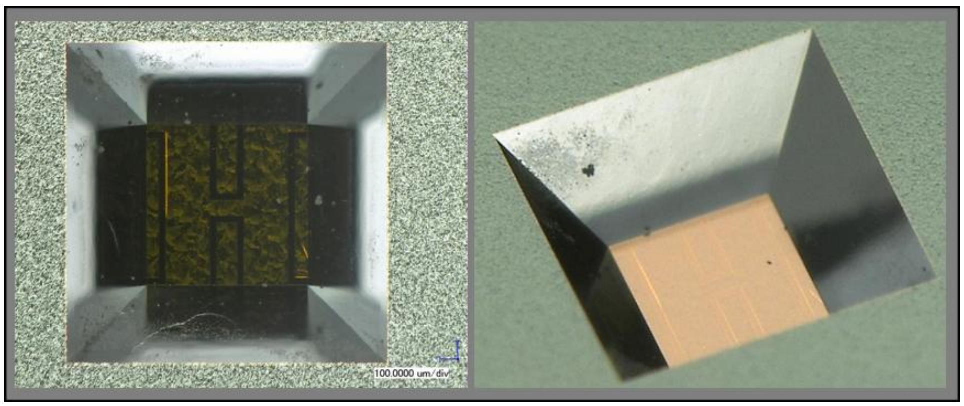
Pressure Sensor Die in KOH Solution

14. It should take between 2.5 to 3.5 hours for the bulk of the silicon on the back side of the die to be removed or etched away. You can tell the process is complete if you can see light through the holes in the die.

15. Once you can see light through the devices, carefully remove the die from the solution.

16. Pour DI or distilled water into the plastic glass. Gently rinse the die in the DI or distilled water.

17. Through a microscope, view the etch on the backside of the die.



Backside of Pressure Sensor Illustrating the Bulk Etch of the Silicon
Courtesy of Keyence

Post Activity Questions

1. What is meant by "anisotropic etch"?

2. What characteristic of silicon allows for its anisotropic etch with KOH (or NaOH)?

3. What type of micromachining process does this activity simulate (surface, bulk, or LIGA)?

4. What are the important safety procedures that must be followed when performing this experiment?

5. This process is just one type of anisotropic etching. Some anisotropic etching occurs within a plasma etcher and affects a thin film on the surface of a wafer, thus being a "surface" micromachining process. However, the process you just performed is considered a "bulk" micromachining process. Explain why.

Post Activity Questions / Answers

1. What is meant by "anisotropic etch"?
   Answer: Straight walled etch or etch that follows the crystalline structure of the silicon

2. What characteristic of silicon allows for its anisotropic etch with KOH (or NaOH)?
   Answer: The crystalline structure of the silicon

3. What type of micromachining process does this activity simulate?
   Answer: Bulk Micromachining

4. What are the important safety procedures that must be followed when performing this experiment?
   The experiment must be performed under a fume hood.
   Latex or Nitrile gloves should be worn.
   Goggles should be worn.
   Always Add Acid to water, never the reverse.

5. This process is just one type of anisotropic etching. Some anisotropic etching occurs within a plasma etcher and affects a thin film on the surface of a wafer, thus being a "surface" micromachining process. However, the process you just performed is considered a "bulk" micromachining process. Explain why.
   Answer: This is a bulk process because it removes material from within the substrate or silicon wafer.