MESA DEVICES

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Research Conducted with Professor Nelson
Winter 2003

OBJECT

To study the effect of geometric affects on the bonding strength of MEMS components mesa strips will be fabricated, in the INRF, on the top of square quarter inch samples. The space between bars starts at 0.10 inches and divides by two each time. That is, 0.10, 0.05, 0.025, 0.0125, 0.00625, 0.003125. Correspondingly the number of bars double each time as 2, 4, 8, 16, 32, 64. The width of each bar is equal to the space between adjacent bars so that the center to center distance between adjacent bars is equal to twice the distance between the bars. While keeping the total area of the mesas constant, numbers of strips is varied by shrinking or increasing the dimensions of the strips. A mask set will need to be designed for the mesa array. These mesas of strips will be attached to a piece of glass with an adhesive material and the tensile and sheer strength will be measured. The glue contact area is 0.20 X 0.25 for the top contact on each bar set, or 0.05 square inches. The area on the single bar test coupon is 0.40 X 0.25 or 0.1 square inches. When the coupons are separated the approximate size is about 0.65 X 0.65 inches or 0.42 square inches. The ratio of the mounting area of the back of the coupon to the top of the coupon is about a factor of 8. In your tests super glue appears feasible both for mounting the glass to the coupon and mounting the glass to the stainless steel blocks. Multiple tests will be performed to check repeatability of the results.

Steps for manufacturing the Mesa Device:

1. Preparing Silicon Wafers.
2. Patterning substrates.
3. RIE (Reactive Ion Etching) etching.
4. Anisotropic Silicon Etching Using 30% KOH.
5. Cleaning glass using RCA cleaning.
6. Spinning adhesive material (Super glue) onto the glass.
7. Attaching the glass to the wafer.
8. Measuring the tensile and sheer strength.

1. Preparing Silicon Wafers.

Purchase 4 inch Silicon Nitride wafer ($33). Bare silicon wafer ($10) can also be used for this experiment, but for better result and to save time, silicon nitride wafer is much preferable. Buying Silicon Nitride wafer will skip the procedure of sputtering nitride on top of silicon wafer.

Soft mask for the quarter wafers was designed with Mr. Allen Kine generosity. For each quarter wafer masks, 2 different patterns of geometrically varied strips were

arranged in six evenly divided locations which will all be cut into each individual piece after desired patterns are produced.

To use quarter wafer masks, Silicon Nitride wafers need to be evenly divided into four pieces. Wafers are very fragile and may shatter if not properly cleaved thus they precautions should be taken. To prevent shattering the wafer, it is very important to break the wafer along the crystal plane. The crystal plane can be determined from the flats of the wafer. First divide the wafer in two pieces. Along the crystal plane by scribing a tiny crevice at the edge of the wafer with diamond scriber, then press hard the end of the scribed line while holding the opposite side. If appropriately pressed (with some practice), the wafer will crack evenly in two pieces. Break these wafers once more to produce four evenly dived quarter wafers.

2. Pattern Substrates.

Place the quarter wafer at the center of the spinner. Turn the vacuum on. Positive photoresist Shipley 1827 needs to be spun at 4000rpm with acceleration rate of 1020rmp for 30 seconds. These parameters may be adjusted by pressing F1 button of the spinner and modifying the program of the spinner. Using eyedropper, drop resist on the center of the wafer approximately covering 2/3 of the wafer. Close the lid and spin the spinner by pressing run button. Put hand over the hole of the spinner machine for better result. After finished spinning, turn the vacuum off and place the wafer on hot plate for ~ 20 seconds at 90^{o}C. If the resist is evenly coated bake the wafer inside the oven at 90^{o}C for 5 minutes. If the coating is not even, strip the photoresist by washing the wafer with acetone then rinsing with DI water.

Pattern deep channel mask using UV exposure (Karl Suss Aligner). Pull out the substrate tray from the aligner. Place the quarter wafer on the substrate holder and align the soft mask on top of the wafer. Push the small screw to initiate vacuum on the wafer, then push the tray back into position. . Tighten the substrate so that the mask and the substrate are in firm physical contact. Set the time for ~ 45 seconds and press the lamp button to activate the UV light source (do not look directly at light). When finished exposing, take the wafer out of Karl Suss Aligner and place it in to the wafer in a container of the developer solution (MF-319) and soak for 60 seconds. Mild agitation may be helpful. Rinse with DI water and blow dry with nitrogen gun. Inspect the wafer under the microscope. If the patterns look acceptable, put the wafer into the oven and hard bake at 120^{o}C for ~ 20 minutes. If the patterns are unacceptable, strip the photoresist with acetone then start over from the spinning procedure.

3. RIE Etching

The RIE process is used to etch silicon nitride using the plasma therm 790. Select the right chamber then vent the chamber. When the chamber is fully vented the monitor will indicate atmospheric pressure and the chamber top will pop open. Load the sample and pump the chamber to low vacuum. Edit the process file. For reference and for this experiment use following settings in the automatic mode for the silicon nitride wafers purchased in INRF:

- STEP 1 (Initial):
  - Base pressure = 1.0 * 10^{-2} Torr.
  - Hold time = 10 sec.
- STEP 2 (Stabilixation):
  - CF_4 = 24 sccm.
  - O_2 = 3 sccm.
  - Time = 1:30 min.
  - Pressure = 90 mTorr.
- STEP 3 (CF_4 etch):
  - Time = 10:00 min.
  - Pressure = 90 mTorr.
  - CF_4 = 24 sccm.
  - O_2 = 3 sccm.
  - Set point = 150W
- STEP 4 (Purge):
  - Time = 2 min.
  - Pressure = 80 mTorr.
  - Set point = 0.
- STEP 5 (Final Evacuation):
  - Time = 10 sec.
  - Pressure = 2.0 * 10^{-2} Torr.
- STEP 6 (Purge):
  - Time = 1 min.
  - Pressure = 80 mTorr.
- STEP 7 (Evacuation and Vent):
  - Pressure = 2.0 * 10^{-2} Torr.
  - Hold time = 20 sec.
  - Vent = Yes.

When done editing save if needed. Load the recipe which just edited then go to room W2331 and turn on CF_4 gas. Press "RUN" to start etching. When done the machine top will pop open automatically.

4. Anisotropic Silicon Etch Using 30% KOH.

KOH is a wet etching method which attacks silicon preferentially in the <100> plane. The KOH process takes ~ 1 hour to etch 40 microns. To prepare 30% KOH solution weight 1 part KOH pellets into a plastic beaker then add 2 parts of KI water (Ex: 100 g KOH with 200ml water). Mix the solution on hot plate until KOH has completely dissolved. Add 40 ml of isopropyl alcohol to the solution; this will increase the anisotropy in the etching. When the KOH solution is ready, heat the solution to ~ 80^{o}C, and then place the wafer into the solution using a wafer holder. Agitation of the KOH solution enables better etching performance. Usually magnetic stir is used to stir the solution. But in this experiment, lack of stir plate led in building a different apparatus to

stir the solution. I attached one end of the rubber tube to the nitrogen nozzle and on the other end of the tube, attached a glass tube. Then place the end with the glass tube into the KOH solution while gently increasing the flow of nitrogen gas thought the tube. The constant nitrogen gas flow generated bubbles into the solution and with different flow rates; I could control the agitation intensity to the solution. The substrates were etched for 20 minutes. After desirable depth has achieved, wafers were rinsed with acetone to remove the photoresist, and then rinse with DI water. Dry with nitrogen gun.

5. Cleaning glass using RCA cleaning.

RCA cleaning is performed to remove the organic residues and films from the glass. I used RCA-1 cleaning method where the decontamination works through the sequential oxidative desorption and complexing with H_2O_2-NH_4OH-H_2O. In preparing the RCA-1 solution; First 5 parts of water (H_2O) or 325 ml DI water was mixed with 1 part of 27% ammonium hydroxide (NH_4OH) or 65 ml NH_4OH and then heated to ~70^oC. When the appropriate temperature was reached, 1 part of 30% hydrogen peroxide (H_2O_2) or 65 ml of H_2O_2 was added to the solution. After 1 ~ 2 minutes, I soaked a holder full of 1 inch square glasses into the cleaning solution for 15 minutes. When finished, I transferred the holder into the overflowing DI water dish to rinse and remove the solution. Then the glass was dried with nitrogen gun.

6. Spinning adhesive material on the glass.

Yet to be experimented.

Suggested method:

- Put glue in warm water before applying it to the glass.
- Drop glue while spinning the glass.

7. Attaching the glass to the wafer.

Yet to be experimented.

8. Measuring the tensile and sheer strength.

Yet to be experimented.

Conclusion