

pn-junction fabrication @ MiNa-lab. Helge Malmбекk, 2010

Updated by Adrian Glaubitz - March 29, 2011

I. OXIDATION

- RCA 1-3 on wafers. 10-15 mins in RCA 1 and 3, and about 10 sec in RCA 2 (wait for hydrophobic behavior). Rinse in DI water between each step. Remember to heat RCA 1 and 3 to about 75°C[1]. RCA 1 = 5:1:1 of H₂O:NH₄OH:H₂O₂. RCA 2 = 50:1 of H₂O:HF. RCA 3 = 5:1:1 of H₂O:HCl:H₂O₂.
- 3 hrs dry oxidation with O₂ @ 1100°C gives about 250 nm SiO₂. Remember to turn the gas on 10-15 mins before loading the wafers. An N₂ flush before removing the wafers might lead to a better oxide interface, according to literature, but no significant differences has been observed. Wet oxidation is supposed to work even better for passivation, but this cannot be done in our lab at the moment.

II. OPENING HOLES IN THE OXIDE

- The backside oxide should be kept as a protective layer during the diffusion, to ensure that no dopants enter the backside. If implantation is used, the oxide at the back is not required but it doesn't hurt having it, too. To protect the oxide, standard photo resist procedures are followed by spin coating the backside and hard baking @ 120°C for about 15 mins.
- Standard positive photolithography process to open holes for oxide etch. Mask 1 (labeled with "Helge") is used with exposure @ 300W for 30 secs. These values might not be optimized, but seem to work fine. Developer needs to be 1:4 of Dev:H₂O or more concentrated. Must also be refilled during developing if many 4" wafers are used. Developing might take as long as 10-20 mins sometimes. Check in the microscope to see if it is completely developed. There should be a high contrast between the remaining photo resist and the exposed oxide. **NOTE: Do not forget to rinse the wafers with DI water and drying them with pressurized air before hard baking them. Remaining developer solution will ruin the photo resist during hard bake otherwise.**

- Buffered oxide etch (BOE) is used to etch the holes into the oxide. Etch rate is about 50-100 nm/min. Wait for hydrophobic behavior. As the backside is covered by photo resist, it might be wise to test the etch rate on a similar oxide thickness to ensure that the etching time is long enough[2]. The photo resist should not be affected by the etch. Always used plastic containers and tweezers when working with HF solutions.
- When the etching is complete, the photo resist is removed by rinsing in acetone for a few minutes. As the primer and residual photo resist is hard to remove by RCA 1, a Piranha etch is used to remove all organics. Piranha etch = 3:1 of $H_2SO_4:H_2O_2$. Be careful when mixing these chemicals, as they generate a lot of heat and fume when mixed. Metal tweezers must be used in this solution as it eats everything that is organic.
- RCA 1-3.
- Wafers should now be put in an appropriate clean container for transport to a diffusion furnace or are ready for implantation.

III. IMPLANTATION OR IN-DIFFUSION

- Standard emitter formation process is used.
- When using implantation, do NOT forget to activate the wafers before proceeding. Activation is performed by annealing the wafers at $900^\circ C$ in the furnace labelled "For Si annealing only". A sufficient flux of Nitrogen is required during activation to prevent further oxidation. Activation takes approximately 30 minutes. Activation must **NOT** be performed when a metal layer has already been deposited onto the wafer as this will contaminate the furnace.

IV. CONTACTING THE DIODES

A. Preparing for Evaporation

- RCA 1-3, with a bit longer time on RCA 2 (about 30 secs) in order to completely remove the oxide layer that has been formed during the diffusion process.
- To remove the backside oxide, standard photo resist procedures are followed by spin coating the front side and hard baking @ $120^\circ C$ for about 15 mins.

- BOE etch to remove the backside oxide.
- Acetone to remove photo resist and Piranha etch to remove organics.
- RCA 1-3 to clean wafers before metalization.
- Load wafers into thermal evaporator for deposition of about 200 nm Al film.

B. Thermal Evaporation

- First, pressurize the chamber by opening yellow valve at the side of the chamber, then open the lid and remove the whole glass tube of the chamber.
- Attach proper filament to the clamps, be sure to use a filament which has been used for the same material you are going to evaporate otherwise the wafer might become contaminated. Cut of 4 pieces of aluminium wire of approximately 2 centimeters length and tie them around the filament.
- Attach wafer to the holder plate with adhesive aluminium tape and attach the holder plate to the center rod.
- Replace the glass tube. Adjust the aluminium foil in the tube such that a small transparent spot is opened. This will serve as a control for the evaporation process as the evaporant will resublimates on the glass surface. Place the the upper aluminium foil over the glass tube, then close the lid.
- Turn on the red mains switch at the right side of the evaporation unit, depress "Pumping Unit" to commence pumping of the chamber. It may take up to 45 mins before a desired pressure of 3×10^{-5} mbar will be established.
- Turn on the quartz micro balance (QMB) and calibrate the zero using the adjustment knob on the right side of the control device of the QMB. Use the "100x" range for a coarse adjustment, then switch to the "1x" range for the fine adjustment. Note that the range for the zero is quite narrow.
- Adjust the proper density for the evaporant. The display reads "XX.X" cm^{-3} .

- Flip mains switch to the right, then to the left to turn on the filament power. Slowly increase the filament current with the adjustment knob to commence the evaporation process. The increasing of the current should be performed very carefully as to not evaporate all of the evaporant at once due to a power surge. Also, the reading on the power knob should not exceed "5" as an overcurrent will destroy the filament.
- Once the target thickness has been reached, turn down the filament current.
- Make an entry to the log book.
- Turn off the pumping by depressing "Pumping Unit". Wait for the chamber to be vented. This will be indicated by an opening and closing of the inlet valve.
- Open the valve manually and open the chamber. Remove wafer, clean the chamber and re-assemble it.
- Close the chamber, turn on the pumping unit again and let it pump for approximately 30 seconds, then turn off the the evaporation unit with the red mains switch at the right side.

C. Etching of the Contacts

- Positive photo lithography with mask 2 and **NO PRIMER!!** The primer will make development impossible, as it sticks very well to Al. It is important to get the alignment correct as shown in Fig.1. Exposure @ 240W for 8 secs. Developer must be 1:6 or lower. Risk of developing non-exposed regions.
- Al etch in 16:1:1:2 (H₃PO₄:HNO₃:Acetic acid:H₂O) @ 100°C. Very fast etch.
- Wash with acetone and DI water.
- The structure should look as in Fig.2. Time for testing of whole wafer in the probe-station.

V. FINAL NOTES

This process works very well for low resistivity substrates, but for high resistivity p-type substrates the substrate-oxide interface provides a huge leakage current. It was found that removing the oxide while keeping the middle part of the Al contact provided good diodes in these circumstances. This was done by spin coating the diodes with the primer - putting a droplet of photo

resist on the Al contact - Hard baking - Al etch to remove the edges over the oxide - BOE etch to remove the oxide - Rinse in acetone.

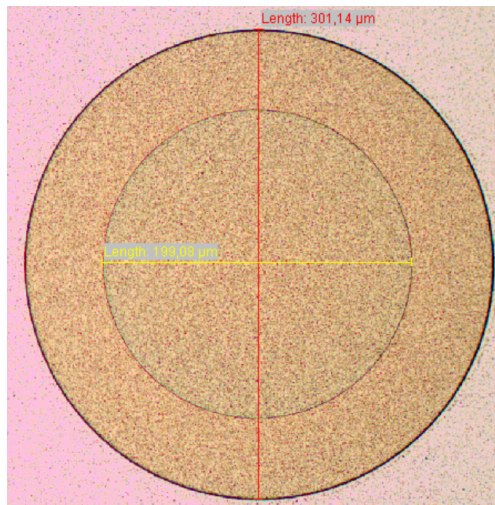


Figure 1: Microscope image of the finished structure, showing good alignment.

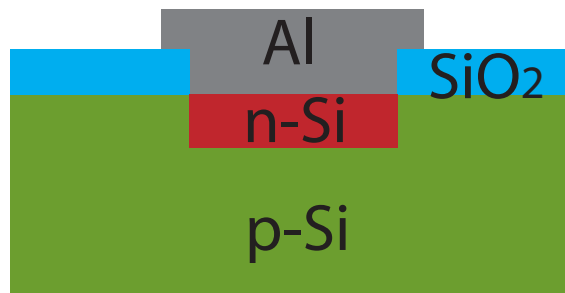


Figure 2: Finished structure

[1] Set the hot plate to 100°C

[2] 5-10 mins should suffice for a proper etching process, however