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Alignment of Metal Electrodes with Optical Fibers

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The field of fiber optics is becoming an increasingly important field to the world of communications. With increased use of optical fibers for communication comes the need for devices to use with the fibers. I have been working on the creation of an in-fiber electro-optic modulator. Earlier I worked on a process of creating a waveguide in the fiber that will allow for modulation. This process involves removing a section of the core of a D-shaped fiber and replacing it with a non-linear polymer. I used a chemical etch to remove the core and then used a method of spinning to fill the region with a polymer. This needed to be done in a way that would maintain low loss of power.

The next step was to put electrodes onto the fiber. The electrodes need to be put directly on the fiber, which is about 120 µm wide. They need to be aligned such that they are parallel, with the core of the fiber between them. In order to do this, we needed to be able to perform photolithography on the fibers.

For this project I worked on a way to align the fibers in a way that photolithography can be done on them. A wafer with V-grooves in it had already been produced in the lab. My task involved finding a way to put the fibers in the grooves such that they are straight, with the flat side of the fiber exactly up. This positioning is needed in order to perform photolithography and to align the electrodes with the core of the fiber.

I worked on making a key structure out of a glass slide that could be used to press the fiber into position in the V-grooves in the wafer. The key structure has ridges that match up with the grooves in the wafer. The ridges need to be the right height to press against the flat side of the fiber and hold it in the correct position.

To create the ridges on the slide, I tried using a wet etch process. In this process, a layer of photoresist is put on the slide. It is exposed using a mask that allows ultraviolet light to penetrate the resist everywhere except for lines going across the slide that match the V-grooves of the wafer. The resist is developed, and the resist is washed away in the areas that were exposed to the ultraviolet light. The remaining resist is then used as a mask to etch the glass in a chemical etch. The chemical etch leaves ridges where the lines of resist are.

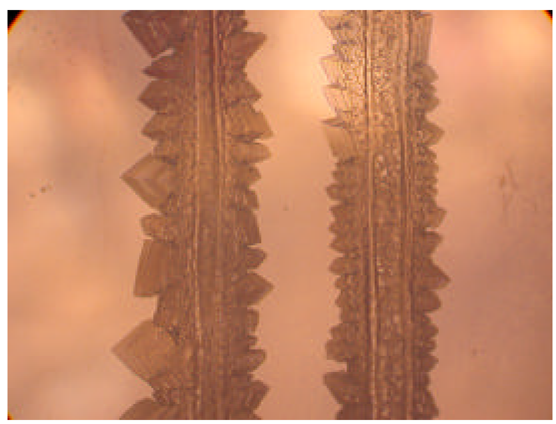
The first obstacle was getting the resist to stick to the glass slides. There were established processes for applying the resist to silicon wafers, but it was harder to get it to stick to the silicon dioxide slides. First of all the slides needed to be cleaned well. I used acetone and isopropyl alcohol to clean off the slides. Then I baked them on a hotplate at 100°C for one minute in order to remove any moisture from the slides. I taped the slides to silicon wafers in order to spin on the resist. First I spun on an adhesion promoter, HMDS. Then I spun on the resist. There were two different resists available for me to use: Shipley 812 and AZ 3312. I had an easier time getting the Shipley 812 resist to stick to the slides.

By changing spin speeds, exposure times, and development times, I was able to get a combination that worked for getting the resist to stick to the slides. I used a spin speed of 4000 rpm, an exposure time of 38 seconds, and a development time of one minute. Using this process I was able to get good, clean lines of resist on the slides.

The next obstacle was the etching of the glass. Buffered oxide etch(BOE) is used to etch silicon dioxide. I baked the slides with the resist masks in an oven at about 100-110°C for a half an hour to hard bake the resist. Otherwise it would come off right away in the BOE. Then I tried dipping the slides in the BOE. By doing this for five to ten minutes, I was able to get some nice clean ridges that were about 3-7 µm tall. I needed ridges around 15-20 µm tall. When I tried etching longer, I ran into problems. The ridges became messier, and the resist started coming off the slide.

I did some research on etch processes for glass and found some that used BOE and hydrochloric acid(HCL) to get a smoother etch. I experimented with different ratios of BOE and HCL, but I did not get anything that worked. The resist lifted off even worse than before, and the ridges were quite rounded. The ridges were more clearly defined, but they were rounded instead of flat on top. I need the flat top to hold the flat part of the fiber in place. The ridges also remained short, the tallest being about 4 µm.

So I have not been able to get good clean ridges for a key structure. I can get clean ridges that are too short and messy ridges that approach the right height. The following pictures show two sets of ridges, as seen through a microscope. The first picture shows two clean ridges that are too short. The second picture shows ridges that are taller, but not really suitable for the key structure.



While I was working on this process, someone else was trying a different way to put the electrodes onto the fiber. He was able to pattern metal electrodes onto the fiber, aligned with the core of the fiber, without using the key key structure. Since he was able to do it, we decided not to pursue this process anymore. The next step is to put the electrodes onto a fiber with the polymer waveguide in the core.