Pressure Sensor Membrane Design & Fabrication using Photo Electro-Chemical Etching on Thin Film & Bulk SiC

Richard A. Castillo, Advanced Materials Engineering Research Institute (AMERI), Mechanical & Materials Engineering Dept., Florida International University

NNIN REU Site: Howard Nanoscale Science & Engineering Facility, Howard University

NNIN REU Principal Investigator: Dr. Gary L. Harris, PE, PhD, Electrical Engineering, Howard University

NNIN REU Mentor: James Griffin, Sr. Research Associate, HNF, Howard University

Contact: rcast001@fiu.edu, gharris@msrce.howard.edu, griffin@msrce.howard.edu

Abstract:

Photo-electro-chemical etching (PEC) is a method that can be used for bulk micromachining in which a material is electrochemically etched using UV radiation and an electrolyte etching solution such as hydrofluoric acid (HF) or potassium hydroxide (KOH). This will be the targeted method for the machining process of silicon carbide (SiC) in order to create a defined structure to be used for pressure sensing. PEC has been chosen since the process generates highly anisotropic, selective and very smooth etch morphologies, perfect for pressure sensor diaphragm design.

This project will be limited to: (1) characterizing the etching rates of such processes including the introduction of different etching solutions/electrolytes, and (2) studying the interaction and behavior of defect densities and micro pipe presence during SiC etching. The quality of the PEC process is very dependent on the amount/densities of such defects within the SiC material. The proposed sensor has been chosen to be part of a pressure sensing device that could be implanted within the human body.

Because SiC has a wide bandgap, is chemically inert, and possesses a very high Young's modulus, it is an ideal material that can withstand the temperature, reactivity and stresses within several regions of the human body.

Introduction:

In the field of biotechnology, pressure sensors have gained notoriety because of their ability to perform in very remote, sensitive and very harsh environments.

Measuring *in-situ* blood pressure on vascular tissue brings all of these challenges to the design board, and the use of specific materials is crucial for efficient sensor functionality. With this in mind, a proposed blood pressure sensor membrane will be fabricated of silicon carbide (SiC). Silicon carbide, a compound material mainly composed of silicon and carbon, is a synthetically made material and has over 200 polytypes. This material has mechanical properties similar to diamond, has a wide-bandgap which allows for high temperature operation, and is very chemically resistant.

Given these and many other physical and chemical properties of SiC, we used the 3C-SiC polytype for our membrane design. This polytype has the highest carrier mobility (~600-1000 $cm^2 \bullet V^{-1} \bullet s^{-1}$), which is perfect for our chosen method of fabrication using photo-electro-chemical (PEC) etching. This method of micromachining is a relatively easy way of machining silicon carbide.

Experiment:

Within our project, both bulk and surface micromachining were attempted using the PEC method. Using the principle of EHP (electron-hole-pair) generation, we used a UV source to excite the surface of the SiC. Excess holes or electrons are created in the sample by the UV light. By applying a bias through the solution, the SiC will etch through an oxidation reduction process. For this project hydrofluoric acid (HF) was chosen as our main electrolyte solution. The HF electrolyte concentration was varied with high concentration levels providing fast etch rates and good surface morphology. Figure 1 shows the diagram of the setup used in this project to perform the PEC etching.

Even though previous experiments have been per-

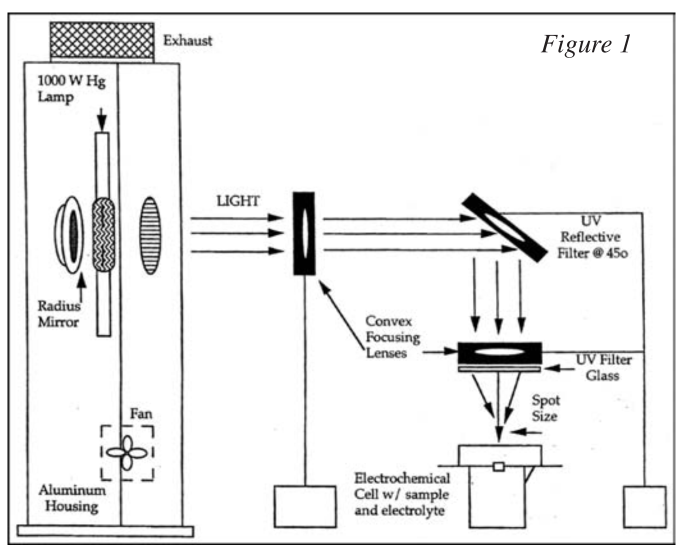
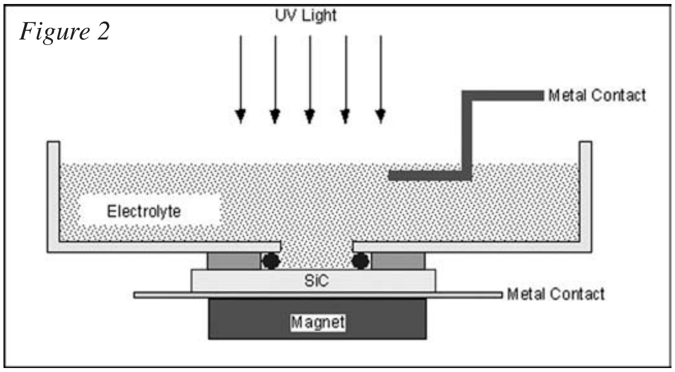


Figure 1



formed with more powerful lamps, we used an existing 200W USHIO mercury vapor lamp we had on hand.

The UV light is focused and reflected with high reflectivity mirrors and lenses onto a spot on a custom built electrolytic cell where the sample is mounted and the electrolyte solution is making contact with it. Figure 2 shows a similar schematic of the custom built cell. Instead of using a spring-loaded screw, in our experiment we used a magnet to attach the sample sandwiched between a metal washer and o-ring to prevent electrolyte loss. The diagram illustrates how the wafer is being exposed to the solution on the top side while being held against the cell with a magnet. The back side of the substrate has an ohmic contact metallization which was evaporated by electron-beam evaporation. The purpose of the ohmic contact was to improve electrical contact between the wafer and the back electrode. Photolithography was employed to create the patterned membrane on the top surface. We also used wax as a mask for etching.

Results and Conclusions:

Photolithography provided limited success because it was attacked by the electrolyte. We had much better success with the wax because it was very resistant to HF and other etchant attacks during PEC. The HF was an excellent electrolyte for this experiment. We obtained etch rates as high as 1 μm/min for SiC and even higher rates were obtained for silicon. This PEC process is an ideal method for SiC MEMS sensor applications. Etching rates were first established for silicon for various concentrations of HF solutions. The etching process was then performed on bulk SiC and then on epitaxial SiC (~5 μm thick) on a Si substrate.

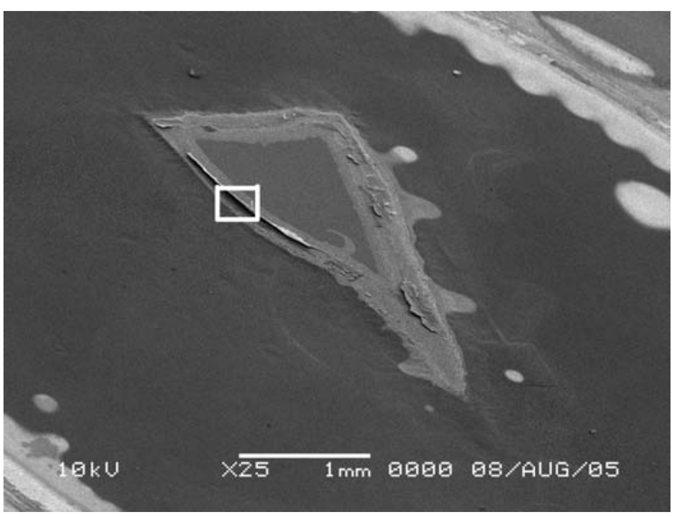
Figure 3 shows one of the etchs done on a thin film of 3C-SiC. It can be seen how the 3C-SiC thin film started to delaminate from the Si substrate. This is the initial step in the fabrication of the thin film membrane for our sensor application. A complete SiC blood pressure sensor mask set was developed and will be fabricated.

To conclude, we have seen that by using this method we have acquired high etching rates, good stop-etch selectivity according to the doping of materials, and the ability to electro-polish the substrates for further processing. It was also found that we do not need high concentrations of etching solutions. This by itself has a lot of implications regarding the decrease in costs from safety to manufacturing and machinery costs.

All of these findings have shown that further optimization of this process is very attainable, not only for sensorial applications but for other MEMS related devices.

Acknowledgements:

I would like to thank Prof. Gary Harris, Ph.D., Mr. James Griffin, the NNIN and the NSF for their contributions in making this opportunity a rewarding experience in my career as a mechanical engineering student and a professional.



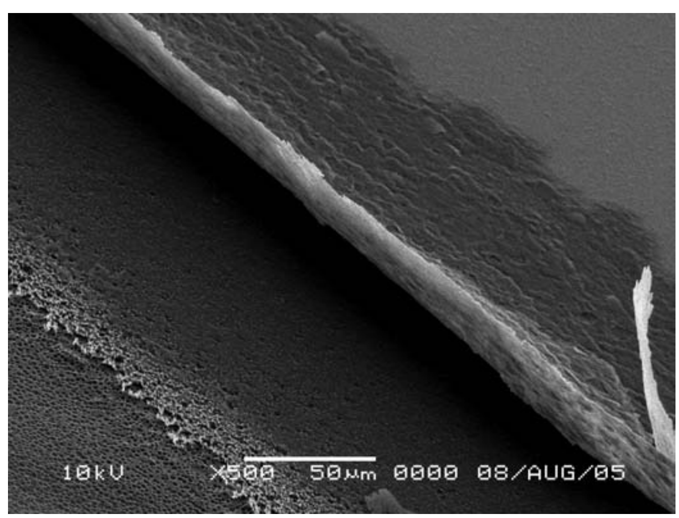


Figure 3: Figure on right is close up of boxed area on left.