Characterization of Etching Techniques on SiC for High Temperature MEMS Applications

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Abstract:

The objective of the project was to examine the strengths and limitations of two etching methods of silicon carbide (SiC). The methods being investigated were reactive ion etching (RIE) and photo-electro-chemical etching (PEC). Reactive ion etching of SiC was done using SF_6/O_2 and SF_6/Ar gas. The gas ratios and etch rates were evaluated. Surface morphology characterization by atomic force microscopy (AFM) was also performed on samples using both methodologies.

Introduction:

Silicon carbide (SiC) possesses characteristics such as high mechanical hardness, chemical inertness, large band gap, high thermal conductivity, and electrical stability at temperatures well above 300ºC, making it very attractive for high temperature micro-electro-mechanical systems (MEMS) applications. In order to create a SiC MEMS, the SiC must be etched. Some of the same properties that make SiC desirable for MEMS also limit SiC to certain etching techniques.

Procedure:

All RIE was done in a reactive ion etcher. After using photolithography to deposit a test pattern, a 1,000Å mask of Ni was evaporated on top of 200Å of Ti in order to protect the areas where etching was not desired. The thin layer of Ti was used because of its adhesive properties which allowed a successful liftoff. The chamber pressure was constant at 10 mTorr, time was constant at 30 minutes, and RF power was constant at 400W. While the gas flow ratio was changed, the total gas flow into the chamber was 50 sccm. Testing was done using a combination of SF_6/O_2 from 0:50 to 50:0 ratios increasing by 5 sccm. The same was done using SF_6/Ar.

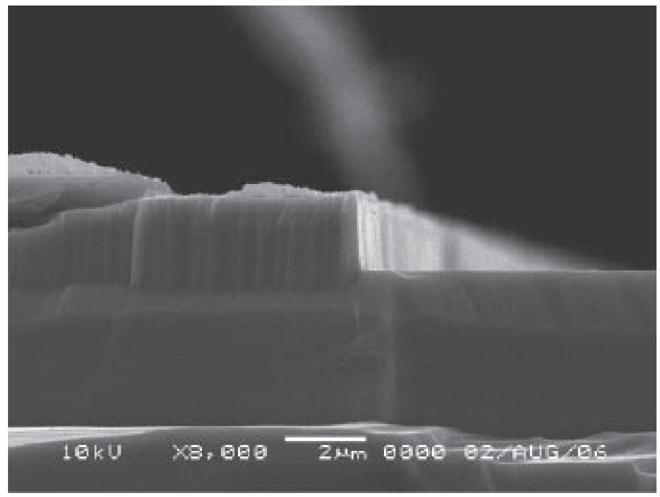

Figure 1: Vertical sidewalls produced by RIE.

All PEC etching was done using an inexpensive set up. Inside of a container, electrical contact was made between the sample and a counter electrode. A 10% concentration of HF was then added into the container covering the sample. A potential difference of 10V was then added. Since the 6H-SiC samples were n-type, the actual oxidation and reduction process could not take place until a UV light was introduced at 1000W.

Results:

Using RIE, we obtained etch rates as high as 900Å/min using SF_6/Ar at a 10:40 sccm ratio. All SF_6/Ar combinations yielded smoother surfaces compared to the SF_6/O_2 combinations. RIE also produced vertical sidewalls between the etched and unetched areas as seen in Figure 1.

PEC etching yielded etch rates as low as 350Å/min. The surface of the PEC etched SiC was very porous as seen in Figure 2. It was also fairly rough compared to the RIE surfaces.

Conclusions:

We found that the maximum etch rate was obtained using an RIE etch with the SF_6/Ar combination at 10:40 sccm ratio. It was also determined that an reactive ion etch of SiC yields a smooth uniform surface compared to a rough, porous PEC etched SiC surface as seen in Figures 3 and 4. It was also observed that RIE etching of SiC produces vertical sidewalls, while PEC etching of SiC produces an undercut under the unetched area.

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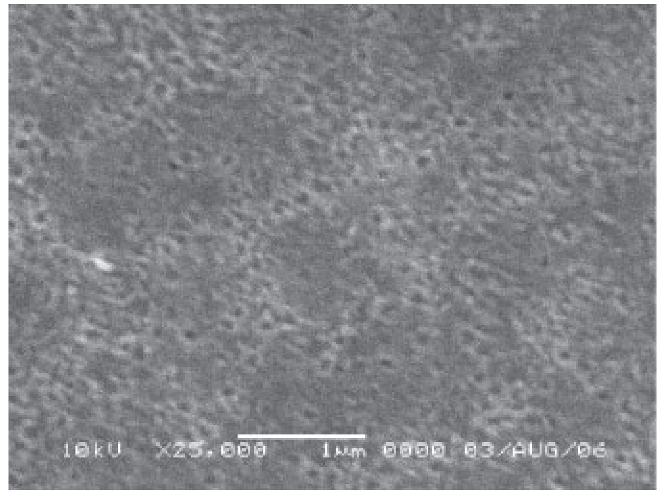

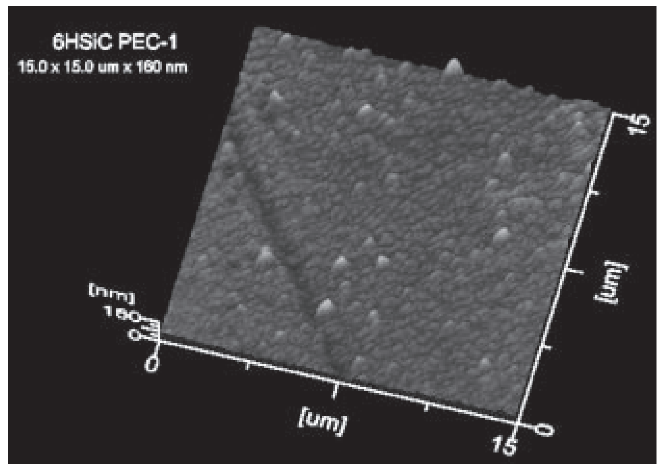

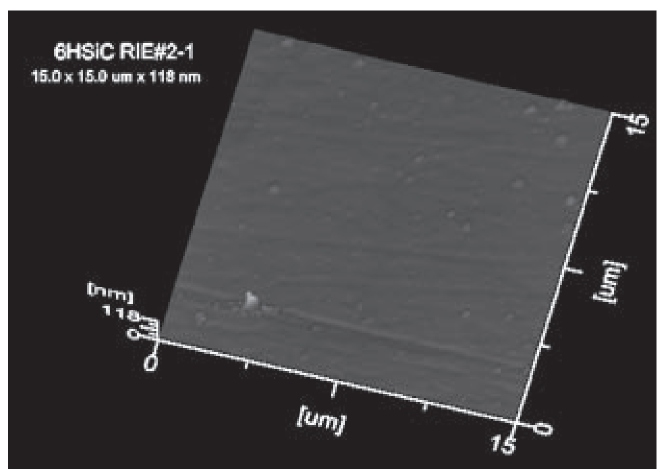

Figure 2, top: An illustration of the porous 6H SiC surface after PEC etching.

Figure 3, middle: Fairly rough 6H SiC surface after PEC etching.

Figure 4, bottom: Uniformly smooth 6H-SiC surface after RIE.