Electropolishing of n-type polycrystalline 3C-silicon carbide

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Silicon carbide has become in recent years a very promising and interesting material for microsystem technology. It shows in fact highly desirable properties for hash environment applications, such as extreme chemical inertness, high thermal resistance, excellent wear resistance and low friction. Its chemical robustness, however, makes quite hard to perform machining and patterning processes with those methods commonly used with silicon. It's well known in fact that etching of SiC is a very difficult process, often requiring high process temperature or very aggressive conditions that can be an issue for some kind of applications [1-5].

In this perspective, electrochemical etching of SiC can be a valid solution, being an inexpensive, simple process carried out at room temperature. Moreover, electrochemical etching is feasible after the fabrication of junctions or ohmic contacts on SiC.

Our work focuses on the application of electrochemical etching to polycrystalline SiC with the specific aim of surface polishing and roughness reduction, in order to produce flat surfaces with reduced adhesion and friction characteristics. Such properties can be critical for microsystem applications, whose performances are often affected by stiction phenomena.

One of the major novelties of our work is the choice of n-polycrystalline 3C-SiC as investigated material. Up to now, in fact, available literature on electrochemical polishing of SiC mainly concerns monocrystalline 4H or 6H SiC, which may find only a limited use in microsystem applications. Polycrystalline SiC, instead, is considered the leading material in current MEMS technology.

For our work, we use 4-inch wafers of n-type polycrystalline 3C-SiC layer deposited on a silicon substrate, cut in small square-shaped samples. Electrochemical etching is performed under galvanostatic conditions in a two-electrode cell containing aqueous solutions of HF, with concentrations ranging from 0.5% to 2% by weight. Silicon carbide acts as working electrode; platinum is used as counter electrode.

In our electrochemical etching experiments, we vary experimental parameters such as etching current density, HF concentration and etching time in order to assess the optimum values providing the best polishing effect.

Etching current density is investigated in the range 1 mA/cm^2 – 10 mA/cm^2, tested etching times are 30, 60 and 120 minutes.

Surface roughness is measured before and after the etching treatment by means of AFM. Initial roughness value is 17.3 nm, while the final value is found to be mostly affected by the applied etching current density. Other experimental parameters show to have a minor effect on surface roughness variation.

We successfully achieved surface polishing etching at 1 mA/cm^2, 2 mA/cm^2 and 10 mA/cm^2, in HF 1% wt. for 30 minutes. In particular, etching at 10 mA/cm^2 provides the highest roughness reduction, being final roughness value 8.3 nm, less than one half with respect to the initial one.

On the contrary of what stated in the case of n-type monocrystalline SiC, there was no need to illuminate samples with UV light in order to perform electropolishing on n-type polycrystalline SiC.

Images of sample surface acquired by SEM show a smoother, flatter and featureless surface after electropolishing compared to the untreated one.

No intergranular corrosion or other degradation phenomena related to the polycrystalline structure was observed on etched samples, and no preferential sites for material removal can be recognized on the surface.

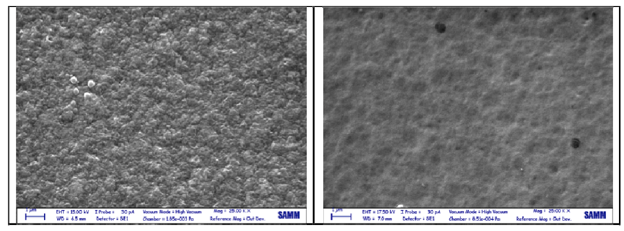

Figure 1: SEM images of polySiC surface before and after etching at 10 mA/cm^2 in HF 1% for 30 min.

Average surface potential was also investigated by means of Kelvin probe force microscopy (KPFM) on samples etched at 1 mA/cm^2 and 10 mA/cm^2; measured values are 0.055 V and 0.029 V respectively. In the case of untreated sample, obtained value is 0.196 V, indicating a decreasing trend for average surface potential after electropolishing treatment.

We demonstrated that electropolishing in HF-based solutions is a suitable method to effective reduce surface roughness of n-type polycrystalline 3C-SiC. Compared to that applied to monocrystalline SiC, this process requires lower current density values and no need of UV illumination, and it provides smooth and polished surfaces.

References

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