Silicon carbide surface micromachining using plasma ion etching of sacrificial layer

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The perfectly-defined micrometric shapes patterned by optical lithography and selective etching seems to be a crucial step in fabrication of high voltage and MEMS devices. Wet chemical etching, reactive ion etching and chemical-mechanical processing are widely used in the semiconductor industry to achieve the required shape of the surface. The processes are well understood and successfully applied for resists or silicon oxide layer patterning [1].

High hardness and chemical stability of silicon carbide (SiC) make the etching process more difficult in comparison with other substrates processing. The shape of the etched junction termination extension (JTE) region for SiC devices often determines the breakdown voltage and reliability parameters simultaneously. Furthermore, in terms of total cost of the process simpler method of the pattering the shape of refractory materials is required. Additionally, the processing of commonly used materials such as photoresist film or deposited oxide layer by optical lithography ensures high resolution and repeatability.

In this paper we contribute to the processing methods by using a new approach define the required surface shapes. We have demonstrated the transfer of geometric shapes on top sacrificial layer to bulk SiC material using Reactive Ion Etching (RIE) and Inductively Coupled Plasma (ICP) process. The work introduces the optimization hints to assure the etch selectivity ratio 1:1 for various materials. It appears that the optimized processes lead to satisfactory selectivity ratio and make possible the transfer of sacrificial layer surface to bulk material. The idea of the process is schematically illustrated in figure 1.

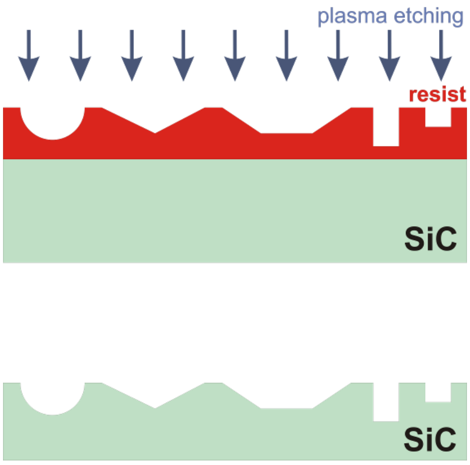


Fig. 1 The basic idea of surface shape transfer.

Unfortunately, it is not possible to obtain such etching conditions that can lead to transfer to the selectivity ratio of 1:1 in the case of resist and silicon carbide using available equipment (STS ICP DRIE from SPTS Technologies). Therefore, an additional layer of silicon dioxide was used for this purpose. The roughly the same etching rate was obtained for silicon carbide and silicon low temperature oxide (LTO) under the same process conditions. The results of our investigation are presented in figure 2 to confirm the usefulness of technology.

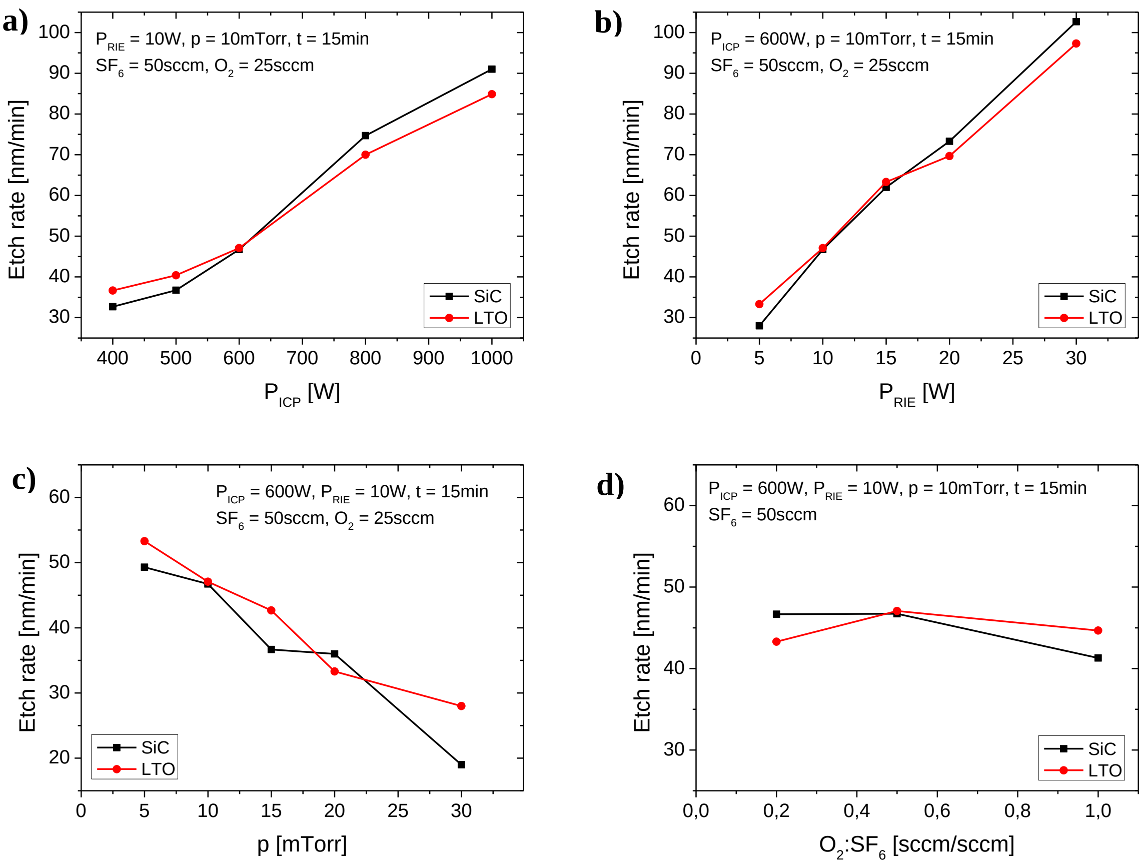


Fig. 2 Etch rate of the LTO and SiC as a function of power, pressure and gas ratio.

The concept of the surface shape transfer was used as a planarization of silicon carbide surface. Photo-benzocyclobutene-polymer resist (BCB) was used for this purpose. The BCB polymer has excellent smoothing ability on the coated surface (fig 3) [2].

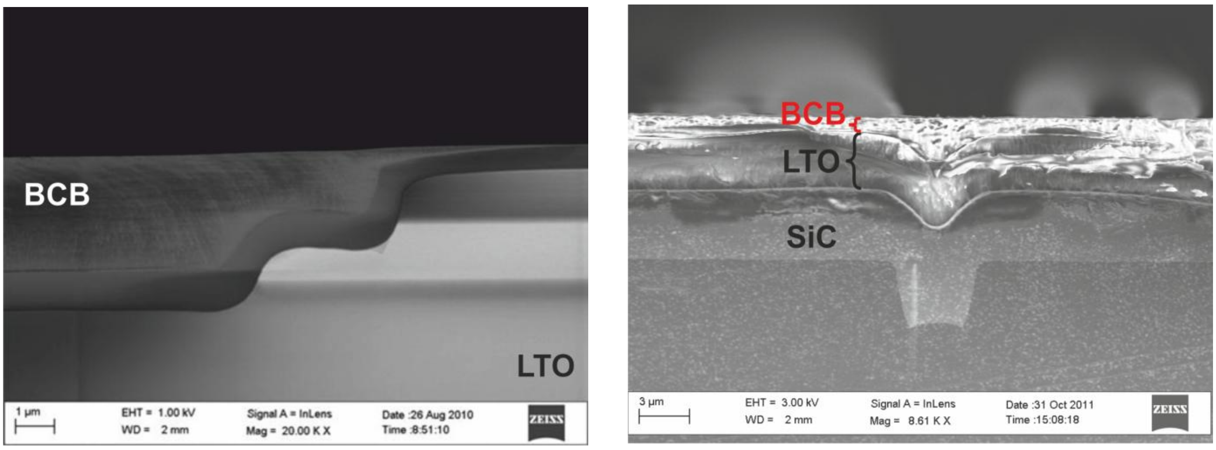
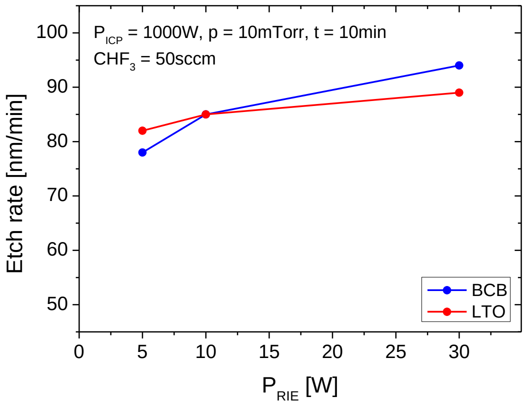


Fig. 3 SEM images of the BCB coated surface.

General idea is to transfer the flat surface of BCB to LTO and then to bulk SiC as it is shown in figure 4. In this approach it is very important to keep exactly the same etch rate for different materials. We have developed the ion etching of photo-benzocyclobutene-polymer resist (BCB) and silicon low temperature oxide (LTO) having roughly the same etch rate for the same process conditions. The results of our tests for BCB and LTO etching are presented in figures 5.



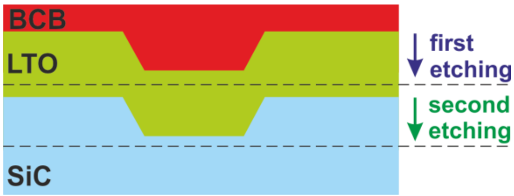


Fig. 4 Flat surface transfer idea.

Fig. 5 Etch rate of the BCB and LTO as a function of power.

Finally, we have developed technological process of plasma etching of various materials at the same etch rate. The primary shape can be transferred from the surface of one layer to another. One of the application is a planarization of SiC material using plasma etching.

References

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