High Aspect Ratio Micromachining of Silicon Carbide for Microthruster Applications

Karen Dowling, Elliot Ransom, Debbie Senesky
Extreme Environment Microsystems Laboratory, Department of Aeronautics and Astronautics, Stanford University

Background

Silicon carbide (SiC) has been proposed for use in a variety of harsh environment applications due to its temperature tolerance and inertness. SiC is a promising structural material for catalyst beds in monopropellant microthrusters, where chemical erosion poses a design challenge [1]. The hardness of SiC makes the fabrication of high aspect ratio (HAR) SiC structures difficult. This study examines the manufacture of HAR trenches in SiC using an inductively coupled plasma (ICP) etch process and presents the highest aspect ratio SiC trench yet realized [2].

Motivation & Approach

ICP etching is a promising processing technique for SiC due to its anisotropy and relative simplicity. This study aims to characterize ICP etching of HAR trenches in SiC in two ways:

- As a function of aspect ratio (AR), with different trench geometries using an inductively coupled plasma (ICP) etch process and presenting the highest aspect ratio SiC trench yet realized [2].
- As a function of ICP process parameters. ICP chamber pressure, ICP chamber pressure, and oxygen gas fraction are examined, specifically.

The examination of ICP etching of trenches under these conditions is an important stepping stone to the reliable manufacture of microthruster geometries in SiC.

Materials and Methods

Fabrication was performed on 4H-SiC samples purchased from CREE Inc. and sized as 1 cm x 1 cm dies.

The dies were first patterned with a 50 nm evaporated gold seed layer using a liftoff process. A nickel mask was then electroplated through a Watts bath at room temperature for 15 minutes. The mask contained arrays of channels of varying widths from 2.5 to 100 microns.

The SiC dies were etched using a Plasmatherm Metal Etcher (PT-MTL). Samples were etched using a sulfur hexafluoride plasma with oxygen additive gas.

After etching, the surface metals were removed using standard wet etch chemistries. The etched samples were then cleaned with a diamond scribe, cleaned with isopropanol alcohol, and imaged with a scanning electron microscope.

Two types of experiments were conducted. In the first, five SiC dies were etched at once in the PT-MTL. Samples were then removed at 15, 30, 60, 90, and 180 minutes to capture the evolution of the trenches as a function of aspect ratio.

The second set of experiments was conducted by varying the three most critical etch parameters: chamber pressure, oxygen mass fraction, and ICP bias power. The etch rate as a function of pressure is best characterized by two competing effects. At low pressure, a pressure increase results in a decrease in etch rate due to a decrease in the mean free path of the ions in the plasma. At high pressures, the etch rate is shown to be more sensitive to oxygen gas fraction.

ICP etching is performed across a large ICP parameter space, and a consistent pattern of evolution in the fabricated trenches was observed. No microetching was observed for aspect ratios less than 1, after which low aspect ratio trenches were observed to develop. These trenches converged at aspect ratios greater than 7, forming a characteristic 'V' shape that was observed in trenches with aspect ratios as high as 18.5, the highest aspect ratio reported for a SiC trench [2].

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Bibliography


Further Information

The Extreme Environment Microsystems Laboratory (XLab) can be found at http://xlab.stanford.edu/.

Conclusions

ICP etching of SiC was performed across a large ICP parameter space, and a consistent pattern of evolution in the fabricated trenches was observed. No microetching was observed for aspect ratios less than 1, after which low aspect ratio trenches were seen to develop. These trenches converged at aspect ratios greater than 7, forming a characteristic ‘V’ shape that was observed in trenches with aspect ratios as high as 18.5, the highest aspect ratio reported for a SiC trench [2].