SiC etching using heptafluoroisopropyl methyl ether plasmas

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Abstract: In this study, heptafluoroisopropyl methyl ether (HFE-347mmy) plasma with a low global warming potential (GWP), as an alternative to SF_6 with a high GWP, was used to etch SiC. Under a source power of 400 W, the etch rate of the HFE-347mmy/O_2/Ar plasma was faster than that of the SF_6/O_2/Ar plasma. Under a source power of 500 W, the etch rates were similar. However, under a source power of 600 W or above, the etch rate of the SF_6/O_2/Ar plasma was faster than that of the HFE-347mmy/O_2/Ar plasma. And the etch rates of the SF_6/O_2/Ar and HFE-347mmy/O_2/Ar plasmas were similar despite changes in the bias voltage.

Keywords: plasma etching, heptafluoroisopropyl methyl ether, silicon carbide, global warming potential

1. Introduction

Compared to silicon (Si), silicon carbide (SiC) has a wider band gap (2.43–3 eV) and a stronger electrical energy barrier, facilitating its applications across a wide temperature range [1]. In addition, it has high chemical and physical stability due to the strong binding energy between Si and C (4.3 eV), so it can be used in extreme conditions such as high-temperature environments or environments where high currents of 20 A or more are supplied [2, 3]. Thus, SiC has excellent chemical and physical properties and can be used in a wide range of applications as a base material for semi-conductors [4].

Typically, SF_6, CF_4, CHF_3, and NF_3 are mainly used as etchant gases for SiC etching. These gases, however, need to be replaced because they have a high global warming potential (GWP) compared with CO_2 and a long lifetime in the atmosphere, which is harmful to the environment. Although previous studies have been suggested alternative etchants with a lower GWP for SiO_2 etching [5, 6], there are few prior studies on SiC etching. Therefore, developing an etching process with a low GWP for SiC etching is essential.

Among several alternatives, hydrofluroethers have advantage of low GWP and containing oxygen in their molecular structure. Moreover, hydrogen in the molecular structure reacts with hydroxyl radicals in the atmosphere and is easily decomposed. Because of these point, hydrofluoroethers are attracting attention as an alternative etching material.

In this study, SiC were etched in heptafluoroisoporpyl methyl ether (HFE-347mmy)/O_2/Ar plasmas, a type of hydrofluroether. The source power and bias voltage for the HFE-347mmy/O_2/Ar and SF_6/O_2/Ar plasmas was changed to compare their etch rates. The etching charactersistics of the HFE-347mmy/O_2/Ar and SF_6/O_2/Ar plasmas were analyzed based on the F radical emission intensity, thickness of the fluorocarbon film, and surface composition after etching.

2. Experiment

Plasma etching of SiC was conducted in an inductively coupled plasma (ICP) system. HFE-347mmy exists as a liquid at room temperature since HFE-347mmy has a boiling point of 29 ℃. So, it was used in a canister. To vaporize HFE-347mmy, a heating jacket was heated to 75 ℃.

The total flow rate was 15 sccm. The flow rates of HFE-347mmy/O_2/Ar and SF_6/O_2/Ar were 3/7/5 sccm. The pressure in the chamber was 30 mTorr, and the substrate temperature was 15 ℃. The source power was changed from 400 to 700 W for the measurement of the etch rate as a function of source power with bias voltage of −500 V. The bias voltage was changed from −400 to −700 V for the measurement of the etch rate as a function of bias voltage with source power of 500 W.

The types and relative amounts of radicals within the plasma were identified by measuring the wavelength of the light emitted using optical emission spectroscopy (OES) (ULS2048, Avaspec.) analysis. The OES measurements proceeded through the quartz window installed on the side wall of the reactor.

The thickness of the fluorocarbon film formed on the surface of SiC and the surface composition after etching were analyzed using X-ray photoelectron spectroscopy (XPS, K alpha, Thermo Electron).

3. Results

Fig. 1 and 2 show the etch rates of SiC according to variation of source power and bias voltage for the HFE-347mmy/O_2/Ar and SF_6/O_2/Ar plasmas.

As shown in Fig. 1, the etch rate of SiC using both plasmas increased as the source power increased. When the source power was 400 W, the etch rate of the HFE-347mmy/O_2/Ar plasma was faster than that of the SF_6/O_2/Ar plasma. When the source power was 500 W, the etch rates of the HFE-347mmy/O_2/Ar and SF_6/O_2/Ar plasmas were similar with 2,599 Å/min and 2,531 Å/min, respectively. Thereafter, with an increase in the source power, the SiC etch rate trend reversed such that the etch rate of SF_6/O_2/Ar plasma was faster than HFE-347mmy/O_2/Ar plasma.

In Fig. 2, the etch rates of HFE-347mmy/O_2/Ar and SF_6/O_2/Ar plasmas increased with an increase in the bias voltage. Additionally, the etch rates of the HFE-347mmy/O_2/Ar were similar with SF_6/O_2/Ar plasmas despite changes in the bias voltage.

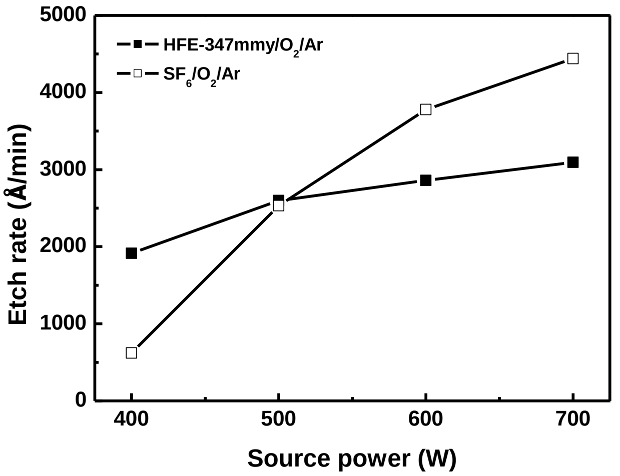

Fig. 1. Etch rates of SiC as a function of source power in HFE-347mmy/O_2/Ar and SF_6/O_2/Ar plasmas.

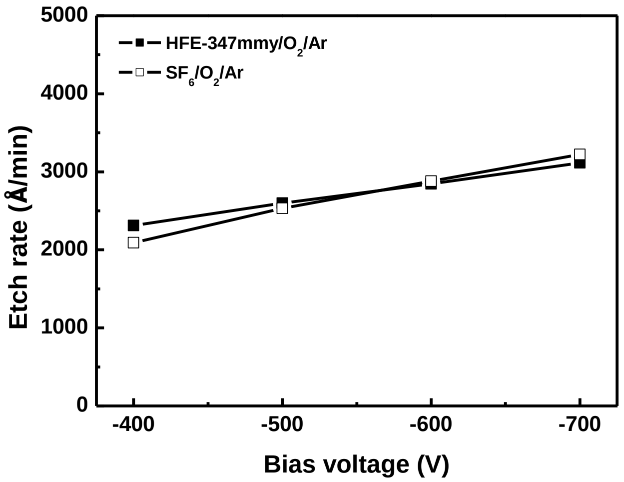

Fig. 2. Etch rates of SiC as a function of bias voltage in HFE-347mmy/O_2/Ar and SF_6/O_2/Ar plasmas.

4. References

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