Plasma etching of SiO_2 using hexafluoroisopropanol

Jin-Su Park[1], Jun-Hyun Kim[2], and Chang-Koo Kim[1]

[1]*Department of Chemical Engineering and Department of Energy Systems Research, Ajou University, Suwon, Korea*
[2]*Institute of NT-IT Fusion Technology, Ajou University, Suwon, Korea*

Abstract: SiO_2 was etched in hexafluoroisopropanol (HFIP)/Ar to evaluate a feasibility of the use of fluorinated alcohol plasmas as an alternative to perfluoro compound (PFC) plasmas. The change in the normalized etch yield (NEY) with ion-incident angle in HFIP/Ar plasmas was obtained from the angular dependence of the SiO_2 etch rates using the Faraday cage system. The NEY curves showed that physical sputtering was the main contributor to the etching of SiO_2 in HFIP/Ar plasmas.

Keywords: Plasma etching, hexafluoroisopropanol, angular dependence, etch yield

1. Introduction

Plasma etching is widely used for patterning of thin solid films such as SiO_2, which is an important operation in the fabrication of microelectronic devices because it offers anisotropic etch profiles [1]. Perfluoro compounds (PFCs) such as CF_4 and C_4F_8 are mainly used as etchant gases for SiO_2 [2-4]. These PFCs, however, are considered to be problematic from an environmental viewpoint because of their long atmospheric lifetimes and high global warming potentials (GWP) [5, 6].

In order to reduce PFC emission during plasma etching, many efforts have been made including process optimization, abatement, recycling (or recovery), and alternative chemicals. Among them, the use of alternative chemicals draws much attention.

Recently, it was reported that fluorinated ethers such as heptafluoroisopropyl methyl ether (HFE-347mcc3) and perfluoropropyl vinyl ether have been used for plasma etching of SiO_2 because these fluorinated ethers had significantly lower GWPs (less than 1000) that PFCs [7, 8]. As an extension in search of low-GWP alternatives for plasma etching, fluorinated alcohols can also be a good candidate because of their lower GWP values than PFCs.

In this study, SiO_2 were etched in hexafluoroisopropanol (HFIP)/Ar plasmas, and its etching characteristics were investigated. HFIP is partially fluorinated alcohol and its GWP is ~190 which is significantly lower than those of PFCs. The etching characteristics of SiO_2 in HFIP/Ar plasmas were studied by varying the ion-incident angles. A Faraday cage system was used to control the angle of ions incident on the substrate. Etch mechanism for SiO_2 etching was discussed based on the angular dependence of etch rates.

2. Experiment

Plasma etching of SiO_2 was conducted in an inductively coupled plasma (ICP) system. The pressure in the chamber was 10 mTorr, and the substrate temperature was 15℃. The source power was 250 W. The bias voltage was changed from –400 to –1200 V for the measurement of the angular dependence of the etch rates. The flow rates of HFIP and Ar were 10 and 20 sccm, respectively. The ICP system was equipped with a Faraday cage in order to control the angle of ions incident on the sample.

3. Results

Figure 1 shows the change in the etch rate of SiO_2 with ion-incident angle at various bias voltages in HFIP/Ar plasmas. The ion-incident angle (θ) was defined as the angle between the ion-incident direction and the surface normal to the sample. The etch rates increased with bias voltage at all ion-incident angles. The etch rates gradually decreased with increasing ion-incident angle for the bias voltages used in this study. When the ion-incident angle was 90°, the etch rates were negative, indicating that a net deposition rather than etching occurred at this angle.

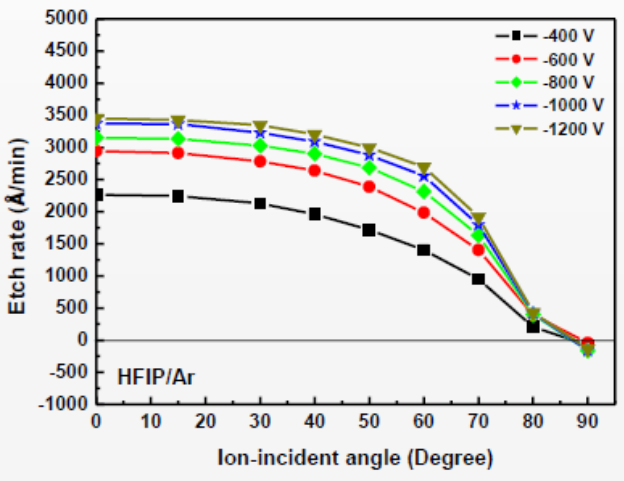

Fig. 1. Angular dependence of etch rates of SiO_2 in HFIP/Ar plasmas at various bias voltages.

Since the ion flux on the substrate changes with ion-incident angle (specifically, proportional to cosθ), it is appropriate to exclude the ion flux variations with ion-incident angles for the investigation of ion-surface interaction. For this purpose, it is relevant to use the etch

yield, which is the etch rate per ion flux on the substrate, instead of the etch rate.

Fig. 2 shows the angular dependence of the normalized etch yield (NEY) of SiO_2 as a function of ion-incident angle at various bias voltages in HFIP/Ar plasmas. The NEYs of a HFIP/Ar plasma showed maxima at angle of 70°.

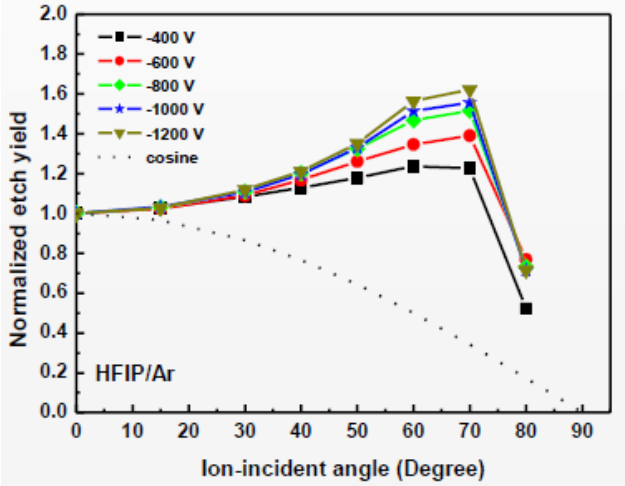

Fig. 2. Angular dependence of normalized etch yields of SiO_2 in HFIP/Ar plasmas at various bias voltages.

The angular dependence of the etch yield can be used to determine the major etch mechanism. When physical sputtering is the main etch mechanism, the etch yield has a maximum at angles between 40 and 70°. On the other hand, when ion-enhanced chemical etching is the main etch mechanism, the etch yield decreases monotonically with ion-incident angle, following the cosine curve. The shapes of the NEY curves in Figure 2 suggest that physical sputtering is a major contributor to SiO_2 etching in HFIP/Ar plasmas.

4. References

[1] S. –W. Cho, C. –K. Kim, J. –K. Lee, S. H. Moon and H. Chae, Journal of Vacuum Science and Technology A, **30**, 051301 (2012).

[2] B.–O. Cho, S.–W. Hwang, G.–R. Lee, and S. H. Moon, Journal of Vacuum Science and Technology A, **18**, 2791 (2000).

[3] J.–K. Lee, G.–R. Lee, J.–H. Min, and S.H. Moon, Journal of Vacuum Science and Technology A, **25**, 1395 (2007).

[4] J.–H. Kim, S.–W. Cho, C.J. Park, H. Chae, and C.–K. Kim, Thin Solid Films, **637**, 43 (2017).

[5] L. Pruette, S. Karecki, R. Reif, L. Tousignant, W. Reagan, S. Kesari, and L. Zazzera, Journal of the Electrochemical Society, **147**, 1149 (2000).

[6] S. Karecki, R. Chatterjee, L. Pruette, R. Reif, T. Sparks, L. Beu, V. Vartanian, and K. Novoselov, Journal of the Electrochemical Society, **148**, G141 (2001).

[7] J. –H. Kim, J. –S. Park and C. –K. Kim, Thin Solid Films, **669**, 262 (2019).

[8] J. –H. Kim, J. –S. Park and C. –K. Kim, ECS Journal of Solid State Science and Technology, **7**, Q218 (2018).