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NO_x(x=1 or 2) / F_2 混合ガスの高温下 Si ケミカルドライエッチング(II)

Si chemical dry etching in NO_x (x=1 or 2) / F_2 gas mixture at an elevated temperature (II)

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【**Introduction**】Si chemical dry etching has been performed by F produced from the reaction of F_2 + NO → FNO + F [1]. This etching technique can be applied for removing sacrificial layer of the microelectromechanical systems (MEMS), texturing the Si surface for the solar panel application to improve the light-electricity conversion efficiency, and eliminating the plasma-induced damage layer after the gate etching process. Previously, we reported that the etch rate, etched profile, and surface morphology were significantly altered by the change in the substrate temperature where the etch rate decreased and the surface became smooth with the increase of the *T* up to 60 ℃ (see cross-sectional images of etched Si in Fig. 1). [2] According to our simulation, F_2, NO_x, FNO_x, and F may chemically react with the Si surface to accelerate or decelerate the etching process.[1] In this study, we evaluated the surface chemical bonding structure of Si before and after the etching in NO_x and F_2 gases to elucidate which molecules (F_2, NO_x, FNO_x, and F) played a key role in changing the etch rate, etched profile, and the surface morphology at different substrate temperatures.

【**Experimental**】6 mm × 15 mm samples were cleaved from a non-doped Si (100) wafer. Ar/NO_x (x = 1 or 2) /10%F_2 at f_{tot} of 107 sccm were introduced in the process chamber while varying the substrate temperature, *T*, from 27 to 300 ºC. The pressure in the chamber was maintained at 600 Pa during the process time of 30 s. Surface chemical bonding structures were analyzed by angle-resolved X-ray photoelectron spectroscopy (XPS) and transmission Fourier transform infrared (FT-IR) spectroscopy.

【**Results and Discussion**】Si 2p, C1s, O1s, and F1s XPS spectra were observed from the Si surface before and after the NO and F_2 gas exposure at *T* = 27 and 60 ℃ but the N1s peak intensity was low. Figure 1 shows Si 2p XPS spectra from Si before and after the etching in NO and F_2 gases at *T* = 27 and 60 ℃. The suboxide, SiO_2, and SiO_xF_{4-x} (X<4) were present at the Si surface. The peak intensity of SiO_xF_{4-x} was low at *T* = 27 ºC but it became the high at *T* = 60 ºC. On the other hand, the peak intensity of $Si2p_{3/2}$ and $Si2p_{1/2}$ decreased with *T*. Unlike previous study of forming the SiO_xF_{4-x} passivation layer in SF_6/O_2 gas mixture at low *T*,[3] the SiO_xF_{4-x} can be formed at *T* ~ 60 ºC in NO and F_2 gases to decelerate the etching process. The detail change in the surface chemical bonding structure and the formation of suboxide, SiO_2, and SiO_xF_{4-x} layers on the Si surface with different morphology produced at the elevated *T* is currently under investigation.

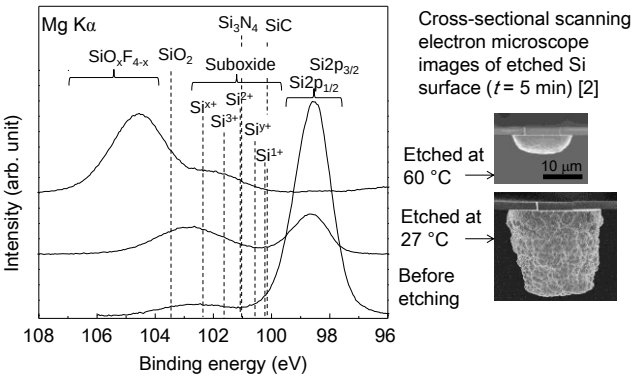

Fig. 1 Si 2p XPS spectra obtained from the non-doped Si surface before and after the etching using the reaction of NO + F_2 → FNO + F. The bottom of the substrate temperature was maintained at 27 ℃ and 60 ℃ during the etching time, *t*, of 0.5 min.

【**References**】 [1] Tajima *et al.* J. Phys. Chem. C **117** (2013) 5118. [2] Tajima *et al.* JSAP Spring Session 22.1, 29a-G7-1 (2013). [3] Tachi *et al.* App. Phys. Lett. **52** (1988) 616; Mallhaoui *et al.* J. Appl. Phys. **98** (2005) 104901; Pereira *et al.* Appl. Phys. Lett. **94** (2009) 071501.【**Acknowledgement**】This research was partially funded by Tatematsu Zaidan and NO gas was donated from Sumitomo Seika Chemicals Co, Ltd..