SiO$_2$ and Si$_3$N$_4$ Etch Mechanisms in NF$_3$/C$_2$H$_4$ Plasma

PUTHAJAT MACHIMA, NOAH HERSHKOWITZ, Department of Engineering Physics, University of Wisconsin-Madison — Low-pressure inductive plasma was used to study SiO$_2$ and Si$_3$N$_4$ etching with the NF$_3$/C$_2$H$_4$ chemistry. NF$_3$ and C$_2$H$_4$ were used so that fluorine and carbon could be supplied from feed gases other than global warming fluorocarbons. Etch rates of SiO$_2$ over a wide range of conditions are less than 0.8 times the Si$_3$N$_4$ etch rates. Ex-situ XPS was used to determine the characteristics of a very thin steady-state film, to establish etch mechanisms. XPS results show that CH$_x$F, CF$_2$, and CF$_3$ were produced but in small concentrations compared to CH$_x$ and CN. Mass spectrometry and optical emission gave consistent results. C1s spectra from etched oxide samples show a large percentage of H$_x$C-CH$_x$ structures. Si$_3$N$_4$ appears to react easily with H$_x$C-CH$_x$ structures, yielding CN-bearing products and SiC. Etch rate and selectivity results of NF$_3$-based discharges fed with C$_2$H$_2$, C$_4$H$_{10}$, and CH$_3$F are similar to the NF$_3$/C$_3$H$_4$ plasma. Comparisons of normalized F1s spectra of nitride and oxide etched under the same conditions show that relative concentrations of CF$_2$ and CF$_3$ on SiO$_2$ are much lower than the concentrations on Si$_3$N$_4$. It appears that SiO$_2$ preferentially reacts with only CF$_2$ and CF$_3$ but not with H$_x$C-CH$_x$ or CH$_x$F. Differences in the abilities of SiO$_2$ and Si$_3$N$_4$ to react with H$_x$C-CH$_x$ contributed to higher etch rates of Si$_3$N$_4$. Effects of bias frequency are presented.

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