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SUMMARY OF Ph.D. DISSERTATION

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Title

Modeling of Feature Profile Evolution of Deep-Si Etching under a Molding in Two-Frequency Capacitively Coupled Plasma

Abstract

In this study, we numerically investigated the relation among the micro-scale pattern on the Si wafer, the interfacial structure of the plasma, and the etching profile in two-frequency capacitively coupled plasma (2f-CCP) in SF_6/O_2 during the micro-scale Si etching.

Chapter 1 summarizes the outline of the motivation and the background of this study.

Chapter 2 describes the outline of the relaxation continuum (RCT) model to simulate the spatio temporal plasma structure in CCP in a periodic steady state. The governing equation system, boundary condition and numerical procedures of the present model are shown.

Chapter 3 describes the 2D-t characteristics of the 2f-CCP in SF_6/O_2 in a periodic steady state. SF_6/O_2 gas is widely used in micro-scale Si etching. Typical characteristics of negative-ion plasma are formed. In this study, we consider SF_5^+ and O_2^+ ions, and F and SF_5 radical as the main etchant for Si etching. In addition, the ground-state atomic oxygen $O(^3P)$ forms the passivation layer on the Si surface to protect the sidewall.

Chapter 4 describes the plasma structure in the vicinity of the artificial hole-pattern on a biased Si wafer. By using the whole plasma structure in the reactor, we recalculate the plasma structure near the pattern in order to investigate the relation between the micro-scale pattern on the Si wafer and the interfacial structure of the plasma (i.e., plasma molding). The results show that the effect of plasma molding only depends on the diameter of the hole. Thus, the influence of plasma molding on the sheath structure is not observed when the sheath thickness is one order of magnitude longer than the hole diameter.

Chapter 5 describes the feature profile evolution of micro-scale Si etching under the presence of the plasma molding in 2f-CCP in SF_6/O_2. We develop the model of feature profile simulation for micro-scale Si etching under plasma molding including physical etching by ions, chemical etching by radicals, and passivation layer formation. Plasma molding strongly affects the ion transport through the sheath, which gives the spatial dependence of the etch rate on the surface in the pattern. That is, the removal of the passivation layer by energetic ions at the bottom corner is strengthened by the effect of excess ion flux with distorted angular distribution. Thus, the etching is enhanced particularly at the bottom corner under the plasma molding, resulting in the suppression of anisotropy of the etch profile.

Chapter 6 summarizes the results of this study.