Modeling $SiCl_4/O_2$ plasmas used for depositing SiO_2 coatings or mask damage recovery

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Coating the reactor chamber before each etch experiment is a widely used preparation step for obtaining higher etch uniformity and higher wafer-to-wafer reproducibility. A commonly used plasma mixture for introducing a SiO_2 coating consists of $SiCl_4$ and O_2 [1]. In this work, we will present numerical simulations for a $SiCl_4/O_2$ ICP. Bulk properties of this discharge as well as information on the surface processes are obtained from the simulations. Plasma properties such as species densities, temperatures and plasma potential are calculated, as well as fluxes of the various plasma species towards the reactor surfaces. Based on these fluxes, surface properties such as chemical composition of the surface layer(s), etch or deposition rate and uniformity are obtained.

1. Introduction

In the micro-electronics industry, inductively coupled plasmas (ICPs) are often applied for processing silicon substrates for the fabrication of electronic devices [2]. These processes, such as etching and deposition, typically occur at low gas pressures (1-100 *mTorr*). It is well known that the nature of the reactor walls can have a significant influence on the etch or deposition process, especially at these low pressures, where the ratio of wall interactions to gas phase interactions is relatively large [3]. During an etching process, etch products are launched into the plasma and can alter the general plasma properties as well as the chamber coatings by redeposition [4]. Coating the reactor chamber, e.g., with SiO_2 or an *oxy-chloride* coating, before each etch experiment is a widely used preparation step for obtaining higher etch uniformity and higher wafer-to-wafer reproducibility. $SiCl_4$ can be a precursor for deposition, while O_2 will oxidise the deposited layer into SiO_2. By tuning process parameters such as gas mixture ratio, power, pressure, gas flow etc., the chemical composition of the deposited layer, the deposition rate and uniformity can be controlled. Therefore, in this work, we will present modeling results on $SiCl_4/O_2$ ICPs. Plasma properties such as species densities, temperatures and plasma potential are calculated, as well as fluxes of the various plasma species towards the reactor surfaces. Based on these fluxes, surface properties such as chemical composition of the surface layer(s), etch or deposition rate and uniformity are obtained. The simulation results will be compared with experiments as much as possible for validation of the model.

The $SiCl_4/O_2$ plasma is not only used for introducing a coating at the reactor walls, but it is, for example, also applied for damage recovery of the mask. Indeed, during etching processes, the mask is always slightly damaged. For improving the profile of the mask again in high resolution devices, the $SiCl_4/O_2$ plasma is used to deposit a layer on the mask, recovering its damaged profile. This process was also investigated numerically as well as experimentally, and will also be presented in this work.

2. Description of the model

The so-called hybrid plasma equipment model (HPEM), developed by Kushner and coworkers [5] is applied to describe the plasma process. This model treats the fast electrons in a *Monte Carlo* module and the slow electrons and *heavy* plasma species in a *fluid* module. In addition to this plasma model, an extra analytical model is applied to calculate changes in the composition of the surface layers due to sputtering or deposition by plasma species. More specifically, the fluxes of all plasma species to the reactor walls and the wafer, as calculated in the plasma model, are used in this analytical model to address the surface processes.

From the latter model, the fluxes of surface species returning to the plasma are defined for an updated calculation of the plasma process. The overall calculation switches between these two models in an iterative way until convergence is reached.

3. Results and discussion

Species densities, fluxes, temperatures and the plasma potential are typical results from the plasma simulations. Wall properties can be predicted as well, such as chemical composition of the deposited layer and the deposition (or etch) rate on the different reactor wall surfaces such as the wafer, the sidewalls and the top dielectric window. These results will be presented at various operating conditions, allowing us to obtain a better understanding of the $SiCl_4/O_2$ plasma and the coating deposition process. Below, two typical simulation results are illustrated. Figure 1 (left) shows a typical density profile of the electron density in the cylindrically symmetric ICP reactor and (right) the calculated SiO_2 deposition rate (formation of the coating) and its uniformity on the different reactor wall surfaces is plotted.

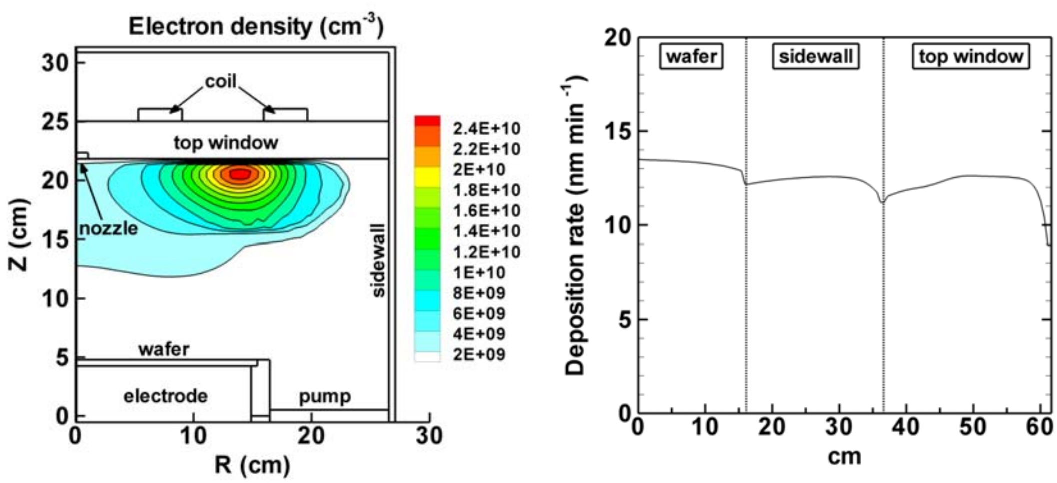

Fig 1. (Left) 2D reactor geometry and electron density profile and (right) the calculated SiO_2 deposition rate.

4. References

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