Influence of the radial plasma non-uniformity on the etch process

V. Georgieva, S. Tinck, A. Bogaerts

Research Group PLASMANT, Department of Chemistry, University of Antwerp, Antwerp, Belgium

SF_6/O_2 plasmas sustained in an inductively-coupled plasma (ICP) reactor are simulated by a hybrid model. An additional model based on the Monte Carlo method is used to simulate the Si etch rate and profiles. Extensive gas-phase and surface chemistry sets are developed. The reactive species fluxes control the deposition rate of the passivation SO_xF_y layer and the chemical etching, while the ion energy and angular distributions control the physical sputtering. It is found that the reactive species fluxes decrease, the ion energy range contracts and the ion angular distribution becomes wider, away from the wafer centre. The present research investigates the effect of the spatial variation in the plasma properties on the etch rate and profile.

1. Introduction

A radial uniformity in the plasma characteristics and in the neutral species densities is an important factor for achieving uniform etch rates [1]. It is well known that the radial plasma non-uniformity at the wafer is due to a combination of different factors, like an inhomogeneous magnetic field, pressure, reactor aspect ratio, applied power and bias, and the complex plasma chemistry typically used in material processing.

Computer modelling can be used for parametric investigation and improvement of the spatial uniformity. In the present work we apply the 2-dimensional Hybrid Plasma Equipment Model (HPEM) [2] to simulate SF_6/O_2 plasma sustained in an ICP reactor. The etch profile and rate are simulated by a Monte Carlo model [3]. The extensive gas phase (37 species) and plasma-surface (33 species) chemistry sets are developed based on a number of papers reporting cross-sections and reaction rate coefficients in SF_6/O_2 gas mixtures and plasma interaction with a Si surface.

2. Setup

We consider a typical ICP reactor operating at a pressure of 10 mTorr. The applied power and bias, and the O_2 content can be varied in order to find optimal operating conditions for etching. The ICP reactor geometry and an example of the calculated electron temperature, T_e, are presented in Figure 1.

3. Results

The fluxes of species with comparatively high density at the wafer are presented in Figure 2. It is clear that the degree of dissociation of SF_6 and O_2 has a radial maximum below the region of power deposition and its absorption by the electrons. The decrease of reactive species fluxes in the radial direction retards the etching. The research on the influence of the plasma uniformity at the wafer on the etch rate and profiles is ongoing.

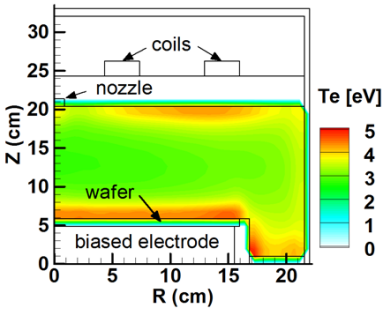

Fig.1. Calculated T_e for applied power 1 kW, bias 300 V, and 15% O_2 concentration in a SF_6/O_2 mixture, at a total gas flow rate of 100 sccm.

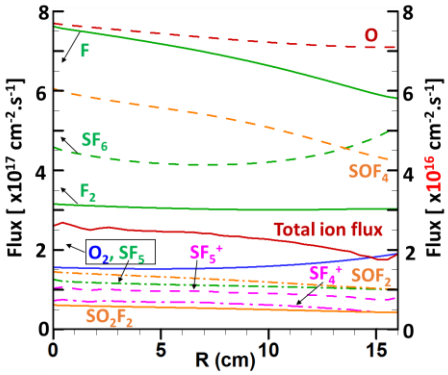

Fig. 2. Calculated species fluxes at the wafer surface. F, F_2, SF_6, SF_5 and O_2 refer to the left y-axis. The other species refer to the right y-axis. The operating conditions are the same as in Fig. 1.

4. References

[1] H. Sasaki, K. Nanbu and M. Takahashi. CP585, *Rarefied Gas Dynamics: 22nd International Symposium*, edited by T. J. Bartel and M. A. Gallis (2001), 262.

[2] M. Kushner, J. Phys. D: Appl. Phys. 42 (2009) 194013.

[3] R. J. Hoekstra, M. J. Grapperhaus, and M. J. Kushner, J. Vac. Sci. Technol. A 15, (1997) 1913.