Modeling of silicon etching under high density plasma of CF$_4$/H$_2$/Ar

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Abstract

A global model has been developed for low-pressure (3-30 mtorr) radiofrequency (13,56 MHz) inductively coupled plasmas (ICP) produced in CF$_4$/H$_2$/Ar mixtures. This gas phase model is coupled to a surface etching model to predict the silicon etching profiles as a function of the surface parameters.

1. Introduction

Plasma processes are being extensively develop to provide nanoelectronic and nanotechnolgy components. High density plasma etching processes has proven to be efficient for narrow trench etching and can therefore contribute to the reduction of the scale of patterns. Nevertheless, optimization of the etching process is still necessary to control the pattern defects such as micro trenching and the roughness of the etched surface. Simulation of plasma surface interaction may widely contribute to the optimization of such process type.

Fluorine-based plasma processes are commonly used in the etching of silicon, silicon oxide...Addition of H$_2$ in fluorocarbon plasmas that are the most common choice for SiO$_2$ etching improves the etching selectivity of SiO$_2$ over Si. This study is focused on the interaction of CF$_4$/H$_2$/Ar plasmas with a silicon surface.

2. Results

The aim of this work is to develop a global model of the CF$_4$/H$_2$/Ar ICP plasmas. Such approach is already used to study O$_2$, Ar and Cl$_2$ plasmas [1], SF$_6$/Ar plasmas [2] and CH$_4$ plasmas [3].

Such gas phase kinetic model is based on the mass balance equations of reactive species coupled to the discharge power balance equation and the charge neutrality condition. The kinetic constants of electron impact reactions are established as a function of electron temperature assuming maxwellian distribution of electron energy.

Numerous species are considered in our model (CF$_x$, CH$_y$F$_z$ and F radicals, CF', H', F' and F' ions...) and their concentration has been determined as a function of plasma parameters (pressure, ICP power, mixture...). Fig. 1 shows the simulation results concerning the evolutions of the electron density and the electron temperature as a function of pressure in a pure CF$_4$ plasma.

Langmuir probe is used to monitor the plasma electrical parameters providing data to validate model simulations. The experimental set-up (ICP reactor...) and the diagnostics are presented in [2].

Another advantage of our model is the coupling between the plasma chemistry model and the surface etching model. The later is based on the Monte-Carlo approach which allows to describe, in a probabilistic manner, the surface mechanisms of silicon etching.

The direct fluxes of the reactive species that are determined from the gas phase kinetic model and introduced as the input parameters in the etching model. The simulation results show the role of the operating conditions on the etched surface profiles and the surface roughness.

References