Publ. Astron. Obs. Belgrade No. 89 (2010), 293-296 *Contributed Paper*

MEASUREMENT OF ETCH RATE FOR SiO_2 SINGLE CRYSTAL TREATED WITH DC-PLASMA

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Abstract. In semiconductor industry low-k materials as SiO_2 play important role. In this paper a SiO_2 single crystal is treated by DC plasma discharge. Our work is focused on interaction between ions and dielectric surface. The etch rates, surface morphology and chemical composition of modified surface layer obtained by DC plasma etching are reported. Influence of plasma chemistry (SF_6, O_2, N_2, Ar and He), discharge voltage (up to 2.2 kV), gas flow (up to 40 sccm, for each gas) and electrode-wafer geometry on etch rate of SiO_2 wafer have been studied. Offline metrology is conducted for SiO_2 wafer by SEM/EDAX technique and Raman scattering. Effects of plasma treatment conditions on integrated intensity of broad Raman peak at around 2800cm^{-1}. An analysis of this correlation could be a framework for creating virtual etches rate sensors, which might be of importance in managing of plasma etching processes.

1. INTRODUCTION

Silicon dioxide (SiO_2) is one of the crucial materials in microelectronic industry. It is widely used for manufacturing integrated circuits. Plasma technologies have become dominant in microelectronics. Plasma processing of materials is one of the most prospect fields of both plasma and surface science. Plasma is widely used tool for surface modification of SiO_2 layer laying on a Si substrate. As electronic devices are diminishing, role of plasma etching techniques has arise. Improving of knowledge in this field is important in managing of plasma etching processes. Main goal of this managing is end point detection with high accuracy. Monitoring of plasma etching processes plays important role in achieving of this goal. It is consist of both plasma and wafer surface metrology technique, such as laser reflection interferometry, optical emission spectroscopy (OES), ellypsometry etc. (Roy et al. 2003).

Despite the fact that it is not often use as a surface metrology technique for wafer inspection, in-situ Raman spectroscopy could be useful in plasma etching analysis. Raman spectroscopy is highly efficient due to fact that Raman scattering process involves electron-phonon interactions, which could provide information of different kinds. In situ Raman monitoring of processes in plasma chambers are described in papers (Faraci et al. 2005). However, Raman analysis of plasma treated SiO_2/Si system, both in situ and off-line, is poorly presented in literature.

2. EXPERIMENT

To perform the study, square shape wafers (15x15 mm) are placed in plasma chamber (discharge tube, Fig. 1). The angle between wafers plane and a constructed channel is 45^0 (Fig. 1). Wafers are immersed in plasma flow during plasma etching. The DC discharge is produced in a Pyrex tube of 5-mm inner diameter and an effective plasma length of 72 mm. The discharge tube is evacuated using a rotary vane pump that gives a base pressure of 2 Pa. The working pressures from 50 to 266 Pa are achieved using a gate valve positioned above the rotary pump. Gas flow into the chamber is controlled via mass flow controllers that precisely determine gas content in the discharge tube. The working gas is a sulphurhexafluoride (SF_6), oxygen, nitrogen, argon and helium with flow rates up to 40 sccm. The power supply used was a Keithley Model 248 high voltage supply with a maximum voltage of 5 kV and discharge current of 5 mA. In this experimental campaign the maximum voltage is 2.2 kV. The wafer processing time is 30 min.

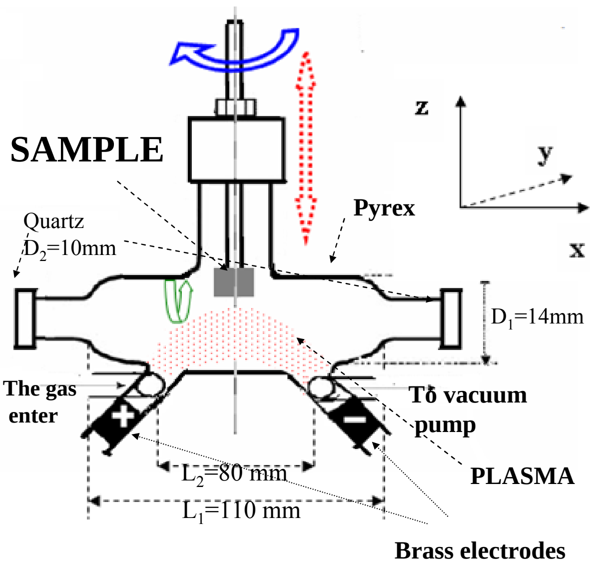

Figure 1:

3. RESULTS AND DISCUSSION

Fig. 2 shows Raman scattering spectra of reference Si-SiO_2 sample. Raman scattering spectra are often analyzed with the help of a Lorentzian function or by the convolution of a Lorentzian and Gaussian curve. In this work is assumed that all lines are Lorentzian type one. Red line corresponds to broad peak, green lines correspond to 512cm^{-1} peak (inherent to silicon) and his overtone and green dot line corresponds to the Rayleigh scattering. Agreement between experimental results and convolution curve (blue line) obtained in this way is very good.

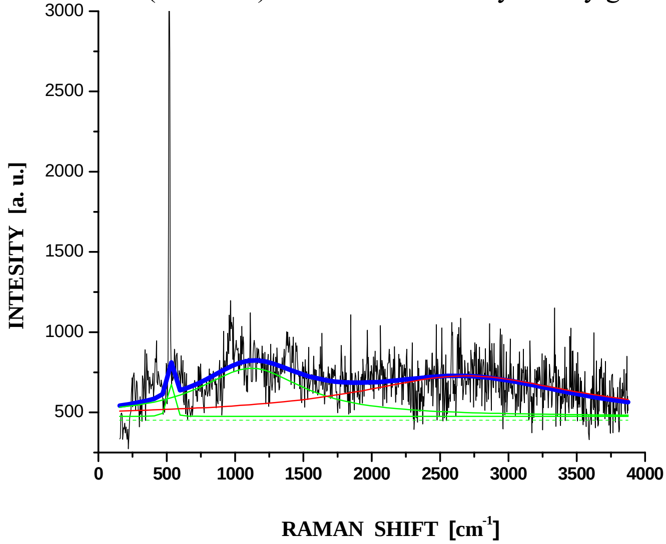

Figure 2:

One could easy notice good correspondence between atomic percent of oxygen, position of broad peak and thickness of the silicon dioxide layer for Si-SiO_2 samples treated with different plasma chemistry (see Fig. 3).

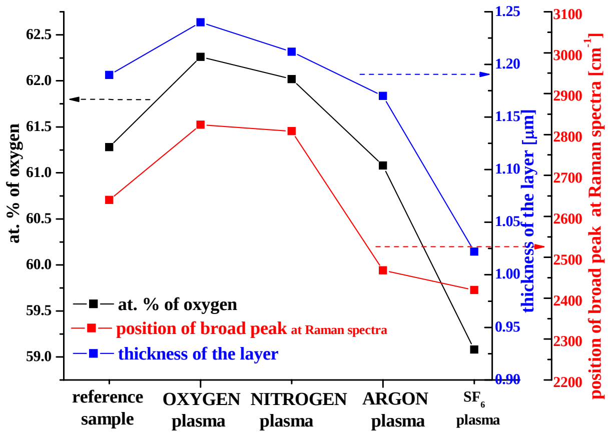

Figure 3:

Fig. 4 shows atomic percent of oxygen for analyzed samples treated by SF_6 plasma vs. gas outlet geometry, presence/absence of gas outlet placed above the sample.

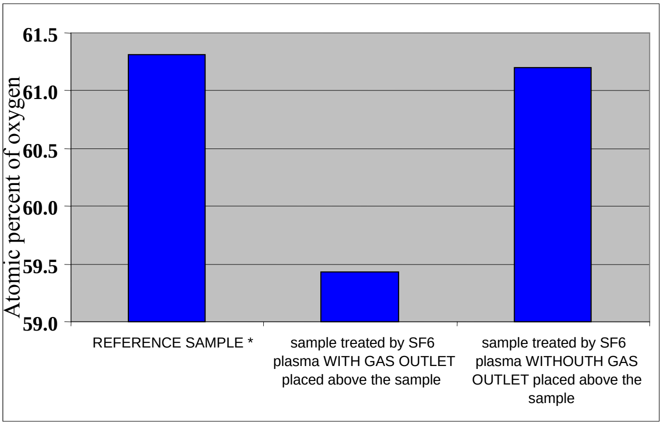

Figure 4:

The atomic percentage of oxygen on samples are proportional to the etch rate. It is clear that the most efficient etching of the SiO_2 could be provide by using SF_6 plasma with gas outlet placed above the sample; in this work no gas mixtures in plasma chemistry were concern. Despite relatively low DC plasma voltage applied during this experimental work, the SiO_2 layer thickness could be increased by oxygen plasma treating. High level of correlation between position of broad peak in Raman spectra and thickness of SiO_2 layer could be noticed for all investigated samples (Fig. 3); there is a possibility of creating a virtual sensor. It is proved by experimental results in this work (Fig. 4) that neutrals in DC plasma discharge plays also role in etching process; that role is emphasise by introducing additional gas outlet placed above the wafer (which create pressure difference between main plasma discharge channel and the expanded pocket).

Acknowledgements

This work is a part of the project No. OI141031 funded by the Ministry of Science and Environment Protection of the Republic of Serbia. V. M. is grateful to the project "The use of non invasive OES as method for the determination of gas species concentration and the main plasma parameters in industrial plasma processing equipment" funded by Enterprise Ireland.

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