Diagnostics of Atomic Oxygen in O_2/Rare Gas Mixture Plasma with Vacuum Ultraviolet Laser Absorption Spectroscopy

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Absolute densities of $O(^1D_2)$ in O_2 surface-wave-excited plasmas (SWP) with high Kr or Ar dilution were measured by tunable vacuum ultraviolet laser absorption spectroscopy. The behaviors of $O(^1D_2)$ densities were almost same, however, the absolute $O(^1D_2)$ density in the Ar mixture plasma was higher than that in the Kr mixture plasma. From these results, the O_2/Ar SWP had a potential to supply the larger amount of $O(^1D_2)$ density to samples than the O_2/Kr SWP.

1. Introduction

Plasma oxidation is essential for nano and micro fabricating on silicon technology. Because the plasma oxidation has a potential to realize much lower temperature processes compared with thermal oxidation. Therefore, the plasma oxidation has been frequently used in the industry and investigated to achieve higher performance. It has been reported that the O_2 surface wave plasma (SWP) with high Kr gas dilution, has the potential to realize a higher silicon oxidation rate and high-quality silicon oxidation films than other O_2 plasmas.[1] In these processes with the O_2/Kr SWP, it is supposed that the high performance of plasma oxidation would be realized by the oxidizing of atomic oxygen in the excited state ($O(^1D_2)$) generated efficiently by the O_2 dissociation due to metastable Kr* collision in high Kr diluted condition (around 97%).[2] However, in our previous study, from estimation of generation rate of $O(^1D_2)$ in the O_2/Kr SWP on the basis of plasma diagnostics results, it was found that the electron impact was a main process to generate the $O(^1D_2)$ in the O_2/Kr SWP.[3] In this study, a quantitative study on the $O(^1D_2)$ in the O_2 SWPs with Kr or Ar mixture was carried out by tunable vacuum ultraviolet laser absorption spectroscopy (VUVLAS).

2. Experimental setup

The plasma oxidation reactor for the 8 inch wafer with a SWP was used to investigate the behavior of at $O(^1D_2)$ in this study. O_2 and rare gases mixtures were employed as discharge gas. Microwave (2.45 GHz) was applied to the antenna on the quartz plate to generate the SWP. Total pressure and microwave power were density fixed at 1 Torr and 1.2 W/cm^2. The absolute $O(^1D_2)$ densities in the O_2/rare gas mixture SWP were measured by VUVLAS. The VUV laser radiations around the transition lines of 3s $^1D^\circ$-2p $^1D_2$ at 115.22nm for the measurements of absolute densities of $O(^1D_2)$ were generated by the phase-matched frequency tripling in the Xe (40 Torr) and Ar (80 Torr) mixture.

3. Results

Figure 1 shows the dependence of absolute $O(^1D_2)$ densities on the flow rate ratio of O_2/(rare gas+O_2). The flow rate ratio was changed from 0.2 to 40%. In the case of Ar/O_2 SWP, the absolute density of $O(^1D_2)$ increased from 4.3×10^{10} to 1.8×10^{12} cm^{-3} with decreasing the total flow rate ratio up to 1%. And then that of $O(^1D_2)$ slightly decreased from 1.8×10^{12} to 1.0×10^{12} cm^{-3}. The behavior of $O(^1D_2)$ in the O_2/Kr SWP was almost same. However, the absolute $O(^1D_2)$ density in the Kr mixture plasma was 1.2×10^{12} cm^{-3} at O_2/(Kr+O_2) flow rate ratio of 1% and lower on all flow rate ratio condition compared with that in the O_2/Ar SWP. The rate constant for collisional quenching of $O(^1D_2)$ by Kr is around ten times higher than that by Ar. Therefore, it is considered the $O(^1D_2)$ density in the O_2/Kr SWP was lower than in the O_2/Ar SWP. From these results, we confirmed that the O_2/Ar SWP had a potential to supply the $O(^1D_2)$ compared with the O_2/Kr SWP.

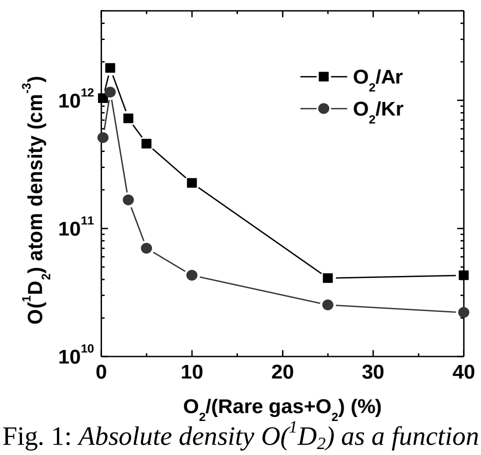

Fig. 1: *Absolute density $O(^1D_2)$ as a function of O_2/(rare gas +O_2) ratio.*

References

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