High quality silicon dioxide by low temperature neutral beam enhanced atomic layer deposition

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Introduction: The demands of high conformal coating and good thickness control are increasing due to the advanced technology nodes. In recent decades, atomic layer deposition (ALD) emerged as a promising technique for thin film deposition. It overcomes drawbacks of conventional deposition techniques which do not generally achieve conformal thin layers on complex structures. Concerning to these problems, plasma-enhanced ALD (PEALD) and thermal ALD were invented. However, plasma irradiation and charge accumulation existed in PEALD [1] can cause defects in thin films; high temperature is also needed in thermal ALD. Silicon dioxide (SiO_2) is an important material in various applications such as gate oxide, gate spacers in transistors, as well as interlayer between the Si substrate and high-k dielectric to prevent from chemical reactions between them [2]. Neutral beam technology has shown high quality neutral-beam oxidation SiO_2 film [3]. In this study, we demonstrated the growth of SiO_2 film using novel neutral beam-enhanced atomic layer deposition (NBEALD) technique.

Experimental: SiO_2 films were deposited on 2 inch silicon wafers in a large-radius neutral beam source reactor which consists of an ALD process chamber and an inductively coupled plasma source. Neutral beam was formed after the plasma pass through the carbon aperture. We used Aminosilane as the precursor and O_2 as the neutral beam source to deposit films on the Si substrate. The sample stage temperature was controlled at 30℃. The ALD cycle was composed as follows: precursor feed, precursor purge, O_2 injection, neutral beam irradiation and O_2 purge. We used spectroscopic ellipsometry to measure film thickness. The atomic force microscope (AFM) was used to investigate the surface morphology, and the X-ray photoelectron spectroscopy (XPS) was used to analyze the chemical composition of the films for investigating the SiO2 film quality.

Results: The ALD cycle shows the thickness is linearly dependent on the number of cycles at room temperature with growth per cycle comparable to that of PEALD [4]. The uniformity of the film was obtained by measuring thickness on different places of 8 inch wafer, and the result shows the film has good uniformity. For the XPS result, pure SiO_2 film composition was confirmed. Furthermore, the excellent surface morphology could be seen on SiO_2 films as no difference for thickness discrepancy. Therefore, we succeeded that the high quality SiO_2 films using NBEALD technique were grown.

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