Effect of Hydrogen Neutral Beam Treatment on Atomic layer deposition SiO_2

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Introduction: As the miniaturization of transistor becoming prosperous, the atomic layer deposition is more and more important. Our neutral beam technology has shown excellent applications such as neutral beam oxidation [1] and neutral beam enhanced chemical vapor deposition for making conductive amorphous hydrocarbon film [2]. We introduced the neutral beam technology into atomic layer deposition, which is called neutral beam enhanced atomic layer deposition (NBEALD), to deposit SiO_2 at room temperature. The thin-film defect caused by conventional plasma damages such as charged particles and UV photon irradiation does not occur in NBEALD since charged particles and UV photons are almost blocked by the high aspect ratio aperture. With NBEALD technique, it is possible to deposit high-quality SiO_2 film at room temperature, which is beneficial for various applications such as gate oxide, gate spacers in transistors, as well as interlayer between the Si substrate and high-k dielectric. In this study, we present a way to improve the film quality which uses the hydrogen neutral beam post-treatment after NBEALD deposition.

Experimental: SiO_2 film was deposited on 2 inch Si wafer 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 high aspect ratio stainless steel aperture. We used Aminosilane as the precursor and O_2 as the neutral beam source to deposit film on the Si substrate. The sample stage temperature was controlled at 30°C. The ALD cycle was composed as follows: precursor feed, precursor purge, O_2 injection, neutral beam irradiation and O_2 purge. After that, the hydrogen neutral beam post-treatment (NBPT) was carried out. To examine the growth behavior, spectroscopic ellipsometry was used, and for film quality, the atomic force microscope (AFM), X-ray photoelectron spectroscopy (XPS), and X-ray reflectivity (XRR) were used to investigate the surface roughness, chemical composition, and mass density of NBEALD SiO_2, respectively.

Results: Figure 1 shows the WER of as-grown and with NBPT SiO_2. As-grown SiO_2 has shown high-quality SiO_2 could be realized at low temperature with low carbon content. However, the wet etch rate (WER) of NBEALD SiO_2 is inferior to that of thermal oxide despite of the same film density. On the other hand, after H_2 NBPT, WER was greatly reduced. As a result, hydrogen atoms can serve as the function of changing the bond angles and bond lengths [3], and reduce the WER. Therefore, low WER which was close to that of plasma enhanced atomic layer deposition (PEALD) and thermal oxide was achieved.

[1] T. Ohno et al, *Results in Physics 8* 169–171 (2018)
[2] Y. Kikuchi et al, *Carbon* 67, 635 –642 (2014)
[3] W. A. Lanford et al, *J. Appl. Phys.*, Vol. 49, No.4, (1978)

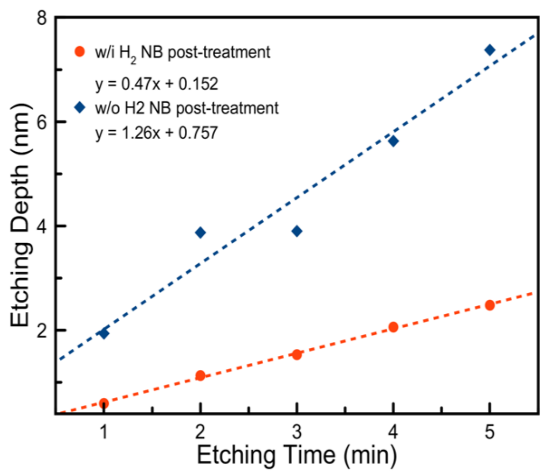

Figure 1. Wet etching depth versus etching time for NBEALD SiO_2 with and without hydrogen NB post-treatment.