Low Temperature Neutral Beam Enhanced Atomic Layer Deposition of Silicon Dioxide and Silicon Nitride

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Introduction: Neutral beam enhanced atomic layer deposition (NBEALD) is a novel deposition technique under the trend of nanoscale miniaturization of integrated circuits. High temperature, plasma irradiation and charge accumulation still exist in several traditional plasma deposition methods [1]. However, neutral beam enhanced atomic layer deposition (NBEALD) has been proven to be the superior technique for depositing low temperature at 30°C, overcoming the inherent problems in plasma process and precise film thickness control. In this work, this technique was used to form the high-quality silicon dioxide (SiO_2) films and silicon nitride (Si_xN_y) films which are widely used in semiconductor protection and passivation [2].

Experimental: Silicon dioxide and silicon nitride 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 passed through the carbon aperture. For depositing SiO_2 and Si_xN_y films, we used bis(diethylamino)silane (BDEAS) as Si precursor, O_2 or N_2 as the neutral beam gases to deposit films on Si substrate. The sample stage temperature was controlled at 30°C. The ALD cycle was composed as follows: precursor feed, precursor, O_2 or N_2 injection, neutral beam irradiation and O_2 or N_2 purge. We used spectrum ellipsometer to measure film thickness, and the film quality were investigated by X-ray photoelectron spectroscopy (XPS) to analyze the chemical composition of the film.

Result: The thickness of film could be precisely controlled at the atomic level based on sequential, self-limiting characteristic of ALD. The XPS result of SiO_2 and Si_xN_y films as shown in (Fig.1 and Fig.2), while keeping the low temperature at 30°C, mass density, chemical composition, and surface roughness of the deposited SiO_2 films show that the quality of NBEALD-deposited films is equivalent to that of thermally grown oxide films [3]. Depositing Si_xN_y films was achieved under the same experimental conditions as depositing SiO_2 films which just changed the O_2 neutral beam to N_2 neutral beam. Although we successfully deposited the Si_xN_y films at room temperature 30°C, more experiments such as changing substrate temperature, source power and bias power need to be done for improving film properties and near-stoichiometric film is believed to be achieved.

[1] Samukawa S, *Japanese journal of applied physics 45, 4R* (2006), 2395.

[2] Moss S J, Ledwith A. *Chemistry of the Semiconductor Industry[M]. Springer Science & Business Media,* 1989.

[3] Chen, H.H. et al, *J. Phys. D: Appl. Phys.* 53, (2020), 015204

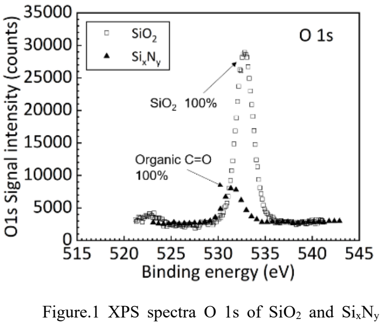

Figure.1 XPS spectra O 1s of SiO_2 and Si_xN_y

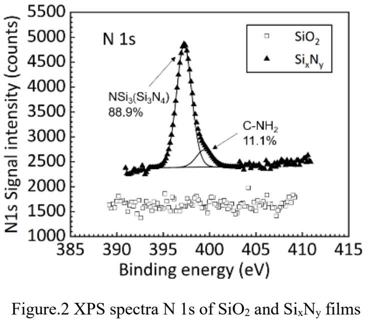

Figure.2 XPS spectra N 1s of SiO_2 and Si_xN_y films