Low Temperature Neutral Beam Enhanced Atomic Layer Deposition of Silicon Nitride

IFS, Tohoku Univ.[1], ASM Japan K.K.[2], AIMR, Tohoku Univ.[3]
°Hua-Hsuan Chen[1], Beibei Ge[1], Daisuke Ohori[1], Tomohiro Kubota[2], Dai Ishikawa[2], and Seiji Samukawa[1,3]
E-mail: chen.hua.hsuan.e5@tohoku.ac.jp, samukawa@ifs.tohoku.ac.jp

Introduction: Silicon nitride (SiN) films have been widely used in microelectronics and with its applications in passivation, isolation, insulation and etching mask, due to its excellent physical and chemical properties [1, 2]. There are several different methods to deposit SiN films such as low-pressure chemical vapor deposition (LPCVD), plasma enhanced chemical vapor deposition (PECVD) and plasma enhanced atomic layer deposition (PEALD). However, the formation of SiN is extremely difficult. Neutral beam enhanced atomic layer deposition (NBEALD) has previously deposited silicon dioxide (SiO_2) successfully [3]. It takes the advantages of very low temperature at 30°C, overcoming the inherent problems in plasma process and precise film thickness control [4]. In this work, NBEALD technique was investigated into the deposition of SiN films with similar experimental conditions as SiO_2.

Experimental: 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 pass through the carbon aperture. We used bis(diethylamino)silane (BDEAS) as Si precursor and N_2 as the neutral beam source to deposit films on the Si substrate. The sample stage temperature was controlled at 30°C. The ALD cycle was composed as follows: precursor feed, precursor purge, N_2 injection, neutral beam irradiation and N_2 purge. We used spectrum ellipsometer to measure film thickness. SiN film quality was investigated by X-ray photoelectron spectroscopy (XPS) to analyze the chemical composition of the film.

Result: According to the self-limiting characteristic of ALD, the thickness of film can be precisely controlled at the atomic level and the thin films are built up in cycles [5]. Figure 1 shows the XPS result of Si2p spectrum, indicating the SiN film is successfully formed with NBEALD technique at room temperature 30°C, with the same experimental conditions as depositing SiO_2 except that the O_2 neutral beam is changed to N_2 neutral beam. By changing the experimental conditions such as source power, bias power, substrate temperature, etc., better film properties and near-stoichiometric film is believed to be achieved, and the refractive index will be further investigated.

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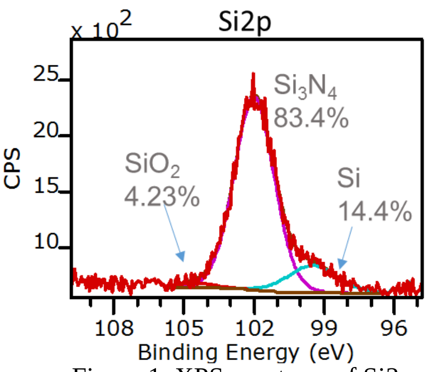

Figure 1. XPS spectrum of Si2p.