Plasma enhanced atomic layer deposition of silicon nitride thin film by organosilane precursor and process engineering

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ABSTRACT

Currently, silicon nitride (SiN) thin film has been widely used in the semiconductor device manufacturers as a gate dielectric, sidewall spacer, passivation layer, etc. Up to now, SiN has been deposited by conventional deposition method such as LPCVD or PECVD. However, a standard LPCVD process temperature can be over 700 ºC and thus often not applicable because of thermal budget restrictions. With PECVD, a film can be deposited at a relatively lower temperature (~ 400 ºC) but without a conformal step coverage (SC). To overcome some of these challenges, atomic layer deposition (ALD) method has been proposed due to its several advantages such as low process temperatures (50 ~ 300 ºC), a precise thickness control, and excellent SCs.

In this study, We demonstrated that a multi chloride ligand organosilane precursor with no oxygen content, designated as Precursor T to deposit SiN film at the identical deposition temperature for a possible low thermal budget and reliable device operating in industrial applications. Precursor T was used as a Si precursor, and NH_3 and N_2 were used as the reactants. Ar gas was used as a main and a carrier gas. Plasma enhanced ALD (PEALD) method was conducted to obtain SiN film at 300 ºC wafer temperature. SiN PEALD deposition conditions with two different reactants are as follows; Precursor T/purge/NH_3*/purge (process A,* denotes plasma use), Precursor T/purge/N_2*/purge (process B), Precursor T/purge/NH_3*/purge/N_2*/purge (process C, applied additional N_2 plasma after NH_3 plasma) and Precursor T/purge/N_2*/purge/NH_3*/purge (process D, applied additional NH_3 plasma after N_2 plasma).

Deposited SiN film with process A and process C exhibited good stoichiometric film compositions at about Si : N ratio of 3 : 4 with low oxygen and carbon contents and excellent SC of more than 95 %. SiN film with process D also showed good stoichiometric characteristic but, SC was ~ 65 % which is not good property than the above two methods. SiN film with process B showed a higher level of impurities over 3 % carbon and chlorine and 20 % oxygen contents, and a poor SC less than 20 % was found. Consistent with the above results, the XRR results also differed significantly from the other three process in SiN film with process B. The film density from process A to D were 2.65, 2.44, 2.73, and 2.73 g/cm^3, respectively, which show that the film density of process B are not perfect SiN film.
For the WER performance with 0.1% HF solution, SiN with process C shows the lowest WER of 10 A/min among the four conditions. (WERs of process A, process B and process D SiN films were 88, 187 and 15 A/min, respectively.) It is demonstrated that WER is improved with combinatorial deposition with NH_3*/N_2* compared to the deposition with NH_3* or N_2* alone.

In summary, we have deposited SiN film by using a multi chloride ligand organosilane precursor and ALD process design. SiN film was deposited with NH_3 and N_2 reactant gases by PEALD. Excellent SC and WER results were obtained for SiN film deposited with Precursor T/NH_3*/N_2* PEALD process. These results would be able to be applied to spacers or passivation layer, etc. by depositing SiN films with process engineering and would be expected to reduce thermal budget or to obtain reliable device operation.