Impact of PMD Silicon Nitride Degradation Techniques on Oxide Integrity

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Aim of this work is to correlate deposition technique and borderless nitride film characteristics with the degradation of active dielectrics [1,2], separating the contribution of "plasma damage" from the impact of the film characteristics. Some critical process parameters will be pointed out to obtain a film with good conformality without degrading active oxides. Two deposition techniques have been evaluated, Single and Mixed Frequency PECVD processes (SF and MF), each of them giving very different morphological and electrical results (no-borderless process as reference).

About SF process, the key deposition parameters are temperature, NH_3 flow and power: the films with best structure coverage are those implementing the higher values Tdep, NH_3 and RF Power. But these growing conditions have a heavy impact on oxide quality. In Fig.1 the charge to breakdown degradation of n-channel (n-ch) and p-channel (p-ch) oxides is reported showing that high degradation occurs if more than one of those parameters is kept high, in particular for n-ch devices. Fig. 2 show that, for SF nitrides, increasing NH_3 gives higher refractive index (RI) and higher Si-H bond content; also the N-H bond content increases slightly (not reported). In the MF process the deposition temperature plays the same role as for SF while NH_3 flow has to be kept low to improve morphological film properties; nevertheless in this case a high electrical degradation is found for both n-ch and p-ch oxides as shown in Fig. 3. To improve morphology without impacting electrical behavior it is been found a strong impact of diluent gas (He instead of N_2, [3]) and chamber pressure. Fig. 4 shows that, for MF nitrides film composition changes on the contrary of SF film: increasing NH_3 lowers RI and Si-H bond content, but the N-H bonds content significantly increases (not reported). Fig. 3 shows moreover the effect of a rapid thermal treatment (RTP), after nitride deposition: using the same nitride film, the RTP contributes to all active oxides degradation. This "damage" has the same appearance of that due to nitride deposition alone. Correlation between active oxides degradation and Si-H bonds content, RI, wet etch rate and stoichiometry (Si-N peak intensity and position, N-rich or Si-rich film) has been observed. On the contrary, no clear correlation between active dielectrics degradation and classical "plasma damage", total hydrogen content [4] or as deposited film stress has been found. Probably the films which give low active oxide degradation are those characterized by reduced hydrogen injection in devices during deposition and RTP: this is controlled by deposition conditions and thermal treatment. The new recipes have been then developed reducing Si-H bond content, not increasing deposition temperature or powers, but changing pressure, SiH_4 and NH_3 flows, gas flow ratios and diluent gas. Finally, also the stress evolution during RTP, related to film stoichiometry and density, could play a role.

References:
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[2] Y.Jin et al, Proc. IRPS 2002, pg. 359
[3] F.H.P.M. Habraken and A.E.T. Kuiper, Microelectronic Engineering, R12 (1994), pg. 123-175
[4] C.W. Lim et al., VMIC 1999, pg. 39-44

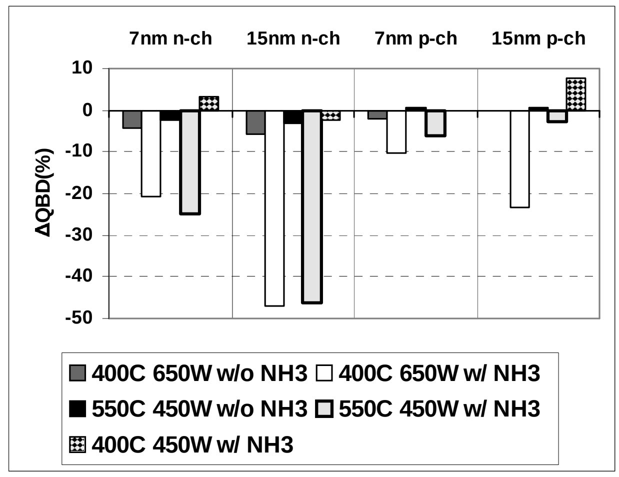

Fig. 1. Single-frequency recipes with (w) and without (w/o) NH_3.

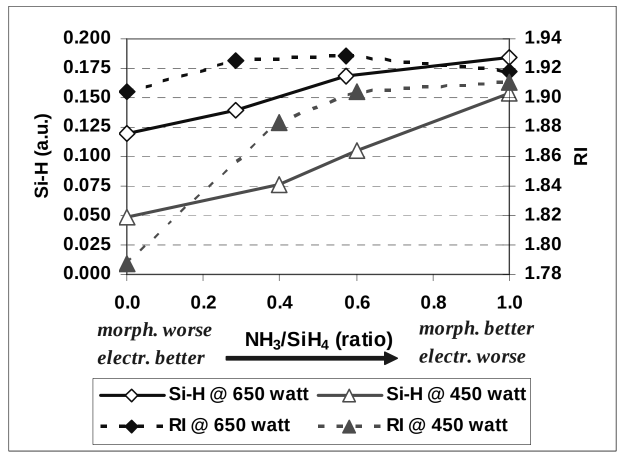

Fig. 2. Single-frequency recipes.

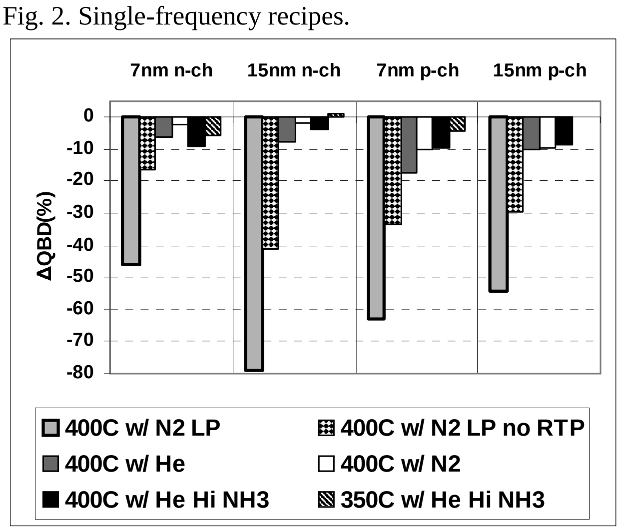

Fig. 3. Mixed-frequency recipes. All these recipes use ammonia.

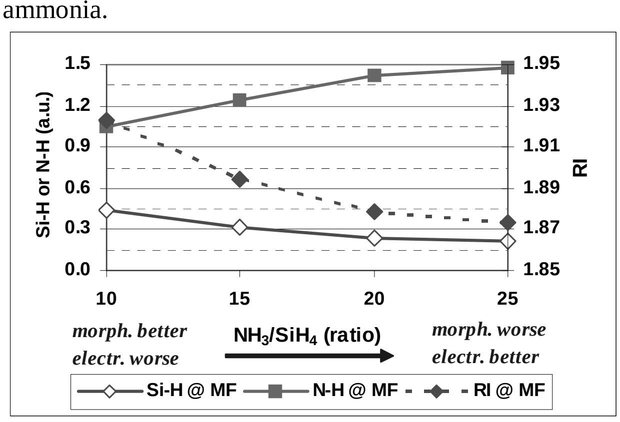

Fig. 4. Mixed-frequency recipes. All these recipes use ammonia.