Characteristics of Metal Gate MOS Capacitor with Hafnium Oxynitride Thin Film

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In the coming MOSFET generations, scaling trends will force the replacement of SiO_2 as the gate dielectric. Among various candidates to replace SiO_2, HfO_2 has attracted considerable attention recently due to their thermodynamic stability in contact with silicon.[1] In addition, HfO_2 is compatible with a polysilicon gate without any barrier materials.[2] However, there are some potential concerns about low temperature crystallization, as well as the degradation of equivalent oxide thickness (EOT) due to the increase in interfacial layer thickness at high temperature. Nitrogen incorporation technology is studied to solve problems such as high leakage current density and high EOT.[3,4] In this work, nitrogen incorporation into HfO_2 films was investigated for gate dielectric applications.

After standard cleaning of p-type Si (100) wafers, HfO_2 (HfO_xN_y) films were deposited by plasma-enhanced chemical vapor deposition using ($Hf[OC(CH_3)_3]_4$ as the precursor. The deposition conditions were performed at a temperature of 300℃ and a pressure of 0.5 Torr. The precursor was vaporized in a bubbler maintained at 30℃ and was carried into the reactor using argon (purity 99.9999%) as the carrier gas. The HfO_xN_y film deposition was performed in $Ar+N_2$ ambient with a RF power of 40~100 W. Pt, Ta, and TaN top electrodes for measurement of the electrical properties were patterned using lift-off lithography. The capacitor area for the MOS structure was 50×50 ㎛^{2}.

Figure 1 shows AES spectrum of HfO_2 (5.6 nm)/Si and HfO_xN_y (6 nm)/Si annealed at 600℃ in an nitrogen ambient for 1 min. Inset in Fig. 1 shows the nitrogen incorporation into HfO_2 film. Figure 2 shows the variation of the EOT of HfO_2 and HfO_xN_y films as a function of leakage current density, as measured at –1 V. All the data in Fig. 2 were collected with PDA (N_2, 600℃, 1 min) and PMA (N_2, 800℃, 1 min). The leakage current density of HfO_xN_y films is approximately one order of magnitude lower than HfO_2 at the same EOT. Figure 3 show the effect of gas flow rate on the resistivity and thermal stability of TaN films. Composition of films was measured using RBS. Resistivity of Ta and TaN electrodes were not degraded after annealing for 1 min in N_2 ambient. Figure 4 showed high frequency C-V curves of HfO_xN_y gate dielectrics with Pt, Ta, and TaN. All the samples were performed at PDA (O_2/N_2=0.1, 600℃, 1 min) and PMA (N_2, 800℃, 1 min). Compared with Pt gate electrode, Ta and TaN gate electrodes showed low hysterisis behaviors.

HfO_2 (HfO_xN_y) thin films for use in gate dielectric were deposited at 300℃ on p-type Si (100) substrates using $Hf[OC(CH_3)_3]_4$ as the precursor by plasma enhanced chemical vapor deposition. Compared with HfO_2, HfO_xN_y show excellent electrical properties including low leakage current density and good thermal stability. Leakage current density of HfO_xN_y is approximately one order of magnitude lower than that of HfO_2 for the same EOT.

References
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2. S. J. Lee *et al*, IEDM 31 (2000).
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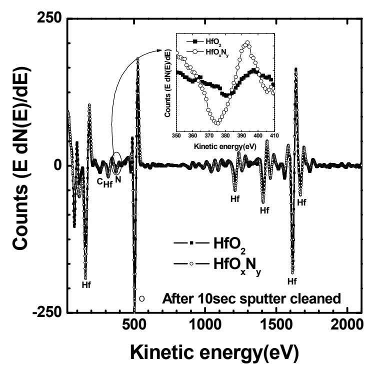

Fig. 1 AES spectrum of $HfO_2(HfO_xN_y)$/Si annealed at 600 ℃ in nitrogen ambient for 1 min. Insert figure shows the nitrogen incorporation into HfO_2 film.

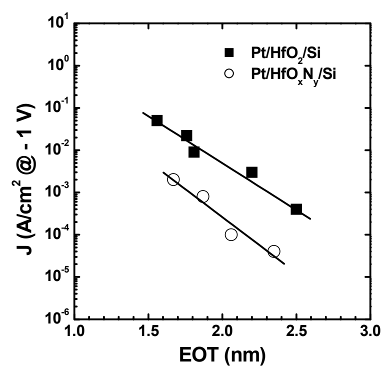

Fig. 2 Leakage current density vs. EOT relationships. HfO_xN_y dielectrics show lower current density compared to HfO_2.

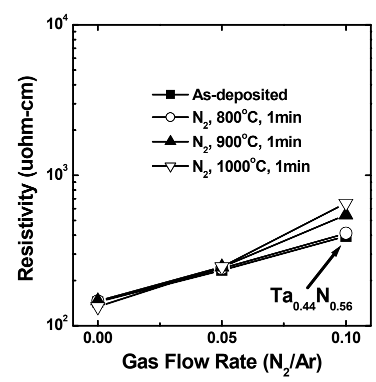

Fig. 3 Resistivty and thermal stability of Ta and TaN gate electrodes.

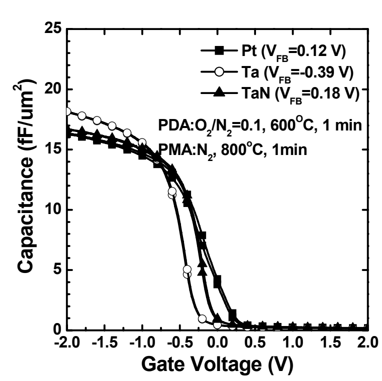

Fig. 4 High frequency C-V curves with Pt, Ta, and TaN.