Hf Cross-Contamination in RTCVD System and Its Effect on Gate Oxide Integrity

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With the dramatic scaling of CMOS devices, high k gate dielectrics have drawn considerable attention as replacements for conventional SiO_2 based gate dielectrics. HfO_2 and its silicate are considered as one of potential candidates due to high dielectric constant and thermal stability with poly Si electrode. There are cross-contamination concerns in conventional microelectronic manufacturing facilities where the processing of high k gate dielectrics such as HfO_2 is proposed. However, the effect of high k element contamination introduced into conventional SiO_2 MOSFET manufacturing steps on the SiO_2 based gate oxide integrity and the behavior of high k elements have not been discussed widely. It is well reported that metallic contaminants act as generation-recombination centers and degrade gate oxide integrity by precipitation or stacking fault formation at Si/SiO_2 interface or by weak spot formation induced by metallic contaminants diffused in gate oxide layer [1,2]. Precipitation in oxidizing solutions and electrochemical plating in HF based solutions were proposed [3-8] as metallic contamination mechanisms. In this work, a cross contamination mechanism in a single wafer, RTCVD high k processing system was investigated and contamination levels were evaluated. The behavior of Hf contaminant as a representative high k element was characterized by the analysis of Hf profiles in oxides and measurement of carrier lifetime for 30Å thick oxides contaminated with Hf.

The Hf contamination level of a high k gate dielectric processing system was characterized over the year by monitoring blank wafers processed in each chamber and the wafer transfer system. It was found that the main contamination source in the system is from contaminants due to particle formation in the chambers. These contaminants may be transferred to other processing tools during subsequent processes. Wafers contaminated with low (low 1E10 atoms/cm^2) to high (high 1E13 atoms/cm^2) levels of Hf were prepared and oxidized to grow 30A thick GOX quality oxide. The oxide wafers were annealed in N_2 at 1000C for 10 min. to investigate the thermal behavior of Hf. The results of SIMS analysis for these wafers are shown in Fig. 1. The peak corresponding to Hf contaminant is in the oxide layer after oxidation as shown in Fig. 1(left). It is much different behavior from other metallic contaminants such as fast diffusing elements. In the case of Ni, for example, no Ni peak was found in oxide, and a flat Ni distribution was found in the bulk Si implying rapid diffusion during thermal process. Fig. 1 (right) shows Hf profile in oxide wafers annealed at 1000C for 10 min. It may be seen from this Fig. that Hf peak was slightly broadened by thermal processing. However, peak was not shifted into bulk Si. It may indicate that Hf is not fast diffusing element and stable in oxide layer. Fig. 2 shows minority carrier bulk recombination lifetime and near surface recombination lifetime for wafers not contaminated with Hf and contaminated with Hf at a level of high E13 atoms/cm^2. It also shows lifetime after thermal annealing. As shown in these figures, bulk recombination lifetime was not affected with Hf contamination. It was also not affected with thermal annealing. However, near surface recombination lifetime was significantly affected. Hf contaminant reduced near surface lifetime. It indicates Hf did not diffuse into bulk, but stayed near the surface confirming the SIMS measurement described above. It has been reported elsewhere [9] that, unlike the Hf behavior reported here, Co and Ni diffuse into the bulk Si and reduce bulk lifetime [9]. In this presentation, in addition to carrier lifetime, the effect of Hf contamination on oxide charge and the removal of Hf contaminant also will be discussed.

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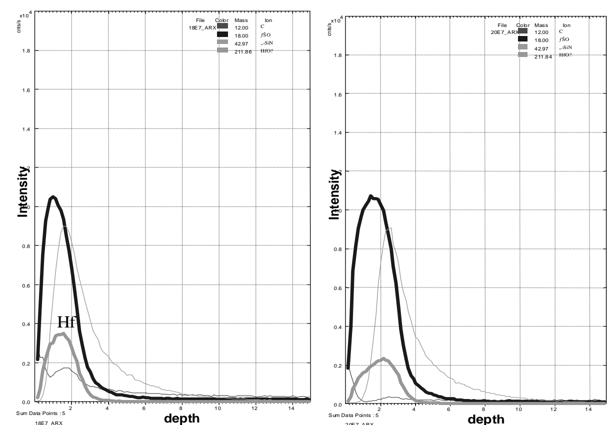

Fig. 1, SIMS profiles of Hf in oxide wafers. (left) after oxidation and (right) after oxidation and annealing.

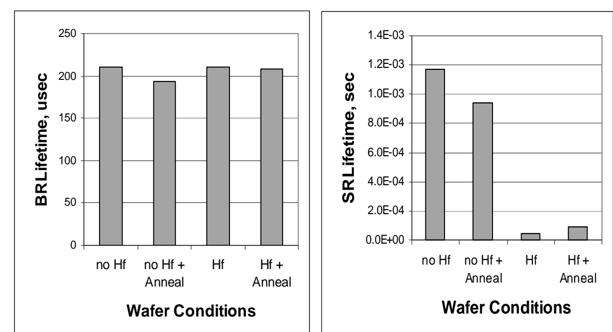

Fig. 2, Minority carrier lifetime for Hf contaminated gate oxide [(left) bulk and (right) near surface recombination lifetime].