The Stability of Carbon-Doped Silicon Oxide Low Dielectric Constant Thin Films

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The performance of ULSI circuits is dominated at the metal interconnect level when the feature size scales down to the 180 nm and below. Interconnects using low dielectric constant (low *k*) materials and copper metallization are being developed and applied to reduce the RC delay, thus meet the demand for increased integrated circuits performance. The use of low *k* dielectric films also lowers power consumption and reduces crosstalk.[1] For interlayer dielectric applications, there are stringent materials and process requirements that demand an exacting combination of electrical, thermal, chemical, and structural stability at submicron dimensions with uniformity over a whole wafer.

Among the materials investigated, low *k* carbon-doped silicon oxide (CDO) with a *k* value around 2.8 is considered a promising candidate in the 130 nm technology and beyond.[2] Nevertheless, the oxygen plasma ashing will degrade the low *k* CDO films and result in the *k* value change.[3] It is found that post-deposition He plasma treatment can significantly reduce this damage.[4] In this work, the impact of H_2/N_2 and NH_3 plasma, and the heat and moisture resistance of the low *k* CDO films have been investigated.

The low *k* CDO films were prepared by a Novellus Concept Two SEQUEL Express plasma-enhanced chemical vapor deposition (PECVD) system. The Si (100) substrates (8 in. p-type single crystal wafers) were heated at 400 °C during the deposition. The precursors used were liquid tetramethylcyclotetrasiloxane, O_2 and CO_2 gas.

Thermal annealing of the low *k* CDO films is performed at 425 °C, no evident shrink or *k* value change is detected. Fourier transform infrared spectroscopy (FTIR) result shows an obvious change of the low *k* CDO film under H_2/N_2 plasma treatment. Moreover, the *k* value also increases to ~3.0 compared to ~2.8 of the as-deposited film. Under NH_3 plasma treatments, a minor bonding structure change is detected by FTIR, but the *k* value increases by 7-14% with the increasing rf power. The effect of moisture penetration is also evaluated by pressure-cooker test, no obvious change in the bonding structure or water absorption peak is observed. However, the *k* value increases to ~3.0. For above treatments, no obvious film thickness change is found. Except for the thermal cycling/annealing, the other treatments result in leakage current increase significantly, indicating a bad resistance against the plasma treatments and moisture stress.

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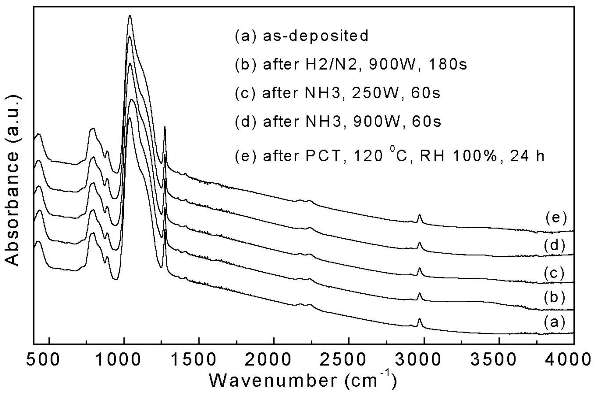

Fig. 1. FTIR spectra of CDO films with thickness ~500 nm after different treatments.

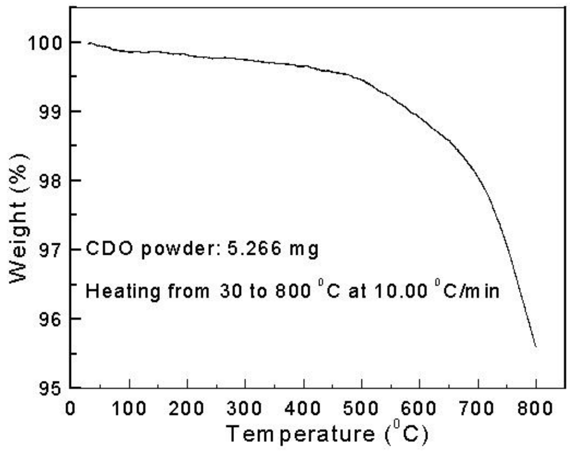

Fig. 2. CDO powder weight loss vs temperature.

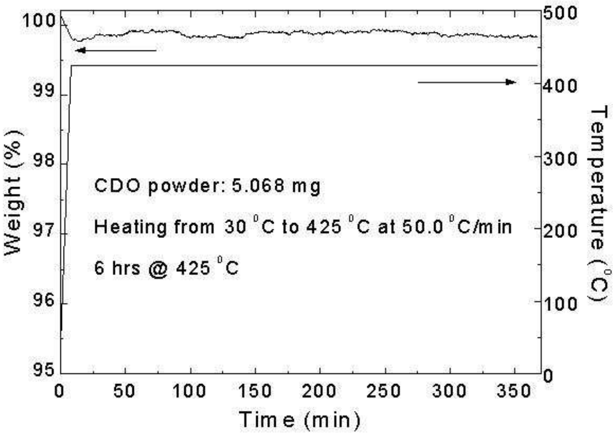

Fig. 3. CDO powder weight loss vs annealing time, showing a high resistance against the thermal annealing/cycling at 425 ^{0}C.

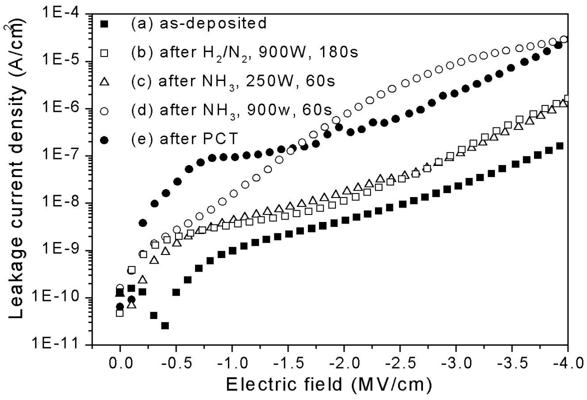

Fig. 4. Leakage current density of the CDO films after different treatments.