Optimization of Soft Bake Step for the Low-k Application using Novel Porous Ladder-type HSQ

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It is very clear that future interconnect technologies will require new metallization strategies together with low-k dielectrics. The ladder-type hydrogen silsesquioxane (L-HSQ) has been studied as a dielectric material. Although it offers benefits of good planerization and excellent gap fill capability, L-HSQ films are unable to use in advanced devices because this film gives a dielectric constant (k) in the region of 3.0. In order to reduce the k-value for future low-k dielectrics, porous ladder-type HSQ (PL-HSQ) has been developed. However, the porogen contained in PL-HSQ is induced the water absorption problem. In this paper, we reported on the formation of a highly porous low-k dielectric film using the optimized bake processing, which gives the water absorption free and time-stable film properties.

The typical L-HSQ polymers were mixed with porogen (polyethylene glycol dimethyl ether) to reduce the k-value of L-HSQ film. The PL-HSQ solution was coated on a silicon wafer at 1000rpm, and then the wafer was baked at the successive temperatures of 80/150/200^{o}C, 80/150/250 and 80/150/300^{o}C. It was enough to evaporate the solvent at the 1st and 2nd step. The porogen was decomposed in 3rd step, so the 3rd step temperature was split by different ones. The final cure was conducted at 400^{o}C to adjust the same heat budget of conventional dielectric application.

As shown in Fig. 1(a), the dielectric constant decreased with an increase of the porogen contents. The FT-IR spectra are shown in Fig. 1(b). The 200^{o}C -baked film retains substantial H-OH and C-H component after soft bake, which is clearly confirmed by the absorption bands at 3300~3600 and 2880, respectively. The intensity of the H-OH and C-H bond was decreased dramatically by increasing bake temperature. The 300^{o}C-baked film loses the amount of H-OH as well as C-H because of a decomposition of porogen. As shown in Fig. 2, the H-OH peaks of 200^{o}C-baked film increase according to expose time, whereas those of 300C baked film were not changed. This means that 200^{o}C-baked film is very weak to water absorption. This water absorption affected the film thickness and reflective index. Fig. 3 shows this effect at different temperature as a function of exposure time to atmosphere. The changes of 200^{o}C-baked film were faster than those of the 250,300^{o}C-baked films. It is important to note that PL-HSQ that gives low water absorption has advantage for both low dielectric constant and time-stable film properties. As shown in Fig. 4, the hardness and modulus increase with an increase of the bake temperature.

The dielectric constant of PL-HSQ could be reduced from 3.0 to 2.5 by increasing its porosity to 100wt%/SiO2. This PL-HSQ film has time-stable properties as well as a proper hardness and modulus based on optimized bake conditions. The proposed PL-HSQ could be attractive in future interconnect applications.

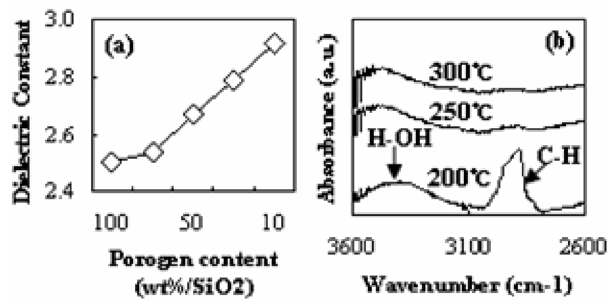

Fig. 1. Dielectric constant of PL-HSQ as a function of the porogen content (a) and FT-IR absorption spectra of PL-HSQ film according to 3rd step bake temperature.

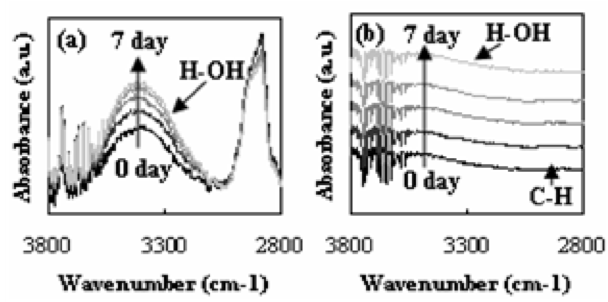

Fig. 2. FT-IR absorption spectra of PL-HSQ film according to exposure time to atmosphere. 200^{o}C-baked film (a) and 300^{o}C-baked film (b), respectively.

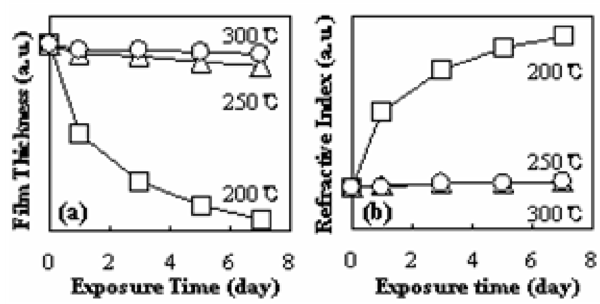

Fig. 3. Measured film thickness (a) and refractive index (b) at various exposure time to atmosphere.

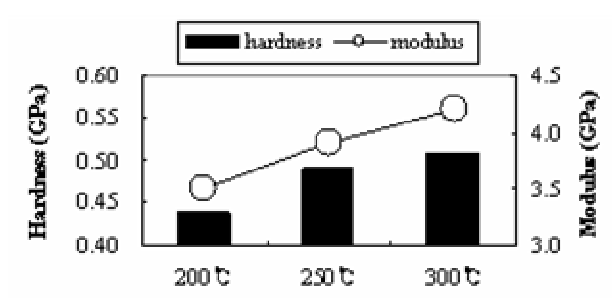

Fig. 4. Hardness and modulus results of PL-HSQ according to various 3rd step bake temperature.