Physical Properties of SiO_2 Layers Deposited at Room Temperature by a Combination of ECR Plasma and High-Speed Jet of Silane

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The demand for low-temperature, high-quality dielectrics is increasing in displays applications. We found that films similar to thermally grown oxide can be deposited at room temperature, with a modified electron cyclotron resonance (ECR) plasma source, in which highly diluted silane in helium is introduced through a small nozzle. The mixture silane/helium was introduced not through a shower ring as before, but through a small nozzle of 0.2 mm (fig. 1). The huge difference between the pressure in the gas line and the pressure in the reaction chamber insures the formation of a supersonic jet of reactive gases. More energy is transferred to the depositing film, eliminating the need of heating the substrate. A quartz shield was bonded to the dome in order to avoid backstream diffusion of silane into the plasma and insure that silane is not dissociated inside the plasma, but through collisions with oxygen radicals. The deposition is local therefore a movable holder with two independent movements (a rotation and a translation), was designed in order to ensure a good uniformity of more than 95% upon the 3-inch wafer. SiO_2 films of 10-20 nm have been deposited using 2% SiH_4 diluted in helium and N_2O, at 400 W and near room temperature. In this work, several deposition parameters as pressure, film thickness silane and nitrous oxide flow rates were varied, while monitoring the film composition and refractive index. Correlations between the physical and the electrical properties presented at length in another paper [1] were made, in order to detect the optimal deposition conditions.

From spectroscopic ellipsometry (SE) measurements, we observed that the refractive index decreases with increasing the pressure (figure 2). Because the layers composition measured by X-ray photoelectron spectroscopy (XPS) is stoichiometric (figure 3), the layers were modelled as stoichiometric SiO_2 layers with voids and as we can see in figure 2, the voids concentration increases with increasing the pressure. Thus, the decrease in refractive index with pressure is caused by a lower film density i.e. increased voids incorporation. Apparently, at high pressures, the plasma radicals and ions loose energy through collisions, therefore the particles on the film surface have lower energy for desorbing the hydrogen.

By comparing the data in table 1, we can notice that the SiO_2 layer deposited with higher N_2O flow possess a higher refractive index, a lower voids concentration and excess silicon. A possible explanation for the low voids concentration is the increased flux of ions and radicals bombarding the surface at high flows.

Besides the good physical and chemical properties, the layers possess also high electrical quality with a breakdown field of 12 MV/cm, net positive oxide charge densities in the order of 10^{10} ions/cm^2 and interface trap densities of 10^{11} eV^{-1}cm^{-2} [1]. In conclusion, it has been shown that the novel deposition method can be a promising tool for depositing stoichiometric SiO_2 films with high density, a refractive index of 1.45 and a very low thermal budget.

REFERENCE

1. G.I. Isai et al., *Proceedings of the 202 Electrochemical Society Meeting*, Salt Lake City, 2002.

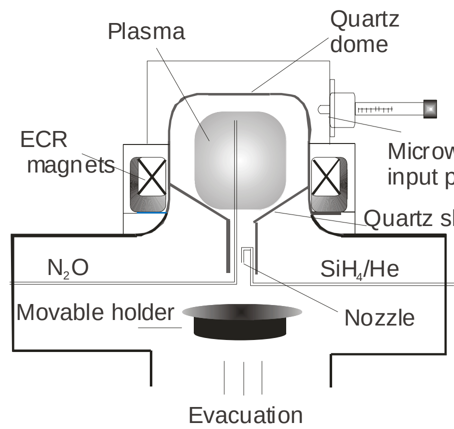

Fig. 1. Deposition chamber

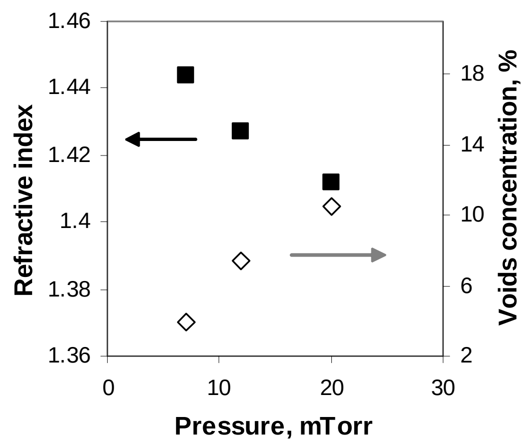

Fig. 2. Refractive index and voids concentration for layers deposited with 5 sccm SiH_4/He flow and 20 sccm N_2O.

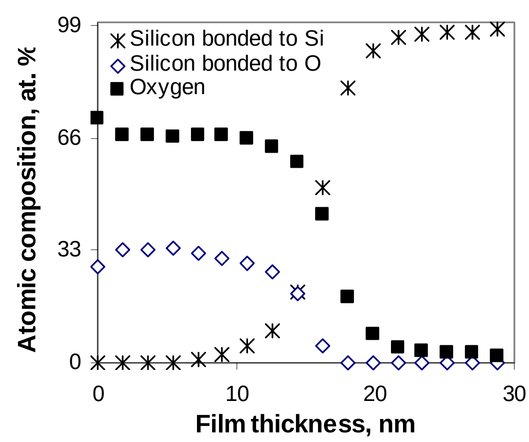

Fig. 3. XPS depth profile for a layer deposited at 20 mTorr, with 5 sccm SiH_4/He, and 20 sccm N_2O.

N_2O flow	Refractive index	Voids conc., %	Oxygen at.%	Silicon at.%
20 sccm N_2O	1.427	7.4	66.95	33.04
50 sccm N_2O	1.46	0.4	66.19	33.8

Table 1. Refractive index, voids concentration and composition for two layers deposited at 12 mTorr, with 5 sccm SiH_4/He flow and different N_2O flow.