

High Quality TEOS Silicon Oxide deposited at Low Temperature for TFT Gate Dielectric Application

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TEOS silicon oxide is widely used in thin film technologies. Plasma Enhanced Chemical Vapor Deposition (PECVD), using tetraethylorthosilicate (TEOS) as silicon source, is a well known technique to deposit silicon oxide thin films [1,2]. This technique presents the advantage of use low temperature in the deposition process allowing the deposition over different types of substrates. We are developing high quality TEOS silicon oxide thin films deposition process to be applied as gate dielectric for polycrystalline TFT technology. The silicon oxide films are deposited by PECVD and by high density PECVD. This work presents a review of the main results obtained by OES, FTIRS and AFM of silicon oxide thin films, in order to understand the physical and chemical mechanisms involved in the deposition process to get a dielectric layer with a suitable electrical behavior. C-V and I-E measurements were performed in MOS capacitors to obtain the electrical characteristics of the deposited films. Moreover, the influence of the surface pre-treatment in the quality of the silicon oxide films is shown.

Experimental and results

The silicon oxide thin films are deposited in a home made PECVD cluster tool system [3]. It has three process reactors, a load lock and a sample manipulation chamber. Silicon wafers (100), p-type, 10-20 Ωcm , 75 mm in diameter were used as substrate. The substrates were cleaned using the piranha and RCA standard cleaning processes followed by a dip in diluted HF. The silicon oxide depositions were carried out in the basic conditions presented in Table 1. The TEOS, oxygen, and argon gases are mixed in a special chamber before entering the process reactor to guarantee a homogeneous mixture. Before each deposition process, a cleaning procedure, using a plasma of a mixture of 50 sccm CF_4 and 15 sccm O_2 , was performed. This procedure ensures the same initial conditions for all deposition processes.

Table 1: process parameters used in all the silicon oxide deposition processes.

TEOS flow (sccm)	6.5
Oxygen flow (sccm)	450
Argon flow (sccm)	0 to 200
Process pressure (Torr)	1
Temperature (°C)	375
RF power (W)	400
Distance between electrodes (mm)	10

To determine the composition of the plasma and to understand the role of argon flow, OES analysis was performed [4,5]. Emission intensity of the O, CO and Ar in the gas phase was measured. The CO emission increases with the argon flow suggesting an enhancement of the TEOS oxidation. We also observed a slight and constant increase of the CO emission intensity, which suggests an enhancement of the TEOS oxidation process by the argon, added to the gas mixture. An increase of O_2 emission is also observed that means that the argon enhances the generation of excited oxygen in the plasma.

The FTIRS analysis showed the regular stretching, bending and rocking absorbance bands of silicon oxide films and also the Si-OH absorbance band. For higher argon flow (100-200 sccm) the Si-OH absorbance band was not detected showing low hydrogen incorporation during the deposition [6,7,8]. Moreover, the independence of the spectra, in function of the argon flow, confirms the almost constant composition as mentioned above despite the variations of the deposition and etching rates.

The CV-HF curves obtained from MOS capacitor showed that there is a shift of the curve towards the positive values after densification. The maximum capacitance decreases after the densification, suggesting also a variation in the permittivity. The leakage current, for as deposited silicon oxide films, increases with the applied voltage up to 10^{-7} A and then stabilizes. The total breakdown occurs at 9.5 MV/cm. This behavior is not observed after annealing, confirming that mainly the volatile TEOS oxidation subproducts create the charges. The breakdown electric field reaches 11 MV/cm and the leakage current remains lower than 10^{-11} A up to 9 MV/cm. The electrostatic permittivity, calculated by using the C_{ox} value in accumulation mode, is close to the thermal silicon oxide one. There is also a decrease of this permittivity after the densification. The density of the interface states, N_{ss} , decreases after the densification that confirms a decrease of the interface defect density.

The first results of the TEOS silicon oxide films deposited in our the new high-density plasma enhanced chemical vapor deposition (HD-PECVD) reaction chamber showed that the quality of the films is not so good as was expected. In the FTIRS analysis, it was not observed the absorbance bands related to the Si-OH bonds at 3600 cm^{-1} . However, around 950 cm^{-1} , the spectrum revealed a low intensity peak of Si-OH bonds incorporation into the deposited films. From the CV-HF plot, we extracted the effective density of charge $Q_{\text{ss}} = 2.0 \times 10^{12} \text{ cm}^{-2}$. It is due to the high value of flat band voltage ($V_{\text{FB}} = -2.3 \text{ V}$). We speculate that the origin of these charges is the OH contamination as observed in the FTIRS spectra and also from the trapped TEOS subproducts produced by the incomplete TEOS decomposition. The leakage current value, at 2 MV/cm, was $2.8 \times 10^{-5} \text{ A/cm}^2$ and the $E_{\text{BD}} = 10.6 \text{ MV/cm}$.

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