CHARACTERIZATION OF Hg-SENSITIZED PHOTO CHEMICAL VAPOUR DEPOSITED SILICON OXIDE AND SILICON OXYNITRIDE THIN FILMS

by
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CERTIFICATE

We are satisfied that the thesis entitled *Characterization of Hg-Sensitized Photo-Chemical Vapour Deposited Silicon Oxide and Silicon Oxynitride Thin Films* presented by Vipan Kumar is worthy of considering for the award of the degree of *Doctor of Philosophy*, and is a record of the original bonafide research work carried out by him under our guidance and supervision, and that the results contained in the thesis have not been submitted in part or full to any other university or institute for the award for any degree/diploma.

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ABSTRACT

Low temperature deposited amorphous dielectric films of silicon dioxide and silicon oxynitride have been extensively used for microelectronics applications viz. as passivation coatings, interlevel dielectrics and gate level dielectrics in silicon metal oxide field effect transistors (MOSFETs) and thin film transistors (TFTs). Although low temperature deposition has been mainly achieved by PECVD, damage produced by ionic and electronic bombardment of deposited film and/or underlying substrate from plasma during deposition could be a serious disadvantage of this process. This problem can be drastically minimized by using a moderately new, low temperature and non surface damaging technique called photo-CVD where UV light is used instead of plasma for dissociating activating reactant gases. There are two basic photo CVD mechanisms viz. (1) direct photolysis (2) Hg-sensitized photolysis. The Hg-sensitized photo CVD has advantage of higher deposition rate as well as of uniformity of the film.

The present thesis aims at conducting an investigation into the characterization of silicon oxide and silicon oxynitride thin films deposited by Hg-sensitized photochemical vapour deposition.

Thin films of silicon oxide have been deposited using a gaseous mixture of high purity gases viz. silane (2 % in argon) and nitrous oxide. The effect of flow rate ratio (SiH_4/N_2O), substrate temperature and total pressure on the physical, optical, chemical and electrical properties have been investigated. The deposition rate was found to exhibit increase-maximum-decrease behaviour with increase of flow rate ratio (SiH_4/N_2O = 0.02 to 0.10). Deposition rate was found to vary directly with pressure while it varies inversely with substrate temperature. Refractive

index of the deposited films was ≈ 1.46 but it increases with increase of flow rate ratio and substrate temperature. Films were found to be structurally uniform and homogenous. Substrate temperature had a little effect on the composition of the films. The stress in the films was found to be compressive and increases with increase of substrate temperature. It was in the range of $1.8\text{-}3.0\times10^9$ dynes/cm^2. Etch rate in $HF:H_2O::1:100$ and pinhole density decreases with increase of substrate temperature.

Silicon oxide films deposited under varying conditions of deposition have been found to exhibit considerable dispersion of the dielectric constant. The stoichiometric films deposited at 350°C and annealed after deposition exhibit negligible dispersion of the dielectric constant. Films deposited at a low substrate temperature (100°C) had a low breakdown strength ($\approx$2MV/cm) while that deposited at higher substrate temperature (350°C) had higher breakdown strength ($\approx$5.5 MV/cm). Fixed charge density as calculated from the shift in the flat band voltage was of the low order of 10^{11} cm^{-2}. A prominent peak in G-V was always found which correspond to the loss dominated by interface traps, but not by bulk traps. The interface state density measured from conductance and Terman's method was comparable and was of the order of 10^{11} cm^{-2} eV^{-1}.

Silicon oxynitride films were prepared using a gaseous mixture of high purity gases viz silane(2% in argon), ammonia and nitrous oxide. The composition of the films was varied over a wide range by changing $N_2O/(N_2O+NH_3)$ flow rate ratio while keeping the SiH_4 and (N_2O+NH_3) flow rate fixed. The physical, chemical, optical and electrical properties were found to depend strongly on the N_2O content in the gas mixture. The deposition rate increases with increase of $N_2O/(N_2O+NH_3)$ flow rate ratio. The refractive index varies from 1.95 to 1.47, dielectric constant from 6.5 to 4.0 as $N_2O/(N_2O+NH_3)$ ratio increases from 0 to 1. The optical bandgap as determined from transmission and reflectance at normal incidence was found to increase with increase of N_2O content in the gas mixture. IR absorption studies showed that as the N_2O content in the gas phase is increased Si-N bond shifts towards higher frequency. This result is attributed to the increase of oxygen content in the film. Stress in the films varied from $+2.8 \times 10^9$ (Tensile) to -3.1×10^9 (compressive). Minimum stress observed in the films was of the order of 10^8 dynes cm^{-2}. Both compressive as well tensile stress of this order was achieved depending on the flow rate ratio. Etch rate increases with increase of $N_2O/(N_2O+NH_3)$ flow rate ratio while it varies inversely with deposition temperature. Density is highest at $N_2O/(N_2O+NH_3)$ flow rate ratio of 0 and decreases monotonically with increase of flow ratio.

Breakdown strength and resistivity of the films increases with increase of substrate temperature as well as with $N_2O/(N_2O+NH_3)$ flow rate ratio. Fixed charge density in the as deposited films was of the order of 10^{12} cm^{-2}. Interface state density as determined by conductance technique was of the order of $\sim 10^{11}$ cm^{-2} eV^{-1}.

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