Effect of Post Plasma Treatment on Water Absorption and Dielectric Properties of Fluorine Doped SiO_2 Films Formed by ECRCVD with SiF_4 and O_2

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The effect of post plasma treatment on water absorption and dielectric properties of fluorine doped silicon oxide (SiOF) films for intermetal dielectrics (IMD) in multilevel interconnections of ultralarge-scale intergrated circuits (ULSIs) with various gases such as N_2, O_2 and N_2O are investigated. The SiOF films were deposited on Si substrates by using electron cyclotron resonance chemical vapor deposition (ECRCVD : AsTeX model AX4505) with SiF_4 and O_2 as source gases in order to avoid incorporation of impurities such as C and H. The SiOF films were deposited as a function of the SiF_4/O_2 gas flow ratio. The post plasma treatment of SiOF films were carried out N_2, O_2 and N_2O plasmas in-situ after the deposition. The deposition condition is shown in Table 1 and the plasma treatment condition is shown in Table 2.

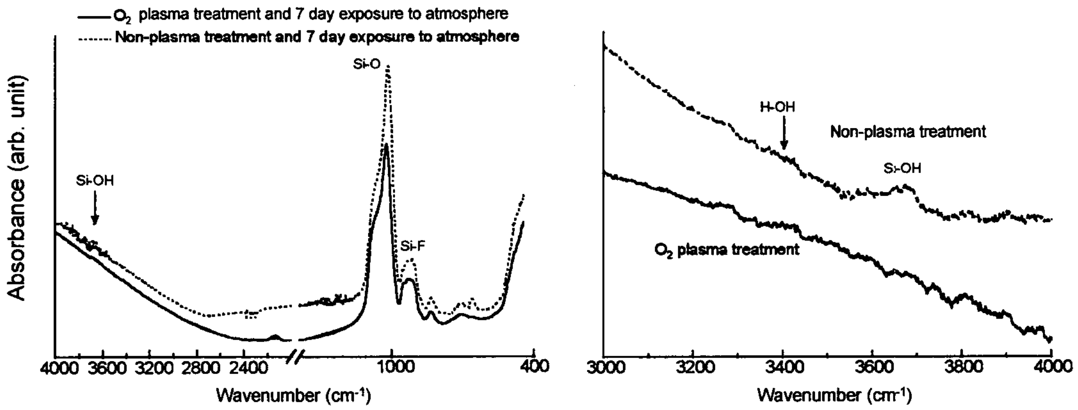
Table 1. Deposition condition of SiOF films.

Gas flow rate (sccm)			Substrate temperature (℃)	Process pressure (mTorr)	Microwave power (W)
SiF_4	O_2	Ar			
1~5	5	10	300	3	700

Table 2. Post-treatment condition

Post-treatment	Gas	Microwave power (W)	Flow rate (sccm)	Temperature (℃)	Process pressure (mTorr)
O_2-plasma treatment	O_2	700	20	400	3
N_2-plasma treatment	N_2	700	20	400	3
N_2O-plasma treatment	N_2O	700	20	400	3

We studied changes in water absorption and dielectric properties of SiOF films as a function of exposure time in atmosphere to learn the effect of post plasma treatment using N_2, O_2 and N_2O gases. Relative dielectric constant was determined from capacitance-voltage (C-V) measurements at 1MHz using a MIS (Ag/SiOF/p-Si) structure. The wet etching rates were measured by dissolving films in a buffered HF solution (50%HF : 40%NH_4F = 1 : 6) step by step and by measuring the thickness at each step. Fourier transform infrared (FTIR) spectra were examined in order to investigate differences in the chemical properties of SiOF films before and after the plasma treatments. X-ray photoelectron spectra (XPS) were taken to investigate changes in surface chemical composition and depth profiles of SiOF films before and after the plasma treatment with N_2, O_2 and N_2O plasmas. chemical bonding structures in the SiOF films were determined by using FTIR spectrometer. FTIR measurement was carried out in vacuum in order to avoid data interference due to appearance of Si-OF and/or H-OH peaks originated from atmosphere.



(a) (b)

Fig. 1 FTIR spectra of SiOF films exposed to the atmosphere for 7 days before and after the O_2 plasma treatment(a)in the range from 400 to 4000cm^{-1} and (b) in the range from 3000 to 4000cm^{-1}

Fig. 1 (a) shows FTIR spectra of SiOF films (deposited with gas flow ratio of 1.0) exposed to the atmosphere for 7 days before and after O_2-plasma treatment and fig. 1 (b) is the spectra in the range from 3000cm^{-1} and 4000cm^{-1}. After O_2-plasma treatment, no appreciable peak directly related to water absorbance is detected. However, the film which exposed to atmosphere without any plasma treatment beforehand appears to have H-OH and Si-OH peaks appearing at around 3400cm^{-1} and 36 50cm^{-1}. This results clearly shows that the O_2-plasma treated SiOF film has lower moisture absorptivity than non-plasma treatment SiOF films. It is regarded that the O_2 plasma treated SiOF film is more dense than non-plasma treatment SiOF films because of ion bombardment effect of O_2 plasma. And it is also thought that some of fluorine atoms in the very top layers of the SiOF film are replaced by oxygen atoms by O_2 plasma treatment. Generally speaking, SiOF films with fluorine content much higher than a certain amount tend to have high moisture absorptivity when exposed to moisture atmosphere. Therefore, it is proposed that the surface oxidation and densification due to O_2 plasma treatment make SiOF films a very attractive material for ULSI's IMD.

In this presentation, we reports studied on changes in dielectric constant as a function of time to atmosphere, effects of plasma treatment using N_2, and N_2O besides O_2, and changes in surface chemical composition and molecular structure of SiOF films due to plasma treatment.

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