Investigation of High Dielectric Film on the Plastic substrate by Novel Liquid-Phase Heterojunction Deposition

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Tantalum pentoxide (Ta_2O_5) has rapidly evolved as a potentially important film material in microelectronics. Numbers of convention techniques used to prepare Ta_2O_5 films are sputtering, sol-gel, anodic oxidation, electron beam evaporation and chemical vapor deposition (CVD).[1-5] Recently, a new method called the liquid phase heterojunction deposition (LPHD) method has been employed to deposit Ta_2O_5 on silicon (Si).[6] To make more lighter and thinner products, technology of deposition Ta_2O_5 on plastic substrate is also necessary for this modern higher dielectric constant materials. Plastic substrates have the advantages of low cost, flexible, light-weighted, thin-shaped and not-so-easily-broken characteristics. LPHD is found superior to previous deposition methods in terms of the following combined characteristics: low processing temperature, modest equipment, selective deposition, uniform film surface, low film cost and high film quality. Cleaning of the substrate is important for the proper adhesion of the film. The plastic (ARTON) substrate is first cleaned by acetone and methanol successively, 10 min each. The substrates are etched by oxygen plasma. The plastic substrate is immersed in the sensitizing solution and activating solution successively, for 5 min each. Finally substrates were washed in de-ionized water and dried by nitrogen gas. The growth solution were prepared by hydrolysis of tantalum ethoxide ($Ta(OC_2H_5)_5$) (99.9%) in absolute ethanol (99.8%), the substrate is immersed in the growth solution for Ta_2O_5 deposition and the solution is maintained at 10 ℃ during stirring for 20 min in environments of N_2 gas. The growth solutions are formed by hydrolysis and condensation reactions of metal-organic compounds. The growth thickness region of Ta_2O_5 film is from 230 to 600Å and the refractive index is from 1.6 to 1.8 with increasing film thickness. Figure 1 shows the film thickness versus growth time under different growth solution at $[Ta(OC_2H_5)_5] = 0.5$ ml and $[Ta(OC_2H_5)_5] = 0.6$ ml. A high deposition rate is obtained for growth solution with higher $[Ta(OC_2H_5)_5]$ concentration, but better refractive index is obtained at low deposition rate, presumably due to the oxide film having less porosity. A maximum Ta_2O_5 growth rate of 1380 Å/hr was observed in $[Ta(OC_2H_5)_5] = 0.5$ ml. The structural properties of the films were investigated by Energy dispersive spectrum (EDS), X-ray photoelectron microscopy (XPS) and Fourier transform infrared (FTIR) Spectrometer. The surface roughness of 14.057 nm and root mean square roughness of 17.778 nm are obtained by atomic force microscope (AFM). It is confirmed that the film was composed of Ta and O in Figure 2, while the plastic substrate was composed of carbon (C). Figure 3 shows Ta-4f and O-1s core level spectra of the Ta_2O_5 film. Ta-4f core level spectra exhibits two peaks centered 29.8 and 27.5 eV that can be assigned to 4 $f_{5/2}$ and $4f_{7/2}$ core level of $Ta5^+$. The binding energy value of 532.3 eV is O-1s core level spectra peak, the core level spectra were referenced to C-1s line at 310 eV[7]. Figure 4 shows the FTIR spectra of Ta_2O_5 film deposited on plastic substrate. The spectrum exhibited three major transmittance bands at 600.2cm^{-1} (due to Ta-O-Ta stretching) at 1100 cm^{-1} (due to short Ta-O terminal groups) and 1246.3cm^{-1} (due to CH_3 deformation), respectively. As for the electrical properties, the breakdown electric field measured via HP-4155 is 4.0 MV/cm for the sample made in $[Ta(OC_2H_5)_5] = 0.5$ ml. In summary, we have successfully produced Ta_2O_5 films on plastic by a low temperature LPHD method. Various characterizations such as XPS, and FTIR show that LPHD- Ta_2O_5 films is good and stable physical and chemical. The LPHD method is confirmed as a candidate for low cost, rapid deposition of Ta_2O_5 on plastic substrate.

References

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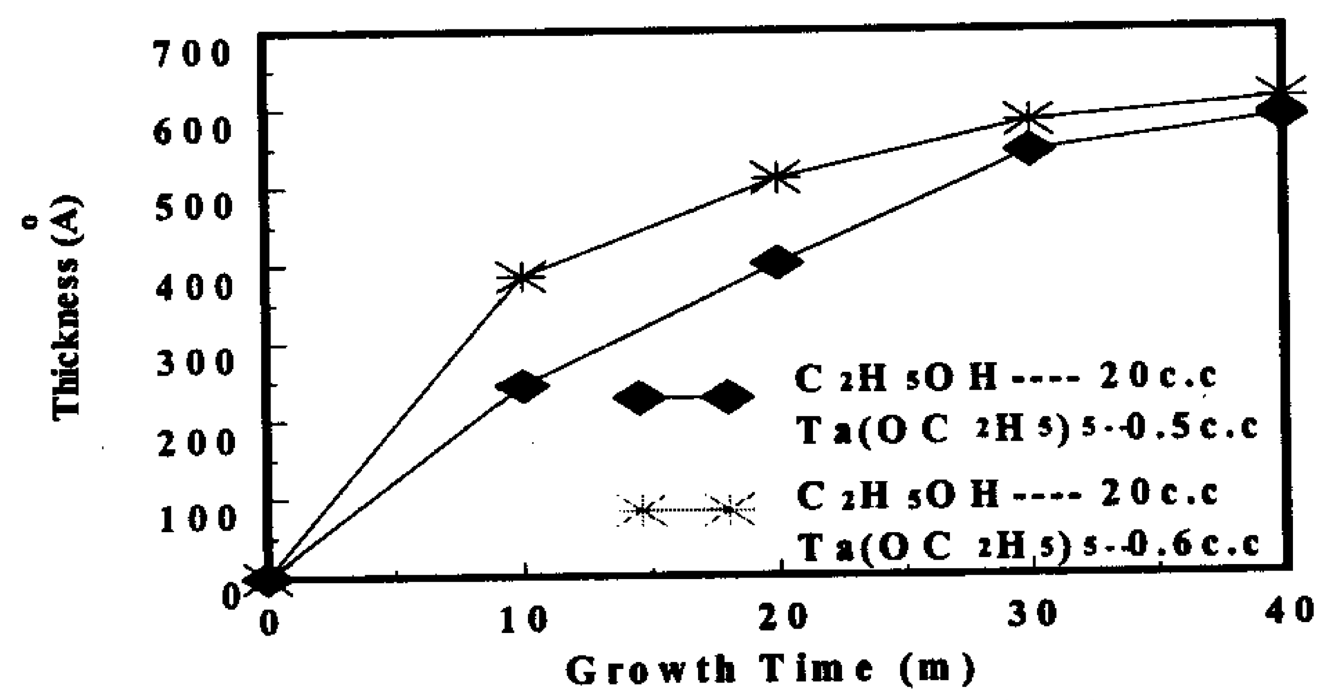

Fig 1. Dependence of film films thickness on immersion time at different growth solution.

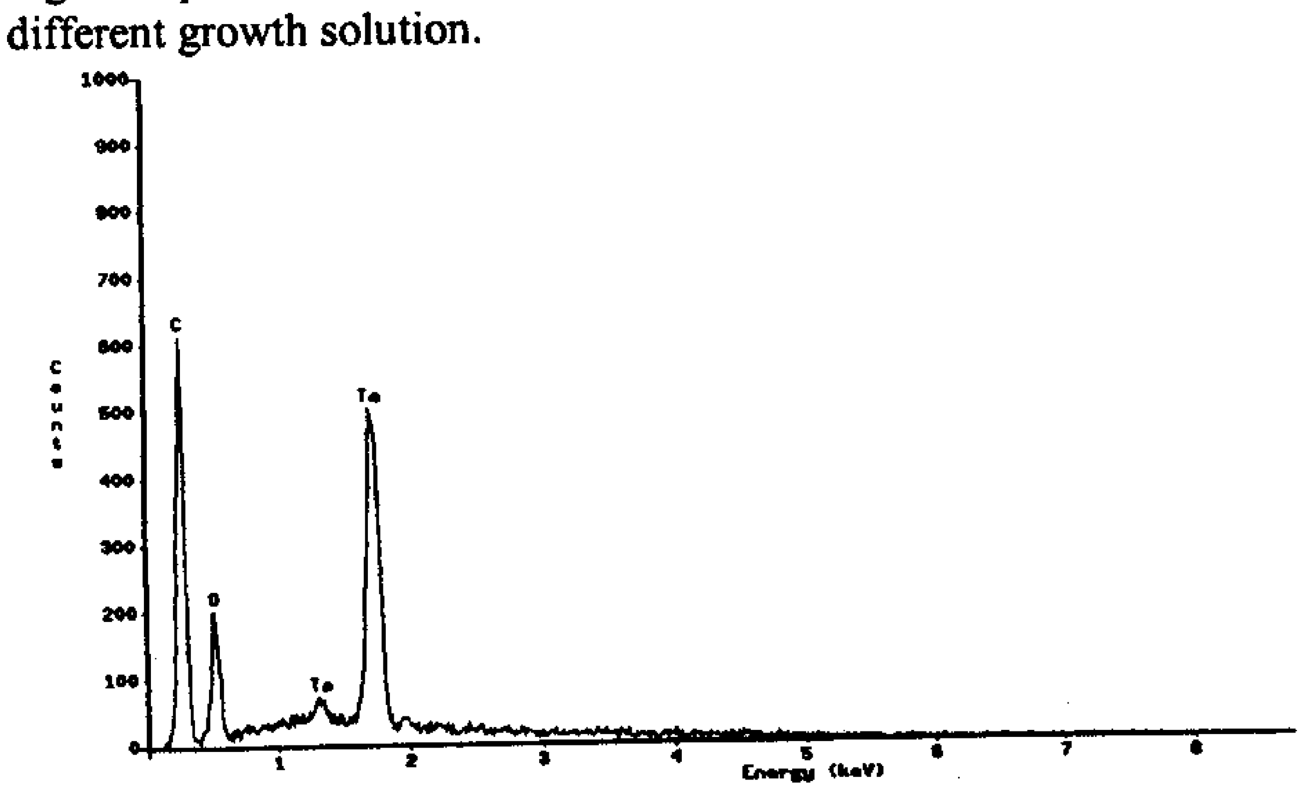

Fig 2. EDS spectrum from the interface between Ta_2O_5 and carbon.

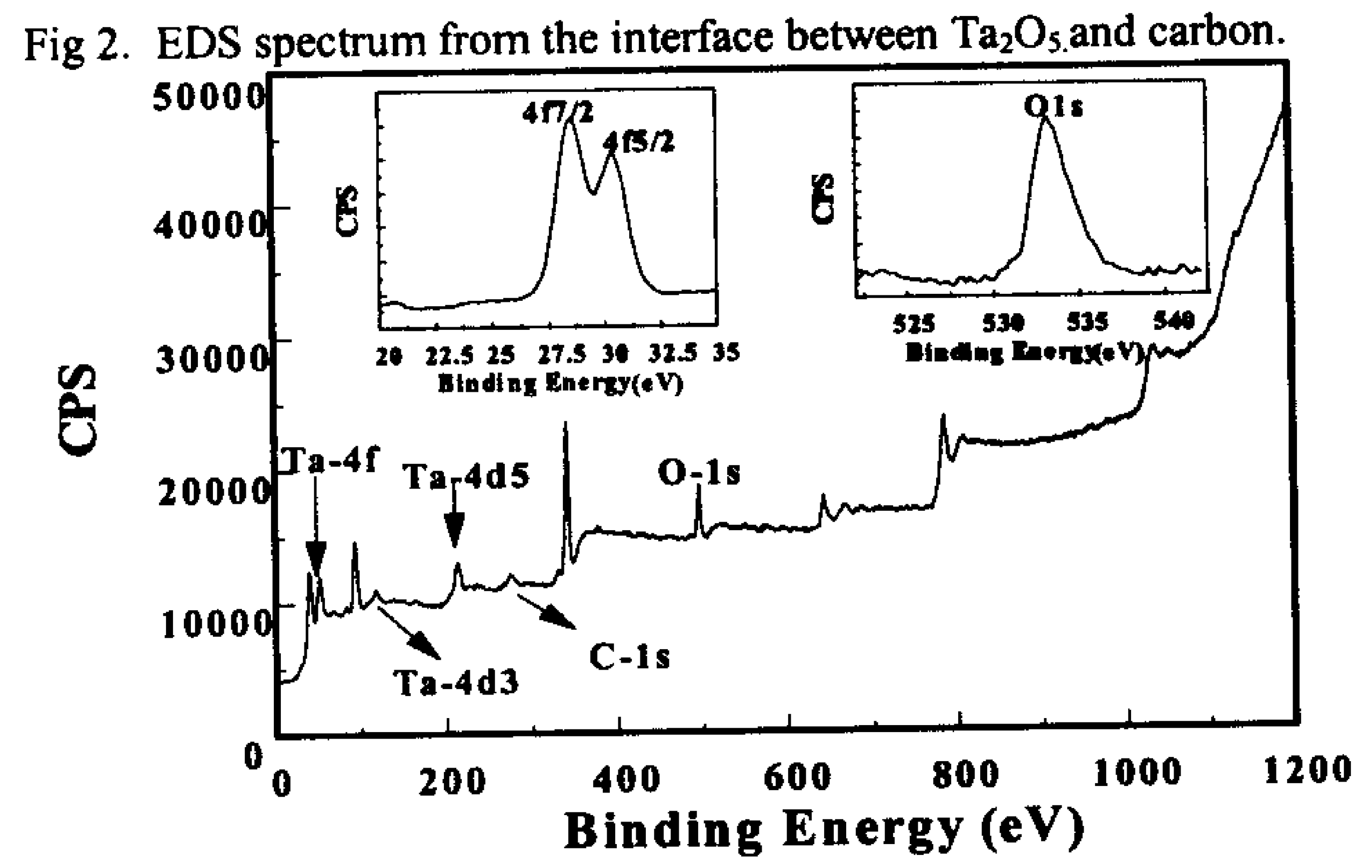

Fig 3. XPS spectrum of Ta_2O_5 film.

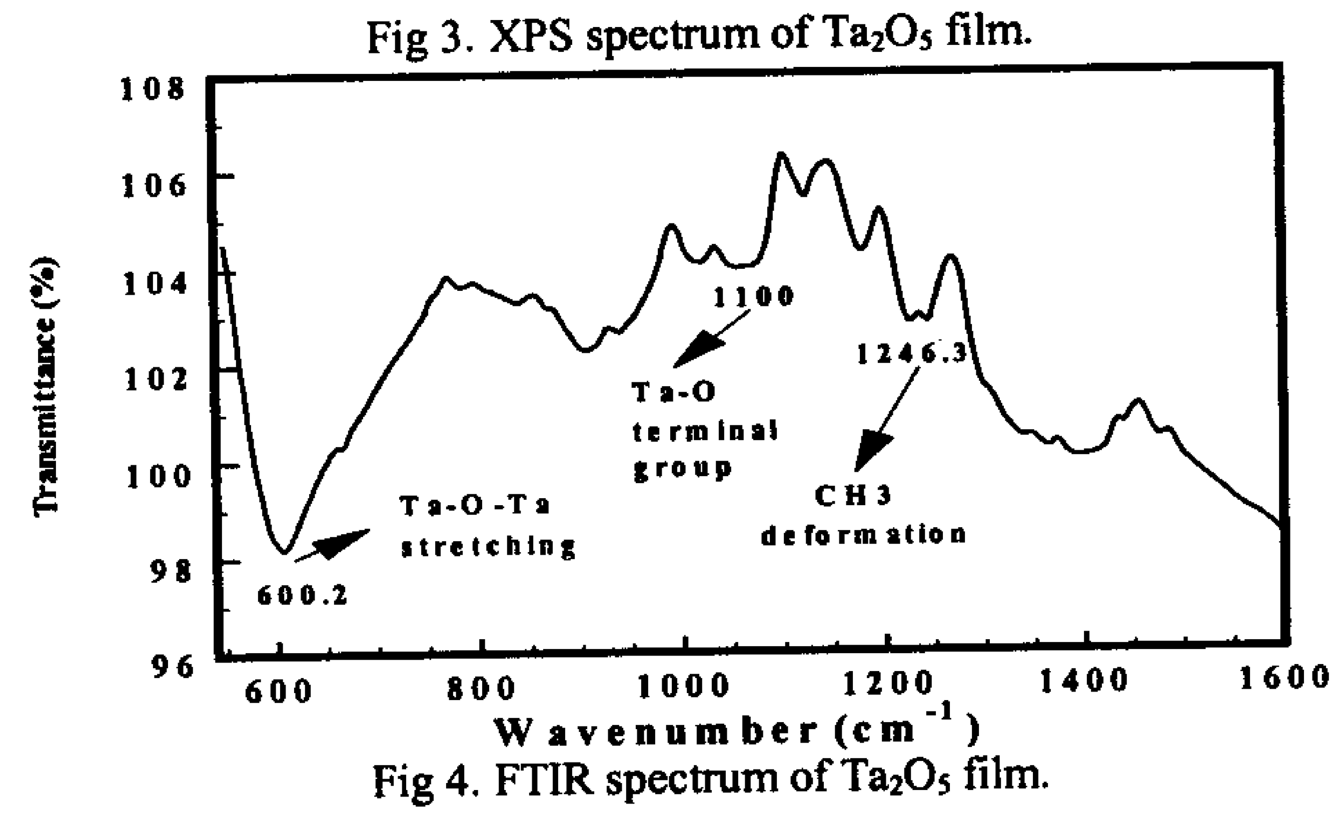

Fig 4. FTIR spectrum of Ta_2O_5 film.