Single layer antireflection coating on PET substrates for display applications

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Abstract

In the present investigation, we tried AR coating simulation by using the "Essential Macleod optical coating design and analysis" program. After various run of the program we selected appropriate materials which have specific refractive indices and for that thickness was optimized to get the low reflectance. By comparing the simulated results for the different materials,we found that SiO_2 and TiN are the appropriate materials for this Flat panel device (FPD) application. Thin films of these materials were deposited using RF magnetron sputtering and Inductively Coupled Plasma Chemical Vapour Deposition (ICPCVD) methods on Polyethyleneterephthalate (PET) substrates. Spectroscopic ellipsometer (SE MF-1000) and UV-Vis spectrophotometer (SCINCO) were used for the optical characterization. The obtained experimental results are in good agreement with the simulation results.

1. Introduction

Anti-reflection (AR) coating has been widely used in many applications including solar cells, and display devices such as cathode ray tubes (CRTs) as well as in Flat panel display (FPD)[1-3]. The major interest in the development of current flat-panel displays is to make products more portable by making them lighter and thinner. One of the essential technologies for this kind of product development is plastic-based flat panel displays, which usually make use of polymer substrate especially PET substrates which show good mechanical properties after some plasma pre-treatment [4]. We tried Single Layer Antireflection Coating(SLAR) coating simulation by using the Essential Macleod optical coating design and analysis program which is alternate for the multilayer layer coating used in the industries. This software contains all the essentials for the design and performance calculation of optical coatings. In particular, it calculates a wide range of performance parameters of a given coating design including the usual reflectance and transmittance magnitude and phase and also ellipsometric quantities. From this study we chose appropriate materials for which thickness was optimized for low reflectance.By comparing the simulated results for the appropriate materials for our process, SiO_2 and TiN were found to be the appropriate materials for the desired application. In general SiO_2 was deposited by high temperature process, but in our case the substrate is polymer, so we used high density plasma source i.e Inductively coupled plasma chemical vapour deposition for depositing uniform film on the PET substrates. RF sputtering system were used for the preparation of TiN. Optical measurements on these films were made to determine the reflectance and other parameters and compared with that of simulated results.

2. Experimental

The SiO_2 films were deposited using planar coil ICPCVD system with the source gases silane (SiH_4) and nitrous oxide (N_2O) with Helium (He) for igniting plasma. In this system, the intense degree of dissociation and ionization of nitrogen is established in a region away from the substrate. Silane-helium mixture passes through a distribution ring located under the plasma region. The plasma was generated by an RF power source .The inductively coupled plasma was generated from the top induction coil through dielectric quartz window. An applied voltage with the frequency of 13.56 MHz generates an oscillating magnetic field around this dielectric coil, which penetrates into the plasma and produces an azimuthal electric field. In our reactor, there was no azimuthal electric field on the axis and on the wall, there by peaking in an annular region at roughly half the radius. In the present process, the working pressure was maintained around 100mTorr inorder to get uniform film when the substrate was at room temperature. The flow rate of SiH_4 was fixed at 25 sccm and the Nitrous oxide flow rate was varied as 100,125,150,175 sccm for varying the refractive index and the power was fixed as 80W. The deposition rate is also varied when we changed the flow rates.The transmittance and the reflectance was measured for the four different samples of different thickness(around 950Å). The TiN films on PET substrates were prepared by RF magnetron sputtering. A 4 -inch disk type Ti with the purity of 99.99% was used as a target. Ar and N_2 gases were used as discharge and reactive gases. The deposition time was optimized for the desired thickness(200Å), at the fixed power of 200W and the N_2 flow rates were adjusted for varying the refractive index by keeping Ar flow rate fixed .The Transmittance and reflectance measurements were done for different N_2 flow rates and the refractive indices were measured. Spectroscopic ellipsometer is used to calculate the ψ and Δ functions, defined as

$$\tan\psi = |r_p| / |r_s|$$

and

$$\Delta = \delta 1 - \delta 2 ,$$

where r_p and r_s are the complex reflection coefficients for p and s polarization and $\delta 1$, $\delta 2$ are the phase different between the amplitude of the electric wave which waving in the plane of incidence (p-wave) and the amplitude of the electric wave waving perpendicular to the plane of incidence (s-wave) of the incident electromagnetic radiation before and after reflection [5], and then the refractive index was calculated from this values by modeling. SCINCO uv-vis spectrophotometer was used for the reflectance and transmittance measurements.

3. Results and discussion

The simulated results of reflectance are shown below for optimized condition of lower reflectance of SiO_2 and TiN , as shown in figures 1 and 2 and it is found to be around 2 and 10 % respectively. It has been found that the refractive index decreases with increase in flow rate. Here ψ is sensitive to the refractive index variation and insensitive to the thickness, which is vice versa in the case of Δ [6]. Also , the average reflectance was reduced from 10% to 2%, as shown in the figure 3. Similarly in the case of TiN the when the refractive index was reduced the reflectance was also reduced with that of the flow rates , as shown in the figure 4.Then, the experimental reflectance for SiO_2 for difference compositions is shown in the figure 5 as 1,2,3,4. It is found that for the gas flow ratio 6, the reflectance was reduced and it matched with that of the simulated results. In the case of TiN, the experimental reflectance for different N_2 flow rates was shown in the figure 6 as 1,2.It is found that for the gas flow ratio 30, the reflectance was reduced and it matched with that of the simulated results Out of these two chosen materials, the refractive index of TiN is found to be higher then that of the SiO_2, so its reflectance is also higher than that of the SiO_2.So SiO_2 can be regarded as a better candidate for the SLAR coating on the PET substrates for the FPD applications.

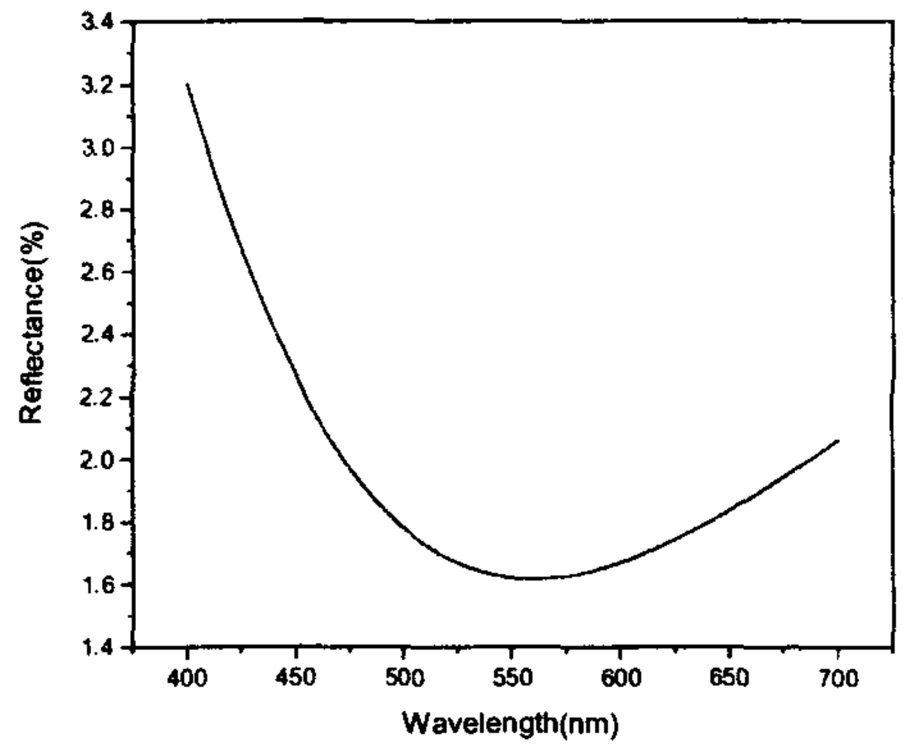

Figure 1: simulated reflectance of SiO2

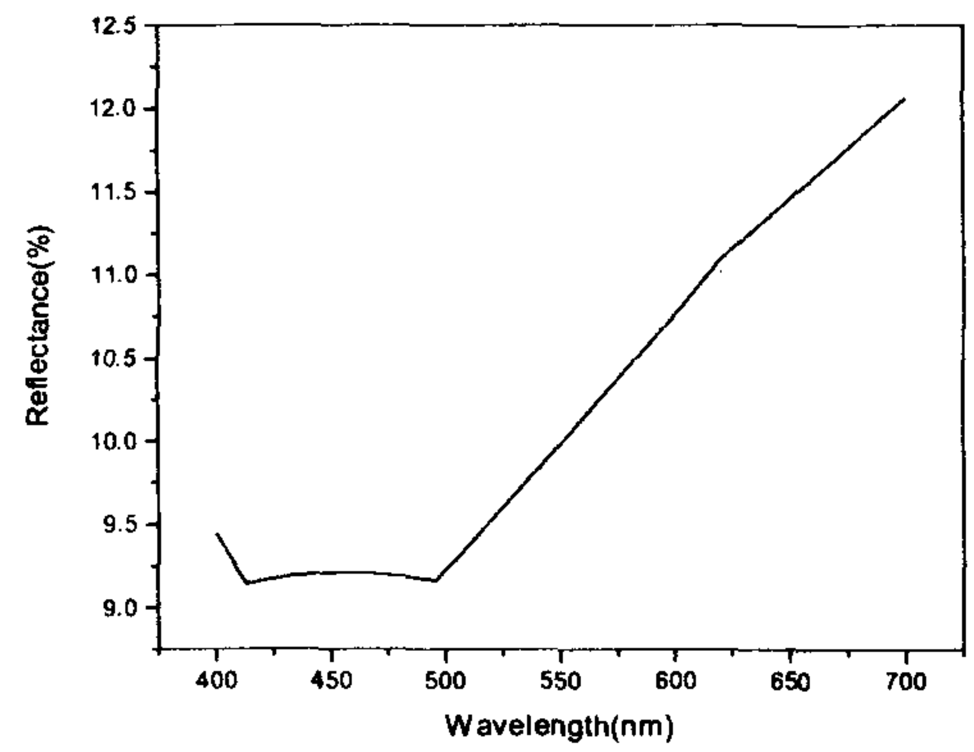

Figure 2: Simulated reflectance TiN

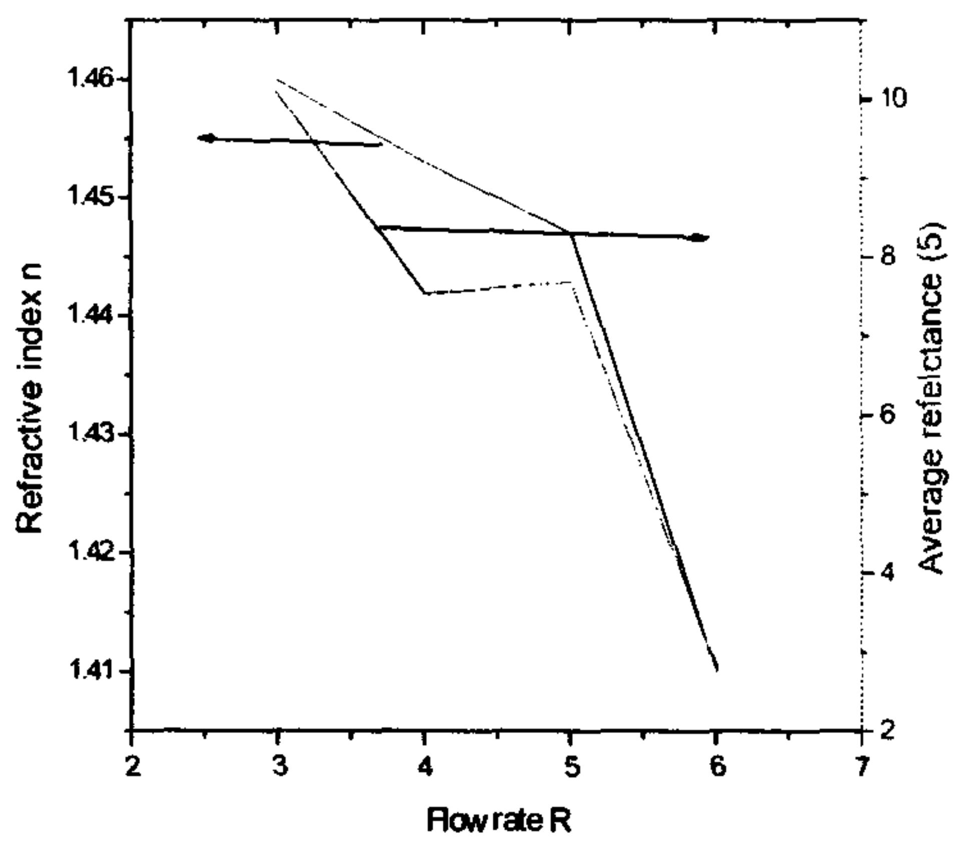

Figure 3 Refractive index Vs flow rates of N_2O Vs SiH_4

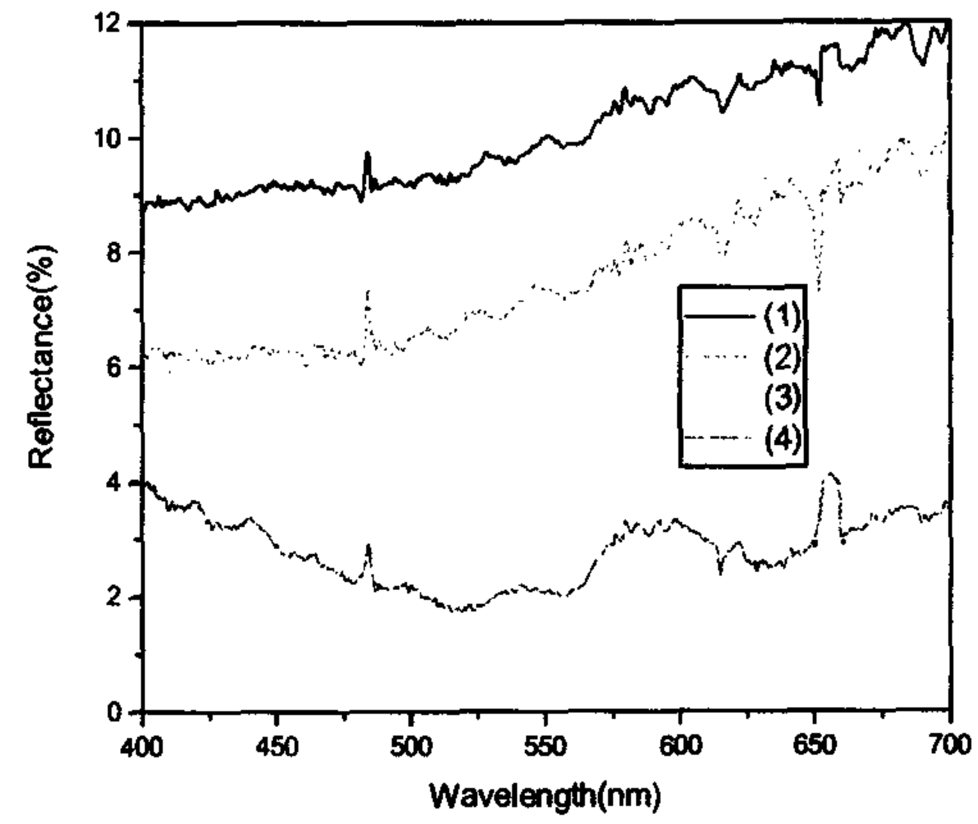

Figure 5 Reflectance of SiO_2/PET

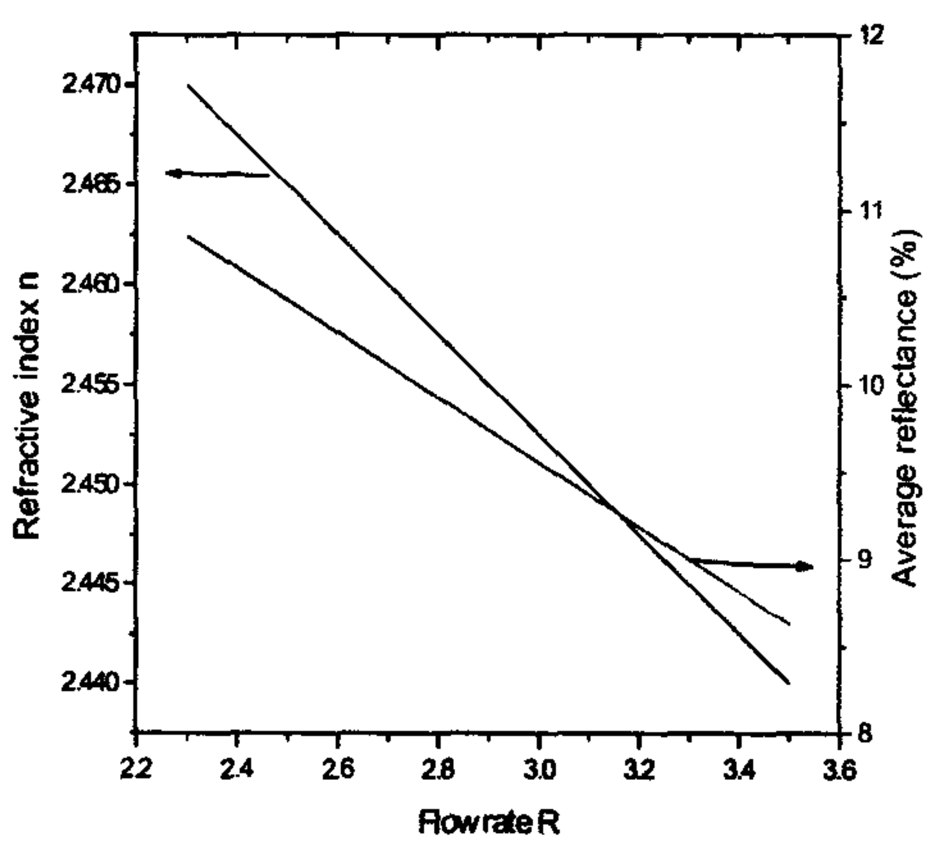

Figure 4 Refractive index Vs flow rates of Ar vs N_2

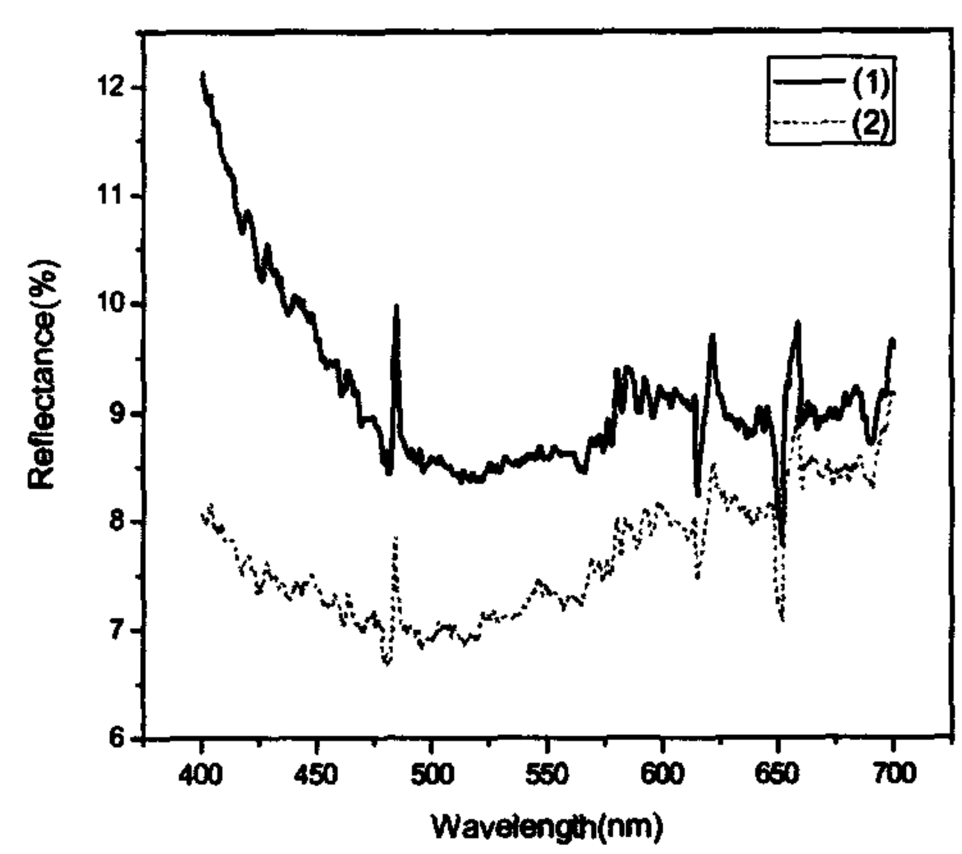

Figure 6 Reflectance of TiN/PET

4. Conclusion

From the simulation analysis and experimental observations, the best condition for the preparation of SiO_2 and the TiN films with low reflectance (3% & 10%) on the PET substrates for the flat panel display application has been reported in this paper. Also we have suggested that SiO_2 deposited by ICPCVD is the best candidate for the FPD application with the optimized conditions mentioned in the paper. These results can be instrumental to substitute multilayer AR coating by cost effective single layer AR coating in display devices.

5. References

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