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Characterization of Single and Double Layer Alq_3 And TPD Thin Films By Varying Growth Rate At Their Constant Thickness

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Abstract

A comparative study of single and double layer transmittance and absorbance of Tris-(8-hydroxyquinoline) aluminium (Alq_3) & N,N´-Bis(3-methylphenyl)-N,N´-diphynyl benzidine (TPD) films at different growth rate with constant thickness by using the UV-Visible spectrophotometer is reported. It is found that the percentage of transmittance and absorbance is significantly affected with the increase of growth rate, which are proved by electrical and optical properties with their figure of merit (FOM) value which is a function of optical transmittance and surface resistance. The best results in single layer Alq_3 and TPD are 85% & 84% (transmittance) and 0.0706 & 0.0757(absorbance) respectively. For the same wavelength region in double layer, the best results are 89.20% (transmittance) and 0.0496 (absorbance).

Keywords: Absorbance, FOM, Optoelectronics, Organic material, Transmittance.

1. Introduction

Transparent electronics is an advanced technology concerning the creation of invisible electronics devices. To realize transparent electronic & optoelectronic devices transparent properties of organic and inorganic materials have been widely utilized. Now a day's bilayer or multilayer thin films have been considered as promising candidate in different display devices. But sometimes it creates surface related problems. In particular, pinhole shorts can appear between the organic layers and as a result sometimes short-circuiting current should be directed into the electronic devices. In localized areas, these shorts can cause dark spots; with sufficient pinhole density the device no longer luminesces at reasonable voltages since current flows through the short rather than the working areas of the device. As a result of which non uniformities are occur in organic layer thickness [1, 2]. Haichuan Mu et al. study the morphology of TPD/ALq_3 film on ITO substrate using both evaporation & sputtering process [3]. Qin DS et al. give the effect of the morphologies & structure of light emitting film layers [4].Similarly Kim SY et al. report the luminescence properties of Alq_3 film grown by ionized-cluster-beam deposition [5].Recently Huang et al. developed a high transmittance NIO/TZO bilayer thin film using radio frequency magnetron sputtering [6]. In this paper we reported an optically high active TPD/Alq_3 thin film using thermal evaporation on glass substrate by varying growth rate at their constant thickness by

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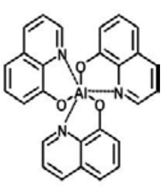
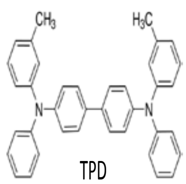
optimizing their growth rate and figure of merit (FOM) value.

2. Experimentel details

Before the deposition of the films on glass substrate, the substrates are ultrasonically cleaned by non –ionic detergent, de-ionized water, acetone & isopropyl alcohol each for 10 minutes. Then the films are dried in a vacuum oven for 12 hours at 60^0C. These approaches enhanced the film morphology of the deposited layer.TPD and Alq3 single layers and double layers are then deposited sequentially on the glass substrates at different thickness and growth rate. Here organic materials are purchased from Aldrich Chemical (Aldrich of 99.9%purity) and used without further purification. The effective area of the films is about 5mm×5mm. Here all the films of single and double layer were deposited by vacuum evaporation unit (MODEL-VT-2015) under the pressure of 10^{-5}-10^{-6} torr. The materials are purchased from Sigma Aldrich. The surface resistance of the films was measured by four probe set up and finally the optical properties of TPD and ALQ_3 thin films are analyzed by UV-Visible double beam spectrophotometer (MODEL LT-2800). Thickness and growth rate of different films are recorded by using thickness monitor (MODEL DTM-10). Chemical structures of Alq3 and TPD are given follow:



Alq3



3. Results and Discussion:

We have observed the absorbance (ABS) and transmittance (Trans) spectra of single and double layer of Alq_3 and TPD thin films which are deposited at different deposition rate by keeping their thickness constant. Here we find that within the same wavelength region, the Alq_3 (40nm) and TPD (35nm) films shows better optical properties with the increasing growth rate up to the critical one (here it is 8 $Ås^{-1}$) in both the single and double layer form of organic films with their different magnitude. The plot of absorbance vs. growth rate and transmittance vs growth rate for the single layer film is shown in figure -1(a) and 1(b) respectively. In this plots it is clear that the values of absorbance is initially decreases and then increases with the increase of growth rate and similarly transmittance values are also increases at first and then decreases with the increase of growth rate after optimum growth rate. This implies that too less or too high growth rate does not help in improving the surface property of the organic materials. There is a particular value in which the surface morphology of the organic layer is suitably enhanced. It is because at higher growth rate i.e. closed to the value of critical one, surface of the organic layers films are became more suitable from optical point of view. In this range of growth rate, the film morphology is greatly enhanced which is due to the less crystal defect and more homogeneity appear in film formation but after optimized value (here it is $8Ås^{-1}$) some localized crystal defect are formed because of the rapid movement of organic materials from source to substrates in small interval of time during crystal scattering process . This result also verifies the earlier report [3, 4, and 7].

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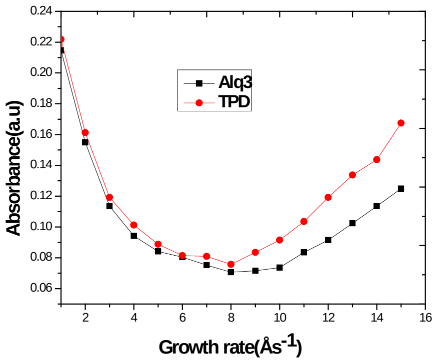

Fig: 1(a) Graph of Growth rate *vs* Absorbance of single layer film.

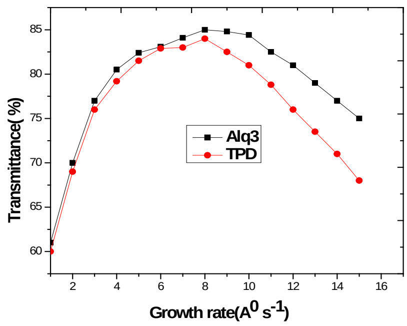

Fig: 1(b) Graph of Growth rate *vs* Transmittance of single layer film.

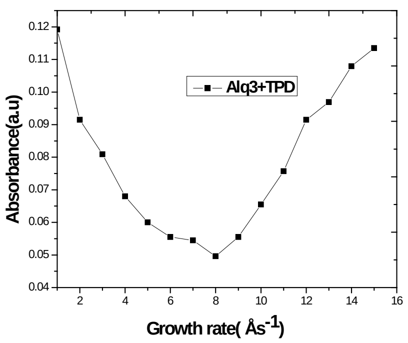

Fig: 2(a) Graph of Growth rate vs Absorbance of double layer film.

The plot of absorbance and transmittance vs. growth rate for the double layer films is shown in the figure-2(a) and (b) respectively. From this figure it is clear that the optical properties of bilayer (i.e. Alq3+TPD) film are better than single layer films within the same wavelength region. As shown in figure-(2), better result of transmittance and minimum value of absorbance of the bilayer films are 89.2% and 0.0496 respectively which are better than the single layer value of each organic thin film, which implies that bilayer film is more suitable than single layer film in practical application.

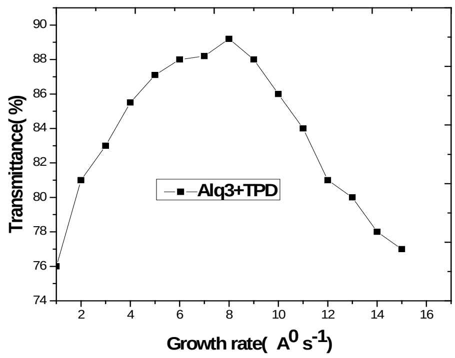

Fig: 2(b) Graph of Growth rate vs Transmittance of double layer film.

It is due to the formation of pinhole free surface with higher uniformity [1,2,5,6,8]. We see that the optical properties are greatly decreases with the increase of growth after optimization (i.e. 8 $Ås^{-1}$). This is due to the fact of appearance of localized crystal defect and non homogeneities at too higher growth rate.

To investigated the electrical properties of single and bilayer organic film we detect the surface resistance of the respected film by using the four probe set up measurement. With the help of this measurement we finally calculated the figure of merit (i.e. a function of optical transmittance and surface resistance) value which is an important parameter for evaluating the performance of transparent conducting organic films. The FOM is defined as **FOM= T^{10}/Rs**, where T is the optical transmittance and Rs is the sheet resistance [9]. As shown in Table 1, the FOM reached a maximum value of $14.76\times10^{-3}\ \Omega^{-1}$ for the Alq3 (40nm) +TPD (35nm) bilayer film, which is greater than the figure of merit (FOM) for the individual single layer organic film used in this study. Since the higher FOM value indicates the better quality of transparent conducting organic films, it is therefore considered that the bilayer organic film with a growth rate of 8Ås^{-1} will clearly perform better result in opto- electronics applications than single layer

Table 1: Electrical and optical properties of single and bilayer organic film with FOM

S.N.	Thin film	Growth rate^{A}	Minimum Absorrbance (a.u)	Optical transmittance (T %)	Surface resistance^{B} (ohm/square)	T^{10}	Figure of merit (Ω^{-1})
1	Alq3	8Ås^{-1}	0.0706	85.0	23	0.19	8.26×10^{-3}
2	TPD	8Ås^{-1}	0.0757	84.0	24	0.17	7.08×10^{-3}
3	Alq3 +TPD	8Ås^{-1}	0.0496	89.20	21	0.31	14.76×10^{-3}

A = Growth rate at the optimized condition, B = resistance fluctuates within the range of ± 0.04 ohm/square.

Table 1 shows the optical and electrical properties of both single and bilayer thin film which indicated that bilayer film properties are more suitable than the single layer film. This is similar to the earlier reported [10], in which the films in bilayer form have a lower resistivity value than that of the single layer film due to increases in both carrier concentration and mobility.

Conclusion:

In this observation we see that when growth rate is slowly increases , the Alq3 & TPD based both single and double layer films became more suitable to use as a transparent layer until the growth rate became too high(i.e. greater than 8Ås^{-1}). After critical value, both the electrical and optical properties are greatly affected by the growth rate. Therefore it is seen that growth rate has a direct impact on the surface properties of organic films and is a critical factor in the determination of thin film morphology. The best results in double layer of TPD & Alq_3 are 89.2% (transmittance) and 0.0496 a.u. (absorbance) at the growth rate 8 A^0 s^{-1} which have potential application in transparent electronic devices like organic light emitting diode.

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