

## Organic heterostructures based on arylenevinylene oligomers deposited by MAPLE



M. Socol<sup>a,\*</sup>, N. Preda<sup>a</sup>, L. Vacareanu<sup>b</sup>, M. Grigoras<sup>b</sup>, G. Socol<sup>c</sup>, I.N. Mihailescu<sup>c</sup>, F. Stanculescu<sup>d</sup>, M. Jelinek<sup>e,f</sup>, A. Stanculescu<sup>a</sup>, M. Stoicanescu<sup>g</sup>

<sup>a</sup> National Institute of Materials Physics, 105 bis Atomistilor Street, P.O. Box MG-7, Bucharest-Magurele 077125, Romania

<sup>b</sup> P. Poni Institute of Macromolecular Chemistry, 41 A Gr. Ghica Voda Alley, 700487 Iasi, Romania

<sup>c</sup> National Institute for Laser, Plasma and Radiation Physics, Str. Atomistilor Nr. 409, PO Box MG-36, Bucharest-Magurele 077125, Romania

<sup>d</sup> Faculty of Physics, University of Bucharest, Str. Atomistilor Nr. 405, P.O. Box MG-11, Bucharest-Magurele 077125, Romania

<sup>e</sup> Institute of Physics ASCR v.v.i., Prague 8, Czech Republic

<sup>f</sup> CR FBMI CTU, Prague, nam. Sitna 3105, Kladno 2, Czech Republic

<sup>g</sup> Transilvania University of Brasov, B-dul Eroilor Nr. 29, Brasov, Romania

### ARTICLE INFO

#### Article history:

Received 30 June 2013

Received in revised form

30 September 2013

Accepted 16 December 2013

Available online 25 December 2013

#### Keywords:

Organic heterostructures

MAPLE

Oligomer

Optoelectronic

### ABSTRACT

Organic heterostructures were fabricated by matrix assisted pulsed laser evaporation (MAPLE) method using arylenevinylene oligomers based on triphenylamine (P78)/carbazole (P13) group and tris(8-hydroxyquinolino)aluminum salt (Alq3). Optical properties of the organic multilayer structures were characterized by spectroscopic techniques: FTIR, UV-vis and photoluminescence (PL). A good transparency (over 60%) was remarked for the structures with two organic layers in the 550–800 nm range. Photoluminescence (PL) spectra proved that the emission characteristics of the materials have been preserved. *I*–*V* characteristics of (ITO/oligomer/Alq3/Al and ITO/Alq3/Al) heterostructures were symmetrically while rectifying properties of these heterostructures have not been observed. A comparison between the heterostructures made of layers with different thickness reveals that the higher current ( $8 \times 10^{-6}$  A at 1 V) was obtained for the ITO/P78/Alq3/Al heterostructure, which is characterized by a larger thickness of the double organic layer. AFM measurements revealed a similar topography while RMS values of the reported structures depend on the organic material.

© 2013 Elsevier B.V. All rights reserved.

### 1. Introduction

In the last years an alternative to the inorganic materials in device applications is given by the organic compounds due to the low cost implied in their processing. Intensive studies regarding the most important applications of these materials in photovoltaic cells (OPV) [1–3], organic light emitting devices (OLEDs) [4–6] and field effect transistors (OFET) based on organics (small molecules, monomers, oligomers or polymers) active material [7–9] were carried out in the research laboratories and industry. Depending on their molecular mass (small molecule or polymers) and the solubility degree of the compounds in adequate solvents, a variety of methods were developed for the deposition of organic thin films. Small molecule materials were successfully deposited by vacuum methods (thermal vacuum evaporation [10,11], molecular beam epitaxy [12,13], etc.) while for compounds with large molecular mass the techniques based on organic solutions are more suitable (spin-coating [14–16], inkjet printing [17,18], etc.).

An alternative method, matrix assisted pulsed laser evaporation (MAPLE) which assures the preservation of the chemical structure of the organic material has been employed for both, polymers and small molecules [19–21].

In the design of organic heterostructures, a crucial role is played by the band alignment of the component layers. ITO was frequently used as transparent conductor in OPV and OLED due to its high optical transparency and low resistivity. Moreover, ITO is characterized by a large work function and it is known as hole injector [22]. The same band alignment considerations are fundamental for the organic materials selection. They are chosen to assure a good injection from ITO electrode in the first organic layer and to facilitate the charge carrier transport. Also, a low energetic barrier at the ITO/organic, organic/organic and organic/metal interface is required.

The molecular structure of the oligomers based on aromatic amines is associated with the doping groups situated at the ends linked by conjugated bridges. Their good optical properties and the improved conduction determined by the reduced steric effect recommend these materials for optoelectronic applications.

Therefore, arylenevinylene oligomers, 1,4-bis [4-(N,N'-diphenylamino)phenylvinyl] benzene (P78) and 3,3'-bis

\* Corresponding author. Tel.: +40 (0)21 3690185; fax: +40 (0)21 3690177.  
E-mail address: [cela@infim.ro](mailto:cela@infim.ro) (M. Socol).

**Table 1**  
Deposition conditions and RMS/Ra values of the organic heterostructures grown on glass/ITO by MAPLE.

| Sample         | Substrate | ITO thickness (nm) | ITO resistivity $\times 10^{-4}$ ( $\Omega$ cm) | No. of pulses | Organic film thickness (nm) | RMS (nm) | Ra (nm) |
|----------------|-----------|--------------------|---|---------------|-----------------------------|----------|---------|
| ITO/1P78       | glass/ITO | 1620               | 2.48  | 80 000        | 130                         | 35.3     | 24.6    |
| ITO/2P78       | glass/ITO | 1580               | 2.49  | 160 000       | 250                         | 36.2     | 23.8    |
| ITO/1P13       | glass/ITO | 1200               | 2.59  | 80 000        | 110                         | 10.4     | 8.2     |
| ITO/2P13       | glass/ITO | 1230               | 1.80  | 160 000       | 200                         | 12.6     | 9.0     |
| ITO/1Alq3      | glass/ITO | 1450               | 2.70  | 80 000        | 160                         | 26.0     | 18.1    |
| ITO/2Alq3      | glass/ITO | 1380               | 2.53  | 160 000       | 300                         | 30.1     | 23.1    |
| ITO/1P78/1Alq3 | glass/ITO | –                  | –   | 80 000        | 290                         | 31.8     | 23.4    |
| ITO/2P78/2Alq3 | glass/ITO | –                  | –   | 160 000       | 550                         | 29.1     | 22.7    |
| ITO/1P13/1Alq3 | glass/ITO | –                  | –   | 80 000        | 270                         | 26.2     | 19.5    |
| ITO/2P13/2Alq3 | glass/ITO | –                  | –   | 160 000       | 500                         | 28.5     | 19.2    |

(N-hexylcarbazole)vinylbenzene (P13), containing electron-donating groups (triphenylamine and N-alkylcarbazole) are attractive due to their photoluminescence properties. The charge carrier transport in such compounds characterized by hole conduction was previously studied [10,23]. The ionization energy ( $E_{\text{HOMO}}$ ) of these oligomers [10] is closer to the ITO work function, which is situated between 4.5 eV and 5 eV [22]. This small energetic barrier can provide a good hole injection in oligomers.

Due to its electron conduction and good luminescent properties, Alq3 is frequently used as electron transport layer (ETL) in the fabrication of OLEDs. The ionization potential of Alq3 ( $E_{\text{HOMO,Alq3}} = 5.1$  eV [24]) allows an adequate transport of the charge carriers to the metallic electrode.

In this paper, we report a study based on single and double organic layer heterostructures obtained by MAPLE method using P78 and P13 oligomers as hole transport layer and Alq3 as electron transport layer. The roughness, optical and electrical properties of these heterostructures was investigated. This paper presents also investigations on the charge carrier injection at the ITO/organic and organic/organic interfaces as well as the electrical conduction in dark of ITO/double or single organic layer/metal (i.e. ITO/P78(P13)/Alq3/Al and ITO/Alq3/Al). The influence of the organic layer thickness on the electrical properties was also studied.

## 2. Experiment

Pulsed laser deposition (PLD) method was employed for the deposition of transparent conductive oxide (TCO) on glass substrates. The laser beam was focused on the ITO target (SCI Engineered Materials) at an incidence angle of  $45^\circ$  using a MgF<sub>2</sub> lens with a focal length of 300 mm, mounted outside the chamber. The KrF\* excimer laser source (Coherent, CompexPro 205) operates at  $\lambda = 248$  nm,  $\tau_{\text{FWHM}} \sim 25$  ns [22,25] and 5 Hz repetition rate. All the depositions were carried out at room temperature. During the deposition, the oxygen pressure was 1.5 Pa while the target-substrate distance and the laser fluence onto the target surface were 5 cm and  $3 \text{ J/cm}^2$ , respectively. Prior the deposition, the glass substrates ( $25 \text{ mm} \times 25 \text{ mm}$ ) were subsequently cleaned in acetone, ethanol and demineralized water inside an ultrasonic bath and dried in high purity nitrogen flow.

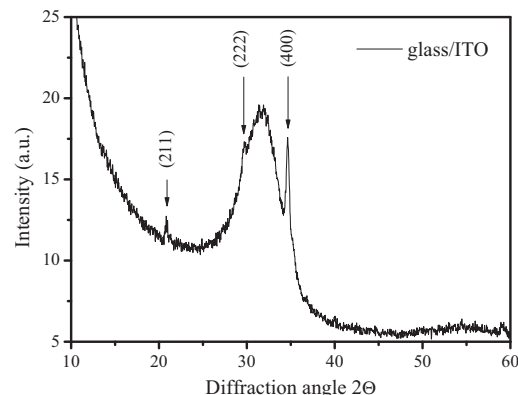
In the second step, the first layer deposited by MAPLE on ITO and double side polished (100) silicon was an arylenevinylene oligomer containing triphenylamine or N-alkylcarbazole group situated at the ends (P78 or P13). These oligomers act like donor (D) layers in the heterostructures. Details about the chemical structure and synthesis of these materials are given in references [10,23]. The second layer of the heterostructures was Alq3 which operates as acceptor (A) layer. During the MAPLE deposition, the substrates were maintained at room temperature. MAPLE targets were prepared from solutions of 2.5% (w/v) oligomers or Alq3 in dimethyl sulfoxide (DMSO) [21,23,24] which were frozen by immersion in liquid nitrogen for 30 min. All the MAPLE

depositions were performed at laser frequency and fluence of 5 Hz and  $250 \text{ mJ/cm}^2$ , respectively. The organic layers were deposited successively in the same condition, firstly the oligomer and secondly the Alq3, as shown in Table 1. It is known that it is difficult to obtain heterostructures with two organic thin film using a method from solution because the solvent used for the deposition of the second layer can affect the first deposited layer. Using the MAPLE method, heterostructures with successive organic films can be deposited due to the soft process implied, mostly of laser energy being absorbed by the solvent used to prepare the frozen target.

The thickness of the MAPLE organic films (Table 1) was measured by spectroscopic ellipsometry (SE) with a Woollam VASE 32 equipment (experimental conditions:  $\lambda = 190\text{--}1340$  nm;  $\alpha_{\text{incidence}} = 65\text{--}70^\circ$  or  $70\text{--}75^\circ$ ; spectral resolution = 10 nm) using a Cauchy model for fitting the experimental data. The inferred thicknesses were 130 nm or 250 nm for P78 films, 110 nm or 200 nm for P13 films and 160 nm or 300 nm for Alq3 films.

The same heterostructure deposited on ITO covered glass has been prepared on Si substrate during the same deposition cycle. This reference sample was used to measure ellipsometrically the thickness of each organic film. The thickness of the first organic layer was evaluated by ellipsometry using the Cauchy model and considering the Si wafer covered with a native layer of SiO<sub>2</sub> as substrate. Subsequently, the second layer was deposited onto the first organic layer. The thickness of this layer was inferred from the new ellipsometric data considering the sandwich consisting of Si wafer covered by native SiO<sub>2</sub> and the first organic layer as the substrate for the second layer.

In order to complete our heterostructures, on the top of the second organic layer was deposited 150 nm aluminum electrode with an area of  $0.30 \text{ cm}^2$  by thermal vacuum evaporation through a shadow mask. The deposition process was carried out at a pressure of  $10^{-4}$  Pa, with a deposition rate of  $4 \text{ \AA/s}$  using a SPECTROS system from Kurt J. Lesker.



**Fig. 1.** XRD diffractogram of ITO deposited by PLD on glass substrate.

Download English Version:

<https://daneshyari.com/en/article/5351631>

Download Persian Version:

<https://daneshyari.com/article/5351631>

[Daneshyari.com](https://daneshyari.com)