Investigation of Photoluminescence and Electrical Properties of 3,6-Di(9-Carbazolyl)-9-(2-Ethylhexyl)Carbazole

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Abstract - **In this paper the photoluminescence of organic semiconductor 3,6-di(9-carbazolyl)-9-(2-ethylhexyl) (TCz1) film and electrical properties of the device on it base are investigated. In the photoluminescence spectrum of TCz1 films at excitation of 320 and 350 nm the new red shifted band appeared which was not observed with the excitation wavelength of 270 nm. An analysis of frequency dependences of the impedance showed that the device ITO/CuI/TCz1/Al can be simulated by an equivalent circuit consisting of two series RC elements representing the organic film bulk and space charge region.**

Keywords - **Organic light emitting devices, carbazole derivates, impedance spectroscopy, photoluminescence spectra.**

I. INTRODUCTION

Organic light emitting diodes (OLEDs) are very promising candidates for flat-panel device applications due to low power consumption, improved contrast and brightness in comparison to LCDs or plasma displays [1]. The efficiency of OLEDs is highly dependent on optical and electrical properties of organic materials [2]. Organic semiconductor 3,6-di(9-carbazolyl)-9-(2-ethylhexyl)carbazole (TCz1) (Fig.1,a), was recently successfully used as efficient blue light emitting [3], electron transport [4] and host material for blue organic electrophosphorescence devices [5]. In this work we studied protoluminescence of TCz1 films and frequency dependences of the impedance of device ITO/CuI/TCz1/Al, which was fabricated by thermo vacuum deposition method.

II. EXPERIMENTAL DETAILS

The formation of the TCZ1 film and the device ITO/CuI/TCz1/Al was described in [3]. Photoluminescence measurements were performed with a CM 2203 fluorimeter. Absorption spectra were recorded with a Shimadzu UV-2450 spectrograph. Scanning electron microscope (SEM) (Hitachi SU-70) was used to investigate the cross-section images of the films. The current density–voltage (J-V) characteristics and the impedance measurements of ITO/HPhP/Al structures were performed in the frequency range of (0.01-1000) kHz at constant bias voltage, using measuring instrument "AUTOLAB" (Eco Chemie) with FRA-2 and GPES software.

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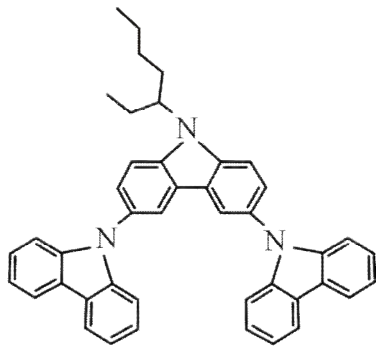
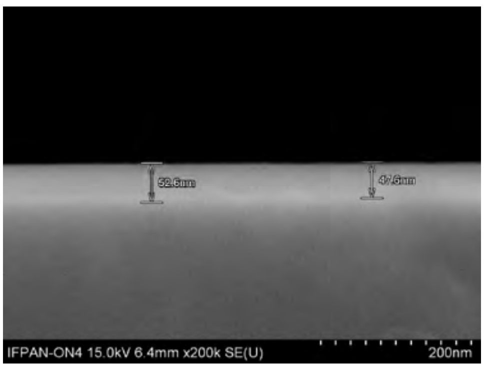
III. RESULTS AND DISCUSSION

TCz1 film is homogeneous with an thickness of ~50 nm, as it is confirmed by SEM images presented in Fig.1,b.
Photoluminescence spectrum of TCz1 films at excitation of 270 nm is characterized by two well-defined narrow peaks at 394 nm and 410 nm (Fig.2) as was been reported for this films and solution previously [3], but at the excitation of 320 and 350 nm the new red shifted band is appeared at 450 nm (Fig.2).



a)



b)

Fig.1. Chemical formula of TCz1 (a) and cross-section for TCz1 films deposited Si (b).

The effect of excitation wavelength on luminescence properties confirm of formation new fluorescence centers in the films that can be explained by intermolecular interaction in vacuum deposited TCz1 films.

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Additional information on relaxation processes, bulk and interface characteristics for organic semiconductors and devices based on organic materials can be obtained using electrical impedance spectroscopy [6].

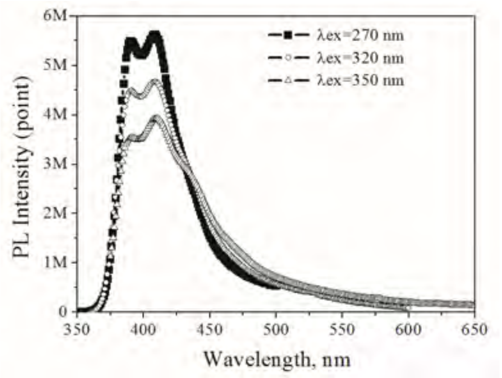

Fig.2. Fluorescence spectra of evaporated TCz1 film.

Figure 3 shows the diagram relating the real Re(Z) and imaginary Im(Z) parts of the complex impedance Z of the ITO/CuI/TCz1/Al device in the frequency range (f) from 10 Hz to 1 MHz at a different bias. As it is shown in Fig.4 the equivalent circuit of the structure consists of a two series *RC* circuits (*R2C1* and *R3C2*) network with a serial resistor R1, characterizing the bulk parameters (*R2* and *C1*) of the device and the parameters (*R3* and *C2*) of the barrier appearing at the interface of organic semiconductor and metal (Al) [7]. Fitting curves match with the impedance spectra in the whole measuring frequencies as seen in Fig. 3.

In the low-frequency region, the device resistance is significant and is mainly controlled by the total real component [6]; in this case, the junction capacitance has a significant effect on the current's flow processes.

Accordingly, we find the bulk and barrier parameters of fabricated devices (Tabl.1)

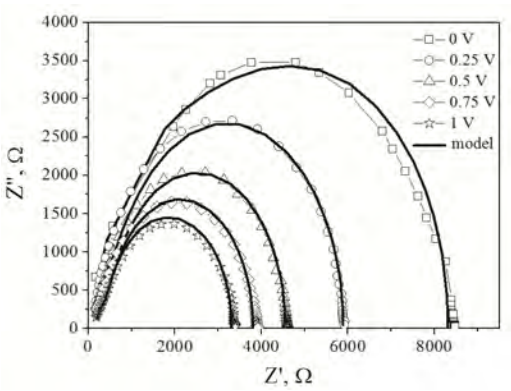

Fig. 3. Nyquist diagrams of device ITO/CuI/TCz1/Al at 0, 0.25, 0.5, 0.75 and 1 V. Symbols are measured data and solid lines represent fitting results.

The low-frequency maximum (Fig. 3) corresponds to the *R3C2* circuit (see Fig. 4) characterizing the barrier. As the frequency increases, the junction capacitance *C2* limits the current flow through the device. Thus, the effect of the *R3C2* circuit responsible for the barrier can be disregarded. The *R2C1* circuit begins to play a dominant role in the current flow; if the relation $R2 = 1/(2\pi C1)$ is satisfied, the second maximum is observed (Fig. 3).

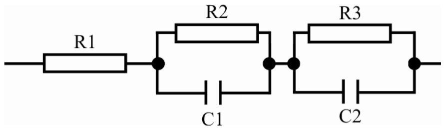

Fig.4. Equivalent circuit of the ITO/CuI/TCz1/Al device.

Table i.

Fitting parameters of impedance data for ITO/CuI/TCz1/Al structure at various bias voltages.

Bias (V)	R1 (Ω)	R2 (kΩ)	R3 (Ω)	C1 (nF)	C2 (nF)
0	178	5.3	2787	2.3	0.5
0.25	180	5.2	459.6	5.5	6.9
0.5	184	4.0	349.7	5.3	4.5
0.75	184	3.3	281.4	5.0	3.0
1	178.8	2.9	252.4	4.6	3.2

III. Conclusion

The effect of excitation wavelength on photoluminescence properties of vacuum deposited TCz1 films was observed. From impedance measurements it was found the bulk and barrier parameters of fabricated devices ITO/CuI/TCz1/Al structure. Fitting and experimental curves match with the impedance spectra in the whole measuring frequencies.

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