

Technology of creating organic light-emitting structures

A E Degterev, I A Lamkin and S A Tarasov

Saint Petersburg Electrotechnical University “LETI”, 197376, Saint Petersburg, Russia

E-mail: alex.degterev@rambler.ru, ialamkin@mail.ru

Abstract. Methods of creating organic layers for light-emitting structures were investigated in this work. The photo- and electro-luminescence spectra of the made structures were measured. The necessary conditions for the creation of optimal layers were experimentally revealed.

1. Introduction

Organic light-emitting structures (OLED) are semiconductor devices created from a number of thin organic films. Light is emitted, when the electric current passes through the structure. The structure of OLED consists of a transparent substrate, a transparent anode, transport layers with a hole and electronic conductivity, an active layer, and a cathode [1].

Each material must be applied in a specific way. In this paper we used the method of vacuum thermal evaporation and the spin-coating method. The choice of the way to create the structure is a serious task. The properties of each of the layers, including the electrodes, greatly influence the parameters of the manufactured sample.

2. Experiment: change of substrate heating temperature

Organic light-emitting structures FTO/PEDOT:PSS/TPD/Alq3/Al were created. Transport layers such as PEDOT:PSS, TPD and Alq3 were alternately applied on the glass substrate with a layer of FTO. Then were created aluminum contacts.

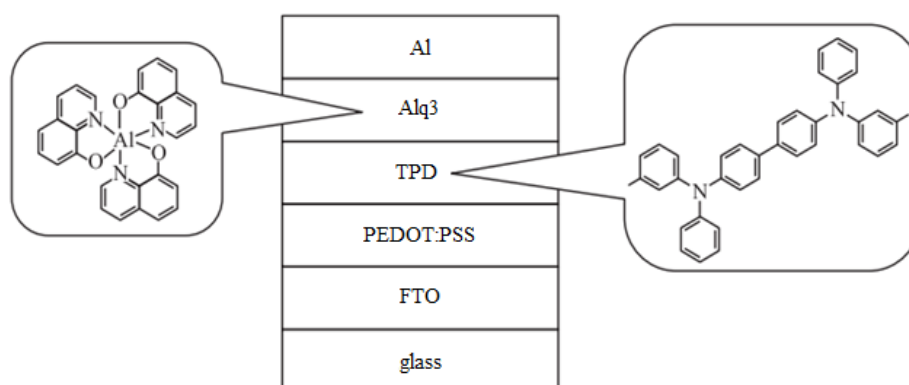


Figure 1. Structure of created OLED [2].

Substance PEDOT: PSS is a polymeric compound. Its properties are p-type conductivity and electron-blocking. The TPD (N, N'-Bis (3-methylphenyl) -N, N'-diphenylbenzidine) is a small molecular



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

compound. It has a hole conductivity. The material Alq3 (Tris- (8-hydroxyquinoline) aluminum) has an electronic conductivity and it is an active layer in the created structures.

Due to the large molecular weight of the material, the evaporation temperature of the compound exceeds the decomposition temperature, so PEDOT: PSS was applied to the substrate with FTO by the spin-coating method. The centrifugation time was 30 seconds, the speed was 3000 r/s, the number of layers was 1. The TPD and Alq3 materials are small-molecular compounds with low solubility. Because of that, they were applied by the method of vacuum thermal evaporation. The precipitation was carried out from a ceramic melting pot heated by a molybdenum heater. The pressure of the residual gases did not exceed 10^{-5} Torr. It was made to maintain the maximum purity of the evaporated material upon deposition on the substrate.

It was established, the temperature of the glass substrate's heating affects the quality of the obtained layers. The photoluminescence spectra of the TPD and Alq3 layers were investigated to determine the optimum substrate heating temperature.

Investigation of the materials photoluminescence was done to determine the homogeneity of the created layers. It was carried out with a scanning excitation laser beam over the entire area of the sample. The optical power of the emitting, measured in relative units, was calculated from the spectral characteristics. Then the surface of the photoluminescence emission power deviation from the mean value was compiled for different substrate heating temperatures. Figure 2 shows the surface of the deviation of the Alq3 photoluminescence emission power deposited at a substrate temperature 60 °C from the average power value. The data for all the measured layers are summarized in table 1.

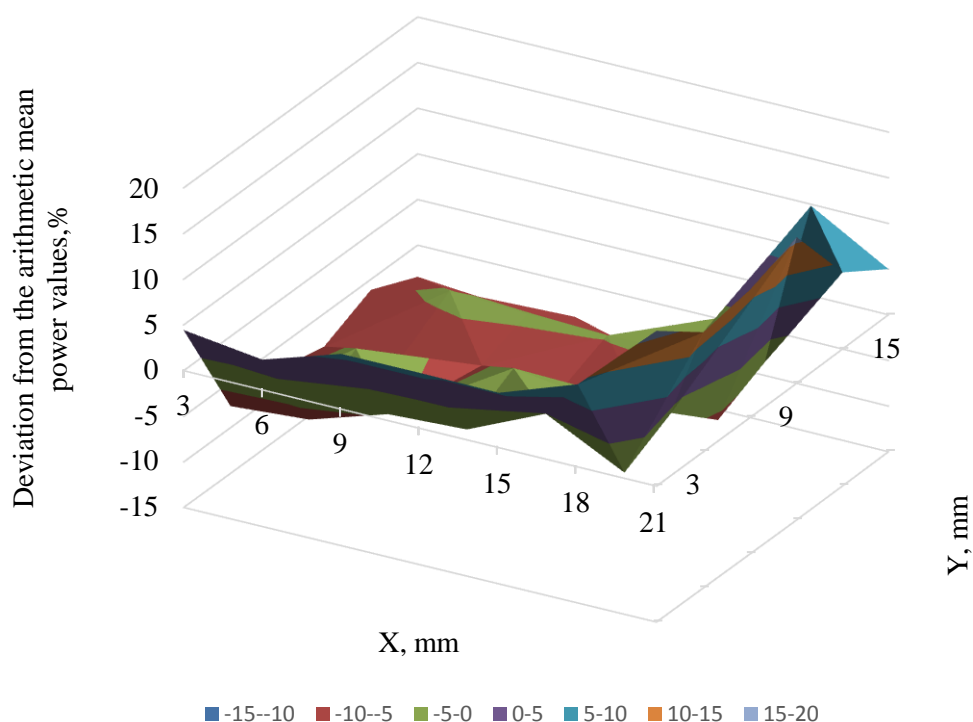


Figure 2. The surface of the deviation of the photoluminescence emission power of Alq3 deposited at a substrate temperature 60 °C from the average power value.

It turns out that the most homogeneous layer of TPD is obtained, when the substrate is heated to 50 °C, and for Alq3 the temperature should be 60 °C. Thereafter, it is better to keep the above said temperatures when these materials are alternately sprayed. There is no necessity to cool down the substrate to room temperature after the deposition of TPD. It could be immediately heat up to 60 °C and then spray Alq3. This procedure didn't affect on the uniformity of the layers.

Table 1. Investigation of the layers photoluminescence as a function of the substrate heating temperature.

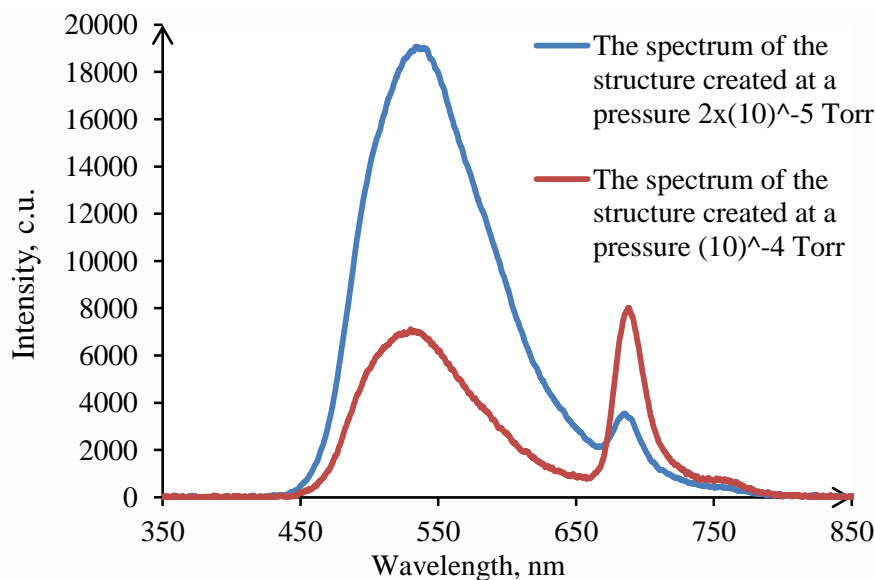
Material	Annealing temperature, °C	The average emitting power over the surface of the structure, rel. units	Deviation from the average power, %
TPD	51	1173	10
TPD	61	967	9,4
TPD	67	320	21
TPD	77	170	17
Alq3	50	690	14
Alq3	60	727	17
Alq3	74	670	16
Alq3	80	477	22
Alq3	88	606	15
TPD + Alq3	51	950	8
TPD + Alq3	TPD at 51 Alq3 at 60	1384	11

It is important to say, there are some increase in the amount of deposited material to the edges of the substrate. The search for a solution to this feature of sputtering is currently underway. However, as recommendations to create better layers, contact shouldn't be created near the edges of the substrate.

3. Experiment: change in residual gas pressure

The next part of the study in the work had become a comparative characteristic of two identical in composition light-emitting structures created at different degrees of evacuation of the vacuum. By the method of vacuum thermal evaporation for one structure, the layers were deposited at a pressure of residual gases no higher than 10^{-5} Torr, and for another at a pressure in the region of 10^{-4} Torr.

The created structures FTO/PEDOT:PSS/TPD/Alq3/Al have their own electroluminescence spectrum shown in figure 3.

**Figure 3.** Electroluminescence spectra of structures.

This dependence clearly demonstrates the need to reduce the pressure of residual gases in the creation of organic films. The emitting intensity of the structure is strongly influenced by the uniformity of the layers deposition and the preservation of the material purity upon deposition on the substrate.

The number of particles collisions of the evaporated material increases because of the high content of air molecules and other impurities in the chamber. This leads to hence the length of their free path decreases and that's why amount of pure precipitated material decreases. The uniformity of the deposition of layers is destroyed. More impurities appear in film, that leads to a distortion of the spectral characteristic. The solution to this problem is to fill the chamber with an inert gas, for example argon [2]. Also any contact of structures with the environment should be prevented.

4. Conclusions

Organic light-emitting structures FTO/PEDOT:PSS/TPD/Alq3/Al were created. Optimal temperatures of substrate heating for organic materials such as TPD and Alq3 were found in order to ensure high uniformity of the deposited layers using method of vacuum thermal evaporation.

It also was demonstrated the necessity of the maximum possible reduction of residual gas pressure to create more efficient light-emitting structures.

Acknowledgment

The work was supported by the Ministry of Education of the Russian under project of the state task in the field of scientific activity, project number 16.1750.2017/4.6.

References

- [1] Stepanov E M, Mikhailov I I, Tarasov S A and Solomonov A V 2016 *Proceedings of the 2016 IEEE North West Russia Section Young Researchers in Electrical and Electronic Engineering Conference (ElConRusNW)* pp 82–4
- [2] Vitukhnovskii A G, Vaschenko A A and Lebedev V S 2013 *Physics and Technology of Semiconductors Mechanism of electron excitation transfer in organic light-emitting devices based on semiconductor quantum dots* **47**(7)
- [3] Vyavahare O 2009 *Fabrication and Characterization of Organic Light Emitting Diodes for Display Applications: Master's thesis* (Rochester Institute of Technology, Henrietta, NY, USA)