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IPROVEMENTS OLED OPERATION DUE TO USING ADDITIONAL LAYERS

ABSTRACT *In this work we proposed OLED structure with NiPc as hole transport layer. Current-voltage and luminance characteristic of ITO/NiPc/Alg3/PEGTE/Al and ITO/Alg3/PEGTE/Al structures were also investigated. It was shown that using NiPc as hole transport layer reduced operating voltage and improved OLED performance.*

Keywords: *Organic Light Emitting Diodes, hole transport layer, electroluminescent*

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1. INTRODUCTION

Organic light-emitting diodes (OLED) have attracted a great attention due to their application in display technologies, backlights, lightning sources. They have a great advantages, such as fast response time, wide viewing angle, high brightness, low cost, picture quality, slimness. Because OLEDs are so thin, efficient and simple, they can be made on transparent or flexible substrate. In addition organic materials are environmentally safe and low cost [1].

The basic single layer OLED structure consist of thin organic luminescent layer sandwiched between a transparent anode and a metallic cathode. As anode usually in OLED used indium-tin-oxide (ITO), because it is stable, transparent and high conductive material. For the injection of electrons, metals with low workfunctions (Al, Ca, Mg) are typically used as cathodes [2]. Light-emitting materials are two types: small-molecular and polymer. Small-molecular materials are easy deposited by thermal evaporation. Polymer materials are deposited using wet-coating or ink-jet printing technologies. Carrier injection, transport, recombination and radiative exciton decay are the fundamental physical processes in OLED [3].

But single structures was inefficient and have a lot of disadvantages: one organic layer have to combine inside a several function: injection, transport and recombination of carriers. Also, the such type of structures worked on high operating voltage and have a low lifetime. Using additional layers can be greatly improved OLED performance (reduce the operating voltage, improve injection properties,etc.) [4,5].

For instance, polyaniline [6], PEDOT:PSS, metalphtalocyanines [7] and metal with high workfunction are successfully used as hole transport layers. These materials decrease the hole injection barrier between the anode and organic layer.

The aim of our work was the investigation of NiPc as hole transport layer in organic light-emitting structure to enhance OLED performance. NiPc have a high conductivity unlike another organic materials used as HTL. Furthermore, NiPc is small molecular materials, it is easy to thermal deposition. Also, HiPc is thermal and chemical stability [8]. This materials is favorable for using in OLED technology.

2. EXPERIMENTAL

Devices were prepared in a sandwich-like structure on glass substrates precoated with ITO using thermal evaporation. Before usage all substrates were cleaned by an ultrasonic treatment in deionized water and acetone. We have fabricated two type of structures: ITO/NiPc/Alg_3/PEGTE/Al and ITO/Alg_3/PEGTE/Al (Fig. 1a) .

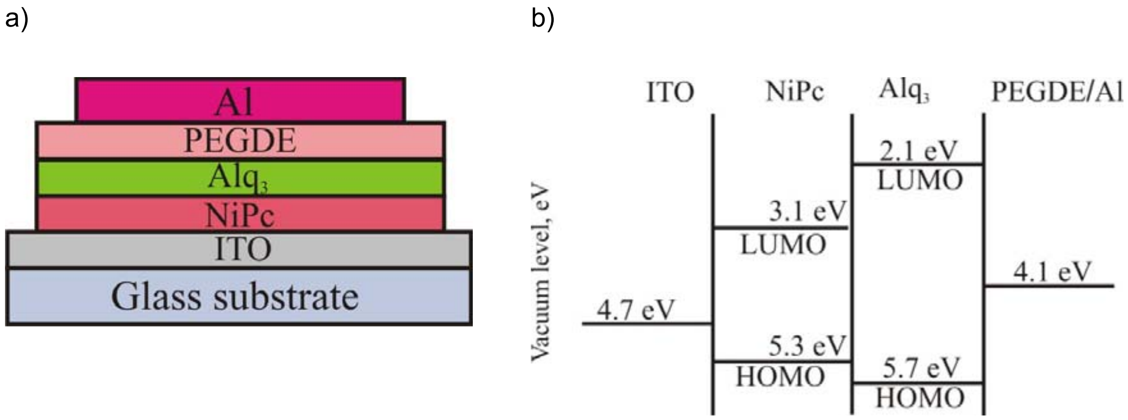

Fig. 1. Schematic drawing and energy level diagram of the ITO/CuI/Alq_3/PEGDE/Al structure (HOMO - highest occupied molecular orbital, LUMO - lowest unoccupied molecular orbital) [9, 10, 11]

NiPc, Alq_3, PEGDE, AL ware deposited on the glass substrate precoated with ITO in vacuum chamber with high pressure (~10^{-5} Torr) from the molybdenum boats. The deposition rates of Alq_3, PEGDE and Al were 0.3 nm/s, 0.4 nm/s and 6 nm/s, and resulting thicknesses were 40 nm, 3 nm and 150 nm, respectively. The thickness of NiPc layer was 20 nm. The thicknesses of NiPc,Alq_3, PEGDE,AL films were determined using ellipsometry technique. The active area of the ITO/NiPc/Alq_3/PEGDE/Al devices was 4 mm^2.

The current density - voltage (J-V) curves of the OLEDs were recorded using an L2-56 curve tracer. The luminance of the devices was measured with a calibrated Si photodide.

3. RESULTS AND DISCUSSION

In Figure 1b is shown the energy level diagrams of ITO/NiPc/Alq_3/PEGDE/Al structure. Inserting of NiPc transport layer decreases the potential barrier for holes at the Alq_3 interface from 1 eV to two steps 0.6 ev and 0,4 eV("ladder effect"). This two smaller barriers improved the hole injection 12]. Current density – voltage curves of ITO/NiPc/Alq_3/PEGDE/AL and ITO/Alq_3/PEGDE/Al are shown in Figure 2. The current-voltage curves of structures can be fit using space charge limited current model with charge trap presence. Functional dependence is $I \sim U^m$, where m characterize amount of charge trap. Inserting NiPc lead to decrease m from 5.6 to 5.2. This decreasing we attribute to reallocation of space charge in structure and decrease the potential barrier for holes. Also amount of charge traps at NiPc/Alq3 interface is smaller than at ITO/Alq3 interface. Furthermore, NiPc hole transport layer reduce operating voltage from 9 to 7 V

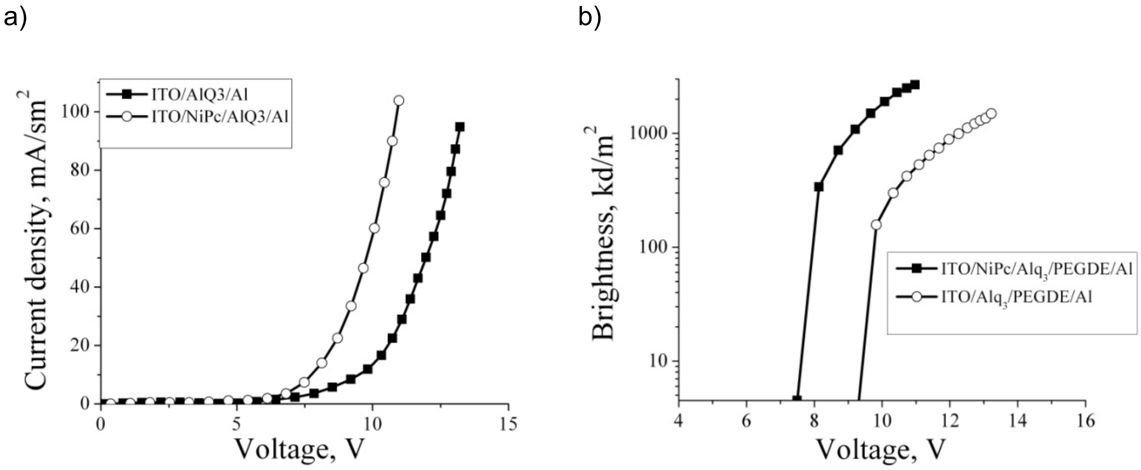

Fig. 2. Current density – voltage (a) and luminance (b) characteristics of ITO/NiPc/Alq$_3$/PEGDE/AL and ITO/Alq$_3$/PEGDE/Al structures

Also using NiPc hole transport layer lead to increase of luminance from 1500 cd/m^2 to 2600 cd/m^2 (Fig. 2,b). It can be explained by improvement of the electron-holes balance in the active layer [13]

4. CONCLUSION

We investigated the effect of NiPc hole transport layer of electrical and light-emitting properties of the ITO/NiPc/Alq$_3$/PEGDE/Al organic light-emitting devices. *J-V* curves of the OLEDs were fit using space charge limited current model with charge trap presence. OLEDs with NiPc hole injection layer have higher current density compared to the devices without NiPc. This improvement is attributed to decrease of the interface charge trap density and decrease of the hole injection barrier into Alq3 active region. NiPc layers also improved balance between electrons and holes in the recombination region and shift this region further from the anode interface.

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POPRAWA DZIAŁANIA DIOD TYPU OLED PRZY WYKORZYSTANIU DODATKOWYCH WARSTW

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STRESZCZENIE *W pracy została zaproponowana struktura OLED z warstwą NiPc jako warstwą transportową. Zbadano jej cha-*

rakterystyki prądowo-napięciową oraz luminancyjną na podłożu ITO/NiPc/Alg3/PEGTE/Al i ITO/Alg3/PEGTE/Al. Wykazano, że używając związku NiPc jako warstwy transportowej zmniejsza się napięcie pracy OLED jednocześnie poprawiając jego wydajność.

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