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Tae-Woo Lee [a] , O Ok Park [a] , Lee-Mi Do [b] & Taehyoung Zyung [b]

[a] Center for Advanced Functional Polymers and Department of Chemical Engineering, KAIST, Taejon, 305-701, Korea

[b] Korea Electronics And Telecommunications Research Institute, P.O.Box 106, Taejon, 305-600, Korea

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Improved Quantum Efficiency by Overneutralization of Ionomers Used in Polymer Light-Emitting Diodes

TAE-WOO LEE[a], O OK PARK[a], LEE-MI DO[b] and TAEHYOUNG ZYUNG[b]

[a]*Center for Advanced Functional Polymers and Department of Chemical Engineering, KAIST, Taejon 305–701, Korea and* [b]*Korea Electronics and Telecommunications Research Institute, P.O.Box 106, Taejon 305–600, Korea*

Polymer light-emitting diodes are fabricated using poly[2-methoxy-5-(2′-ethyl-hexyloxy)-1,4-phenylene vinylene] as an emissive material, and sodium sulfonated polystyrene (SSPS) ionomers with several different neutralization levels as an electron injecting and hole blocking layer. The SSPS with higher neutralization level makes the EL device more efficient. The highest efficiency was found at 200% overneutralization of the ionomer. The main reason for this is that the overneutralization in the ionomer helps to form a more favorable morphology to block holes better by tightening the cluster.

Keywords: Electroluminescence; Ionomer; Overneutralization

INTRODUCTION

Light-emitting diodes (LEDs) based on conjugated polymers have attracted much attention because of their potential applicability to flat, large area displays which can be operated at a relatively low driving voltage [1]. To make more efficient electroluminescent (EL) devices, it

is necessary to enhance the injection efficiency of the negative carriers. Recently, it was reported that a sodium sulfonated polystyrene (SSPS) ionomer possesses good electron injecting and hole blocking properties for an efficient EL device [2]. It is generally accepted that the ion concentration has an important effect on the structure and properties of ionomers. The morphology of ionomers can be seen in the reference [3]. The optimal ion concentration of neutralized SSPS ionomers for the EL device was found near 6.7 mol % [4]. In this paper, we report the effect of the neutralization level in the ionomer as a further optimization of the device using the ionomer to make an efficient EL device.

EXPERIMENTAL

A 6.7 mol % sodium sulfonated polystyrene (SPS) sample was synthesized via the same procedure as the previous paper [4]. The neutralization was achieved with a solution of NaOH in methanol. The chemical structure of the obtained SSPS is shown in reference [2][4].

The polymer light-emitting devices of poly[2-methoxy-5-(2'-(ethyl-hexyloxy)-1,4-phenylene vinylene] (MEH-PPV) were fabricated to be an ITO/60 nm MEH-PPV/15 nm SSPS/Al structure.

RESULTS AND DISCUSSION

Figure 1 shows the current density vs electric field characteristics in polymer light-emitting diodes of MEH-PPV using SSPS ionomers with various neutralization levels. When an unneutralized SPS layer is introduced between MEH-PPV and Al, the observed current density is much more relative to the neutralized SSPS. This might attribute to its

chain flexibility because the SPS possesses only hydrogen bonding in contrast to the strong ionic crosslinking and clustering in the SSPS. The SPS could not block holes well for recombination, judging from the Figure 1 and 2. The 50% underneutralized SSPS (50SSPS) possesses slight electron-injecting and hole-blocking properties due to the small ionic dipoles and ionic clustering. 100% neutralized SSPS (100SSPS) can block holes from the anode excellently and helps the electron injection from the cathode by the corresponding ionic dipole moment or ionic space charge field. The fact that the 200% overneutralized SSPS (200SSPS) has more current density than 100% neutralized SSPS is originated from the extra ionic dipoles' contribution to help the electron injection. As a result, the EL device with 200SSPS achieved the most balanced carrier injection among the EL devices with the SSPS as an electron injecting and hole blocking layer.

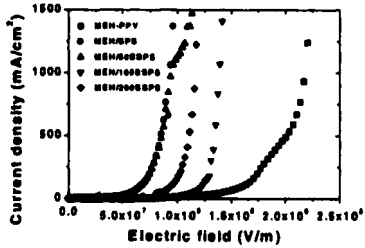

FIGURE 1 The current density vs electric field in polymer LEDs using SSPS ionomers with various neutralization levels.

Figure 2 shows the optical output vs electric field characteristics and relative quantum efficiency (Q.E.) in polymer LEDs using SSPS ionomers with various neutralization levels. The device with the overneutralized 200SSPS has strongest optical output and reduced

operating field by ~60 %. In addition, the maximum Q.E. is also found at the device with 200SSPS. The amount of sodium cation in ionomers critically affects the Q.E. in the EL device. As the neutralization level increases in ionomer, the cluster is more tightened and the ionic dipole moment or ionic space charge field is much stronger. In the case of the underneutralized ionomer, its device has more current but the Q.E. is lower because of the ineffective hole-blocking. In contrast, the device with the overneutralized ionomer is more efficient because the overneutralization in ionomers helps to form a more favorable morphology enough to block holes better from the anode by tightening the cluster and extra ionic dipole moments makes the electron injection more favorable.

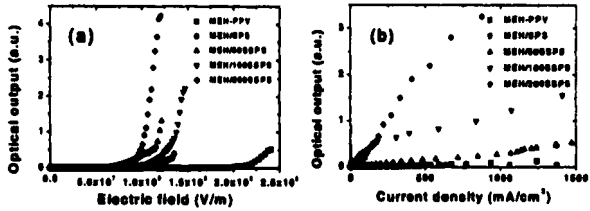

FIGURE 2 (a) Optical output vs electric field and (b) relative Q.E. in polymer LEDs using SSPS ionomers with various neutralization levels.

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