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## Change in Quantum Efficiency of Self-assembled Films Based on PPV and Ionic Salt Added PSS

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Electrical characteristics of self-assembled devices based on Poly(*p*-phenylene vinylene) (PPV), Poly(sodium 4-styrenesulfonate) (PSS) and carrageenan (CARRA) were investigated. Relative quantum efficiency of ITO/(PPV/PSS)<sub>20</sub>/Al device was significantly decreased with the increase of ionic strength of the PSS solution. In contrast, the relative quantum efficiency of ITO/(PPV/PSS)<sub>5</sub>/(PPV/CARRA)<sub>15</sub>/Al device prepared by inserting (PPV/CARRA)<sub>15</sub> bilayers between the (PPV/PSS)<sub>5</sub> film and Al electrode were increased with the increase of ionic strength in the PSS solution. The performance improvement of ITO/(PPV/PSS)<sub>5</sub>/(PPV/CARRA)<sub>15</sub>/Al device is believed to be due to the formation of a stable interface between the (PPV/CARRA) and the Al electrode as well as the enhancement of hole transporting characteristics of (PPV/PSS) bilayers with added ion salt.

**Keywords:** poly(*p*-phenylene vinylene) (PPV); electroluminescence (EL); self-assembly method

### INTRODUCTION

A layer-by-layer self-assembly method based on the electrostatic attraction between opposite charges has been implemented in the LED fabrication. It was shown that this method could easily control the film thickness at a molecule level and allow one to include desired heterogeneous layers in the organic thin film structure [1,2].

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In present work, we have investigated the electrical characteristics of electroluminescence (EL) devices composed of alternating poly(*p*-phenylene vinylene) (PPV) and poly(sodium 4-styrenesulfonate) (PSS) films in the case of including recombination region of (PPV/Carrageenan)<sub>15</sub> between the (PPV/PSS)<sub>5</sub> layer and the Al electrode. The change of quantum efficiency of the self-assembled EL devices as well as the origin of the change was investigated.

## EXPERIMENTAL

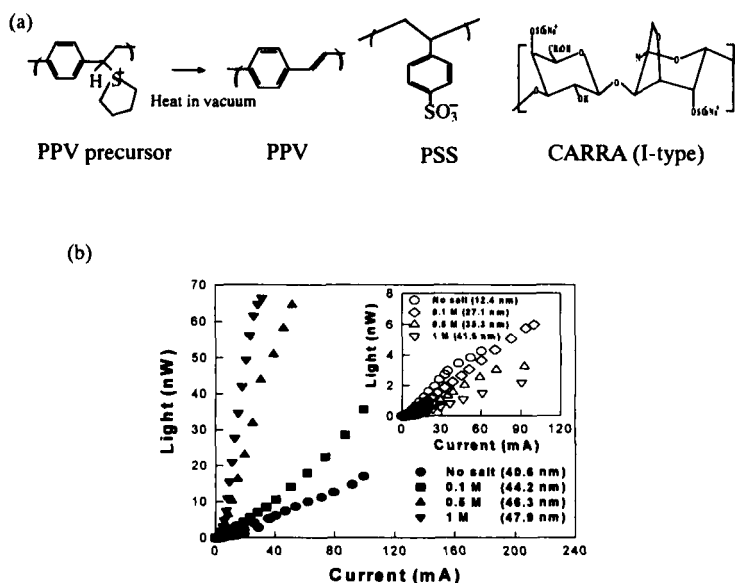
Poly(*p*-phenylene vinylene) precursor, poly(sodium 4-styrenesulfonate) (PSS) (Aldrich,  $M_w = 70K$ ) and carrageenan (CARRA) (Aldrich, I-type) were diluted to 0.01 M and used without further purification.

The fabrication of self-assembled films on ITO glass is identical to the procedure described previously [3]. For a number of experiments, the ionic strength of the PSS solution was adjusted to be 0.0, 0.1, 0.5 and 1.0 M by adding NaCl: the thicknesses of the corresponding (PPV/PSS)<sub>20</sub> films determined with an ellipsometer (Auto EL-II ) after thermal conversion are 124 Å for 0 M, 271 Å for 0.1 M, 353 Å for 0.5 M and 416 Å for 1M, respectively. Also, the bilayer thickness of (PPV/CARRA) was found to be about 25 Å.

## RESULTS AND DISCUSSION

We have measured the light (L) - current (I) characteristics of the self-assembled EL devices to investigate the effect of added ionic salt in the self-assembled film on the quantum efficiency. Figure 1 shows the relative quantum efficiency from the slope of the L - I relationship: the larger the slope, the more efficient the device [4]. As shown in the inset of Figure 1, the

relative quantum efficiency of  $(\text{PPV}/\text{PSS})_{20}$  devices decreases despite the increased thickness of the adsorbed PPV layer with the increase of ionic strength in the PSS solution. We believe that the decrease in the device efficiency upon the increase of ionic salt concentration is mainly attributed to residual salt existing at the interface of the  $(\text{PPV}/\text{PSS})$  film and the Al electrode thus inducing the electronic interactions such as excited quenching [5]. In order to confirm our hypothesis described above, we inserted 15 bilayers of  $(\text{PPV}/\text{CARRA})$  between the  $(\text{PPV}/\text{PSS})_5$  film and the Al electrode resulting in a multilayer structure of  $\text{ITO}/(\text{PPV}/\text{PSS})_5/(\text{PPV}/\text{CARRA})_{15}/\text{Al}$ .



**FIGURE 1** (a) Chemical structure of cationic (PPV precursor) and anionic polymers (PSS and CARRA). (b) Relative comparison of the device efficiency of  $\text{ITO}/(\text{PPV}/\text{PSS})_5/(\text{PPV}/\text{CARRA})_{15}/\text{Al}$  devices (in black symbols) and  $\text{ITO}/(\text{PPV}/\text{PSS})_{20}/\text{Al}$  (white symbol in the inset) thermally converted at 230 °C for 1 hr with different ionic strengths in the PSS.

These devices produce the stable and continuous lights with increasing voltage and current compared with the devices without the (PPV/CARRA) bilayers. The most notable change is the improvement of the quantum efficiency upon the increase of ionic salt concentration. In addition to the increase of net efficiency, it should also be noted that the relative quantum efficiency are improved upon the cases where the thickness of the (PPV/PSS) film, known as a hole transporting layer, was increased due to the addition of salt to the PSS solution. All of these observations clearly point to the fact that the residual salt in the multilayer self-assembled films induces defects for the non-radiative decay of excitons near the Al electrode and this effect degrades the device performance as described in our previous paper [6]. In contrast, the inserted (PPV/CARRA) bilayer film suppresses the defect formation at the interface between the (PPV/PSS) film and the Al electrode and moreover, functions as a recombination region. Without the defect formation induced by the residual salt, the increased recombination region leads to the increase in the quantum efficiency.

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