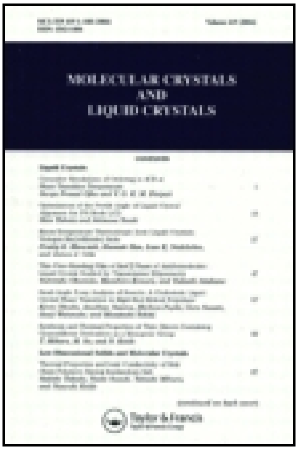

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Pmma Langmuir-Blodgett Films Inserted in a Polymer Light Emitting Diode to Improve Quantum Efficiency

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PMMA LANGMUIR-BLODGETT FILMS INSERTED IN A POLYMER LIGHT EMITTING DIODE TO IMPROVE QUANTUM EFFICIENCY

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Abstract PMMA Langmuir-Blodgett film is found to be an ideal insulating layer possessing good film forming ability with controllability of thickness in nanometer range and small number density of pinholes. Electroluminescence efficiency of a light emitting device is improved significantly when the several nanometer thick LB films are inserted in the device between an emitting layer and an aluminum cathode.

INTRODUCTION

Poly(methylmethacrylate) (PMMA) has been utilized as a lightwave guiding material in plastic optical fiber[1] and as a host matrix in nonlinear optical polymer system because of its good optical transparency.[2] Recently PMMA LB films have also been utilized as an optical waveguiding layer to fabricate a geodesic lens.[3] The material is known to give one of the highest resolution in electron beam lithography and its LB films have been successfully utilized as an electron beam resist to fabricate nanoscale patterns.[4,5] It is also known that PMMA is an electrically good insulating material. Excellent LB film forming ability combined with very small number of pinholes and precisely controlled thickness in nanometer range enables the LB films to be utilized as an ideal insulating layer in tunneling range.[5,6]

Light emission from polymers and organic materials is in active research nowadays. Improvement of quantum efficiency is an important research issue in the area. Inserting a thin insulating layer between the emitting layer and the cathode is a method to improve the quantum efficiency without using reactive metals such as Ca and Mg-Ag for the cathode.[7-8] In this paper we will demonstrate the utilization of the PMMA LB films as very thin insulating layers to improve the quantum efficiency in a polymer light emitting device. LB technique is adequate for the purpose because the device requires very thin films within tunneling range.

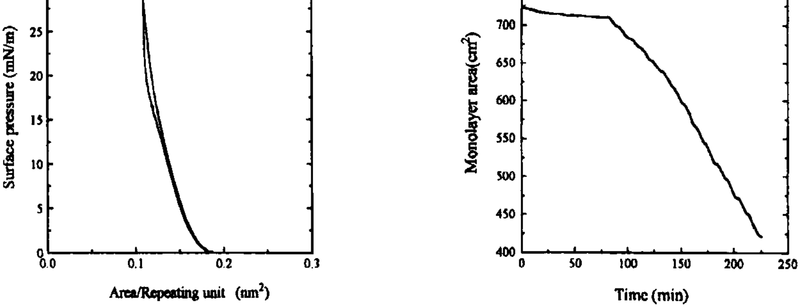
EXPERIMENTAL

Atactic PMMA (Mw=185,000 and Mw/Mn=1.05) was purchased from Polyscience Inc. and used without further purification. It was dissolved in chloroform and the solution was spread on deionized water. A computer controlled normal type polytetrafluoroethylene Langmuir trough was used to transfer the monolayer on substrates. The surface pressure was measured using the Wilhelmy plate technique.

Electroluminescence devices were fabricated on glass substrates coated with ITO. A layer of poly[2-methoxy-5-(2-ethylhexyloxy)-1,4-phenylene-vinylene] (MEHPPV) was deposited onto the ITO by spin coating from dichloroethane solution. The thickness of the layer was about 90 nm measured with an Alpha Step profilometer. After drying at 100 °C for an hour in an oven, PMMA LB films were transferred onto the emitting layer at the surface pressure of 10 mN/m. The number of the monolayers varied from 2 to 14. Aluminum electrodes were vacuum evaporated onto the upper surface of the PMMA LB films after drying the films in an oven at 100 °C for 1 hour. Light output from the devices was measured using an optical power meter (Newport 835) as a function of the applied field and current. Electroluminescent spectra were measured using a dual grating monochromator (Spex 270M) with the photomultiplier tube (Hamamatsu R955). All the experiments were performed in air and at the room temperature.

RESULTS

The surface pressure-area isotherm is shown in Fig. 1(a), which is qualitatively



(a) (b)

FIGURE 1 Characteristics of PMMA LB films: (a) Surface pressure -area isotherm and (b) transfer characteristics at the surface pressure of 10 mN/m.

consistent with previous reports.[4,5] It shows hysterisis if compressed above 10 mN/m and released. The film was transferred as Y type at the surface pressure of 10 mN/m on MEHPPV with the transfer ratio of almost one as indicated in Fig. 1 (b). It was found to have very small number density of pin holes when tested by etching technique. The thickness of one PMMA monolayer was measured to be 1 nm.

Electroluminescence characteristics

Current-voltage characteristics of the EL devices under forward bias are shown in Fig. 2. The current density at a certain electric field decreases as the number of PMMA LB layers increases. The behavior is expected because the blocking of the hole current by the PMMA LB films becomes more effective. Major current in the device is known to be hole current. The dependence of the emission intensity on the injected current (L-I) is

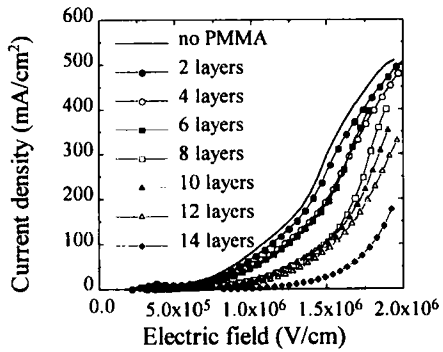


FIGURE 2 Current versus voltage characteristics of the EL devices for various number of LB layers

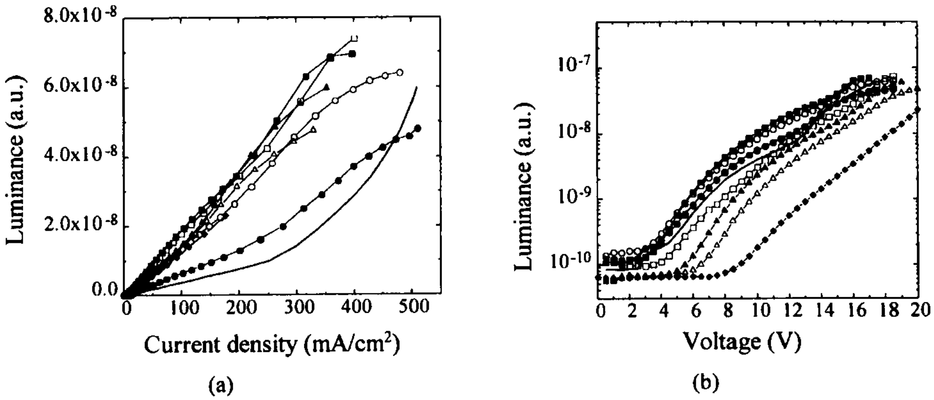


FIGURE 3 (a) Luminance versus current characteristics, and (b) luminance versus voltage characteristics of the EL devices for various number of LB layers. The same symbols are used as in Fig. 1.

shown in Fig. 3(a) for different number of LB layers. As are typical polymer light emitting devices, the emission intensity increases linearly with the injection current for all the devices. The relative quantum efficiency (the slope in the L-I curve) increases rapidly up to 6 layers and remains or slowly decreases as the number of layers increases further. The quantum efficiency was enhanced by more than 4 times compared to the MEHPPV only device by inserting the thin insulating layer. Moreover, the voltage required for the electroluminescence to be observed (threshold voltage) remains almost the same up to six layers as displayed in Fig. 3(b). This fact indicates that the power efficiency of the device is also improved 4 times.

The improvement of the quantum efficiency in the device without increasing the threshold voltage can be attributed to the charge carrier confinement in the active layer resulting in the potential redistribution in each layer.[8] Large band bending when the active layer is in contact with the insulating layer[9] or the prevention of electroluminescence quenching by metal electrode are another possible explanation.

CONCLUSIONS

We have demonstrated that the quantum efficiency in a polymer light emitting device can be significantly improved by inserting a thin insulating layer in a light emitting device without increasing the threshold voltage. PMMA LB films have been utilized as the thin insulating layer. The LB films were proved to be adequate for the purpose to form thin and uniform insulating layers. The enhancement may be attributed to the lowering of the effective barrier height for electron injection while increasing the effective barrier height for hole injection.

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