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Observation of Photoassisted Electroluminescent Emission Enhanced by Near-Infrared Irradiation

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1. Introduction

Recently, near-infrared light has become widespread as a light source in the optical communications system or remote sensing system of audio equipment and cameras. This is because light emitting diodes or semiconductor lasers in the near-infrared region have come into wide use. Since near-infrared light is not visible to the human eye, there has been increasing interest in the visualization of near-infrared light.

On the other hand, various optoelectronic functional devices such as light transducers, light amplifier devices, image storage devices, etc. have been proposed, recently [1-4]. These studies have shown that combination of photosensor with light emitter is applicable to optoelectronic devices.

In this study, we have examined the device fabrication combined with electroluminescent (EL) materials and photoconductors as light absorber and report the observation of photoassisted electroluminescent enhancement induced by near-infrared irradiation.

2. Experimental

Figure 1 shows the structure of the prepared device. Tris(8-hydroxyquinoline) aluminum complex (Alq_3) and *N,N'*-Diphenyl-*N,N'*-di(*m*-tolyl) benzidine (TPD) were used as an organic emitter and a hole transport compound, respectively. The titanyl phthalocyanine (TiOPC) film was deposited onto an indium-doped tin oxide (ITO) glass substrate. Alq_3 and TPD were deposited successively by vacuum evaporation onto TiOPC film. Finally, an aluminum (Al) electrode was deposited on the TPD film. The near-infrared laser of the wavelength (λ) of 780 nm (8mW/cm^2) was used as an incident light source, which was irradiated from the ITO electrode side. Device characteristics were measured at room temperature.

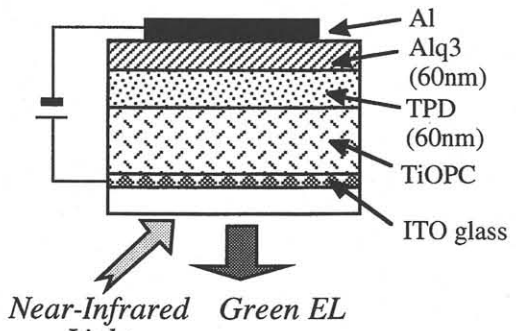

Figure 1 A schematic of device structure.

3. Results and Discussions

Typical emission spectra of the device consisting of ITO/TiOPC(15nm)/TPD(60nm)/Alq_3(60nm)/Al are shown in Figure 2. Applied voltage was 10V. Although light emission was observed without the incident light, its intensity was very small, as exhibited in Figure 2 (light off). When an input light with the wavelength of 780 nm was applied, the green EL emission appeared around 520 nm, as shown in Figure 2 (light on). This figure clearly shows that the EL emission was enhanced ca. 60 times by light irradiation. The spectral shape well corresponds to the photoluminescent spectrum of the Alq_3 film, giving evidence that the observed light arises from EL emission of the Alq_3 layer.

Figure 3 shows EL intensity of the output light versus

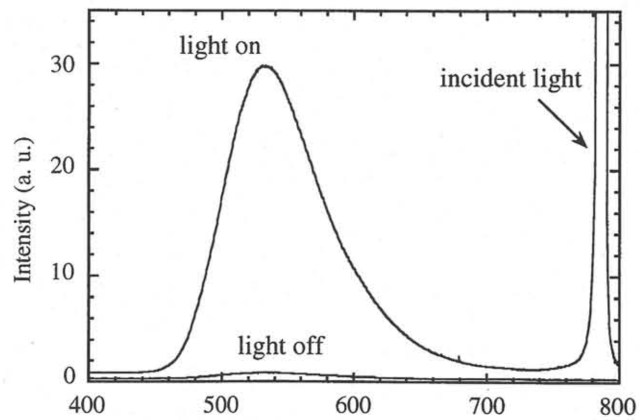

Figure 2 EL emission spectra of the device.

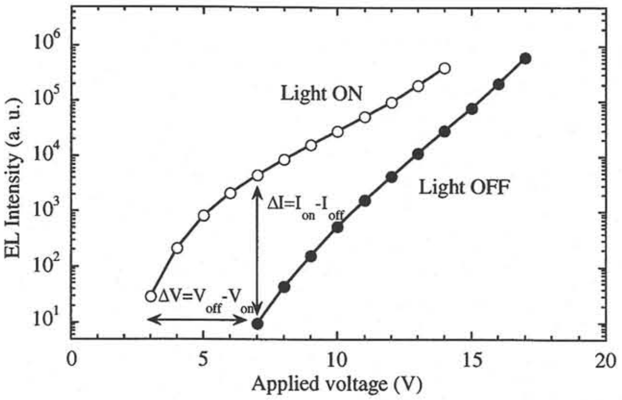

Figure 3 EL intensity dependence of applied voltage.

applied voltage. The device structure is same as mentioned in Figure 2. The open circle indicates the EL intensity under input light irradiation, and the closed one indicates that without irradiation. In Figure 3, V_{on} and V_{off} means threshold of EL turn on voltage with and without irradiation, respectively. I_{on} and I_{off} indicates EL intensity at V_{off} with and without irradiation, respectively. This figure clearly shows that light irradiation decreases the threshold of turn on voltage. Therefore, green light emission was observed between 3.0 and 7.0 V only when near-infrared light was exposure to the device.

EL intensity enhancement was also observed with light irradiation under identical bias voltage. The ratio of EL intensity (I_{on}/I_{off}) reaches 470 at V_{off} = 7.0 V.

From these results, we considered that the present device could be used as a photosensor to visualize near-infrared light. In order to improve the photosensor performance, the followings would be required: large difference of threshold voltage (ΔV), the small V_{on} value, the large ratio of I_{on}/I_{off}, and small threshold slope for EL intensity curve under irradiation. To find the conditions that influence the values mentioned above, we fabricated and examined the device with various PC layer thicknesses up to 200 nm.

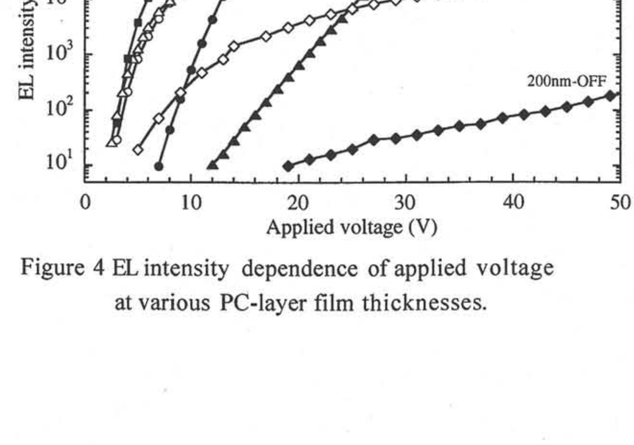

Figure 4 EL intensity dependence of applied voltage at various PC-layer film thicknesses.

The obtained results are shown in Figure 4. The open symbols indicate the EL intensity under input irradiation (ON), and the closed ones show that without irradiation (OFF). OLED represents the device without PC layer.

It is clearly seen that as the PC layer thickness increases, V_{off} value without irradiation increases. On the other hand, V_{on} value is less dependent on the PC layer thickness and stay around 3 V, which is the threshold of turn on voltage of OLED device. As a result, the value of ΔV becomes large. These results would be well explained as follows. When the device is irradiated through the ITO electrode, the conductivity of the TiOPC photoconductive layer will be increased, which establishes an increased voltage across the EL part of the device. Consequently, the device with light irradiation comes to be achieved at lower threshold voltage than without irradiation.

As the PC layer thickness decreases under irradiation, intensity curve slope becomes large approaching to the OLED curve. These results also support the PC layer mainly works as a resistor in the device.

I_{on} value does not show simple relation with the thickness. Consequently, I_{on}/I_{off} reaches maximum when PC layer thickness is around 60 nm. This film thickness is correspondent with the thickness that gives 1/e intensity of input light due to absorption of TiOPC thin film. Therefore, it can be said that taking into account the absorption coefficient is essential to fabricate the device with a high I_{on}/I_{off} ratio.

3. Conclusions

Photoassisted electroluminescent (EL) enhancement has been observed by near-infrared irradiation. It was found that the optimum PC-layer thickness exists to obtain a high amplification factor of EL intensity. It was demonstrated that the output light on/off can be controlled with an applied voltage and an irradiation light. Therefore, the present device would be a good candidate for a photosensor to visualize near-infrared light.

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