Light Enhancement of Organic Light-Emitting Diodes (OLED) Via The ethylene terephthalate (PET) substrate with Optimized Periodic Pyramids Structure

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Abstract

In this study, we reported the improved light outcoupling efficiency of an OLED by antireflective periodic micro-pyramids structure. The flexible PET substrate with the micro-pyramids structure was fabricated using fully Roll-to-Roll(R2R) processed method. During the measurement, the light emission from the OLED with the texture structure has light enhancement of 1.3 times. A special angle of far-field pattern is also observed from the OLED with the texture structure due to periodic structure of the pyramids.

Keywords: OLED, micro-pyramids, R2R, light enhancement, far-field pattern

1. Introduction

Recently, organic light-emitting devices (OLEDs) has been attracting much attention for applications such as full-color flat-panel-display, backlight for liquid-crystal displays (LCD). Besides, the OLEDs possess many advantages such as ultrathin, light weight, good flexibility, large viewing angle, high contrast ratio, fast response and low power consumption. As a result, the OLEDs have been considered as a new generation of solid-state lighting sources[1-2]. Owing to the applications, the performance of the light source must been improved and the high extraction efficiency needs to be increased. However, a shortcoming of conventional bottom-emitting OLEDs fabricated on a flat glass substrate is that only a small fraction (<20%) of the light generated in the device can escape with the 80% trapped in the glass substrate (glass mode) and the high index organic layer (waveguided modes). Many techniques have been developed to enhance the outcoupling efficiency. To outcouple the waveguided light, methods such as textured microstructures, microcavities[3-4], and low refractive index silica aerogel layer, have been adopted. On the other hand, to extract the glass-mode light, methods, such as microlens arrays with different geometries and the high refractive index substrate, have been developed.

2. Contents

In this study, we reported the improved light outcoupling efficiency of conventional OLEDs by antireflective micro-pyramid arrays prepared by R2R process on the PET substrate. Due to the micro-pyramid structure of the gradient refractive index, the light loss of the total reflection at the glass substrate and air interface was effectively lowered.

2.1 The design of the pyramid structures

In this work, an algorithm of numerical simulation based on rigorous coupled-wave analysis (RCWA) is developed to calculate the angular transmission of periodic micro-pyramid structures. The dependence of the transmission on the geometric dimensions of the textures is studied without considering the side-wall roughness and scattering. The RCWA method is often employed to solve the diffraction and transmission efficiency of optical diffractive elements, where the transmission is obtained as a sum of the transmission diffraction efficiencies of different diffraction orders.

As shown in Fig.1, the transmissions at the normal incidence are also investigated for various base widths and pyramid heights, Figure 2 showed that the properties of transmission are found to be only dependent of the aspect ratio of the pyramids. A transmission higher than 90% can be obtained as the aspect ratio is larger than. 0.4.

As the results of Fig. 1. and Fig. 2, the optimized size of pyramid with a base width (w) of 3.5 μm, and a height (h) of 3.5 μm was decided. Figure 3 shows the calculated transmission of the optimized micro-pyramids as a function of the incident angle for the average of both transverse electric (TE) and transverse magnetic (TM) polarizations.

The transmission of periodic micro-pyramids can be as high as 90%, up to an incident angle of 0^o~75^o.

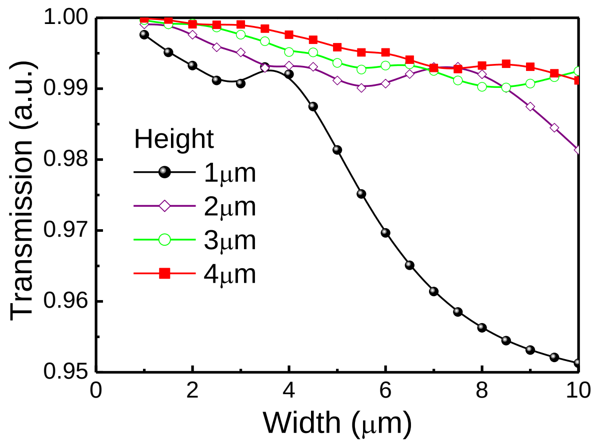

Fig. 1. The transmission of a periodic micro-pyramid structure is calculated as various base widths and pyramid heights.

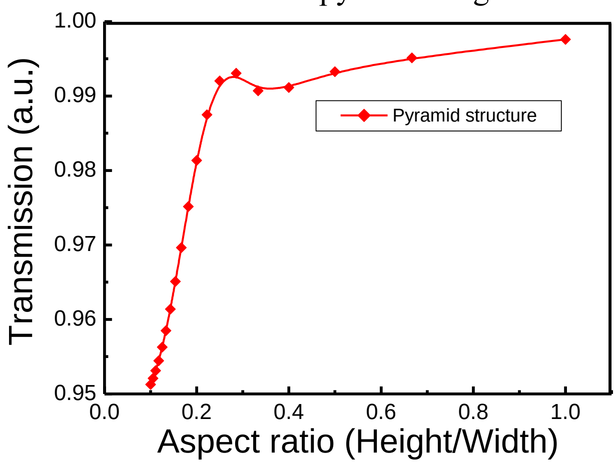

Fig. 2. The dependence of transmission on the aspect ratio of the micro-pyramids.

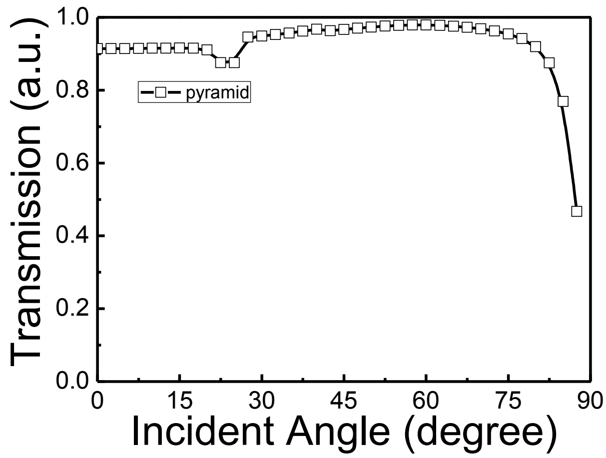

Fig. 3. The transmission of a periodic micro-pyramid structure is calculated as a function of the incident angle.

2.2 Fabrication process

First, the material of the steel was machined. Then the steel was used as a mold to imprint on the Nickel alloy. Finally, the mold of the Nickel alloy was placed on to the PET substrate with UV glue. After that, the Nickel alloy was removed at the end of process. The detailed fabrication processes of micro-pyramids are shown in Fig. 3. For this study, the sizes of the fabricated PET substrate with pyramids are approximately 2.5 cm^2 as shown in Fig. 4(a). Figure 4(b) is the PET substrate without texture structure. And the pyramid structure has a width of 3.5 μm, and the height is also 3.5 μm[5]. Figure 5 shows the scanning electron microscopy (SEM) image from the angle view.

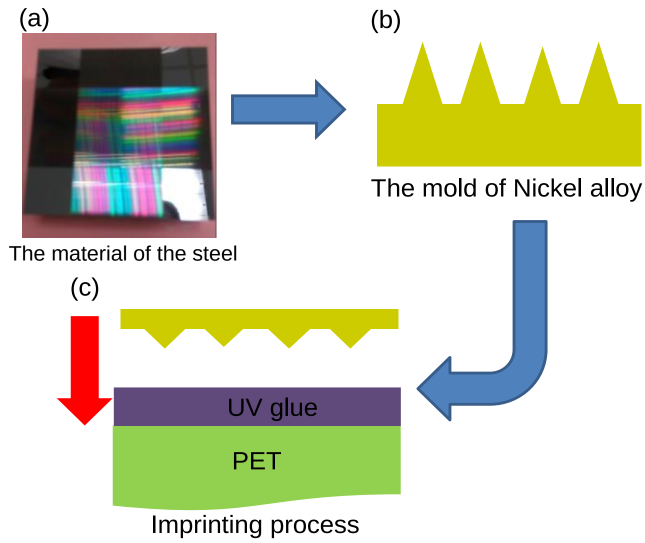

Fig. 3. The fabrication processes of the pyramids structure.

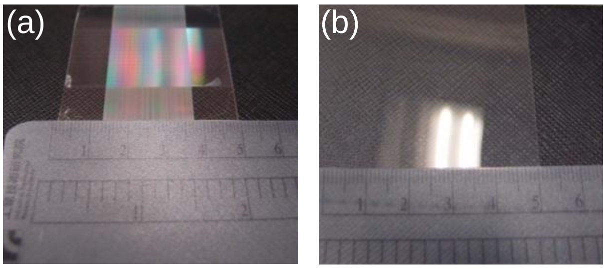

Fig. 4. Images of fabricated GaN PQC sample (a) with texture and (b) without texture.

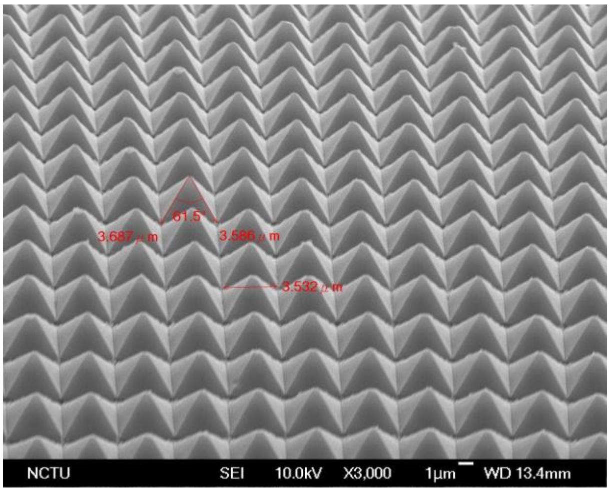

Fig. 5. The SEM image of the pyramids structure from the angle-view.

2.3 The method of the measurement

The light source of Philips OLED was prepared for measurement. The oily of SiO_2 was coated. Then the micro-pyramids of the PET substrate was stuck on SiO_2 surface as shown in Fig. 6.

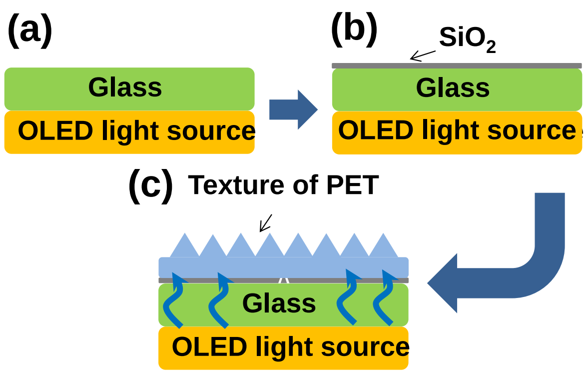

Fig. 6. (a) OLED device (b) Coating oily SiO_2 layer on the glass (c) To stick the PET with pyramids structure on SiO_2 surface.

3. The measured results

The total optical power from a light emitter can be estimated by integrating the spectrum over all the wavelengths (i.e. P= ∫ P(λ)d λ). Figure 7(a) shows that the optical power from the PET/Bare light is 1.3 times. And the far-field pattern has a high intensity at wide angle of 30 degree and 140 degree due to the periodic micro-pyramids structure as shown in Fig. 8(b).

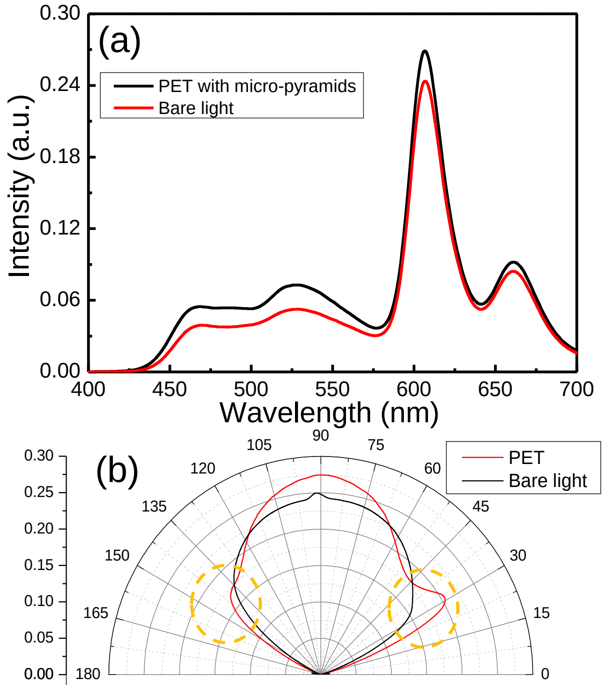

Fig. 7. (a) Spectrum (b) Far-field pattern.

4. Conclusions

In short, we have demonstrated the light enhancement from the OLED with the texture PET substrate in visible light region. An algorithm based on RCWA is developed to calculate the angular transmission of the periodic micro-pyramids. The emission of OLED light source is enhanced by 1.3 times with the texture structure. Owing to the directional periodic structure of the pyramids, a special far-field pattern is observed from the OLED. The PET substrate with the periodic structure is fabricated simply by the method of R2R process. The flexible substrate could be a potential material for the applications of lighting in the future.

5. Acknowledgement

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6. References

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