Enhancement of Power Efficiency in Photonic Crystal structured OLED

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A new high-efficiency Photonic crystal structured organic light emitting diode (PC-OLED) is fabricated using a low pressure and room temperature nanoimprint lithography (NIL) process. The PC structure is imprinted on the glass substrate using ultraviolet NIL and the OLED layers are deposited on to the PC structure without coating a planarization layer. Therefore, the deposition is done in such a manner that each layer follows the patterned surface of the previously deposited layer. This accounts for the formation of a multi-layer PC-OLED. The multi-layer PC effect on the substrate, anode and organic layers and the Bragg diffraction on the patterned metal mirror results in a high efficiency even with a sub-100 nm pillar height. The pillar height of the PC is a critical issue because the optical and electrical properties are highly affected by that. The OLED samples with different pillar height were fabricated and measured. We found that the power efficiency of the fabricated PC-OLED with a pillar height of 50 nm is 93% higher than the reference OLED with no PC structure.

In order to understand the reason of such a superior efficiency even with sub-100 nm high pillar, the roles of PC effect and the Bragg diffraction on PoMPC-OLED were examined by utilizing 3D finite difference time domain (FDTD) analysis. Three sets of FDTD simulations were performed. The first simulation set was performed with the assumption of a flat anode surface. In other words, the first set was for single-layer PC-OLEDs. The second set of simulations was performed considering the multi-layer PC-OLED with the assumption that there is no polymer PC structure to estimate the effect of the Bragg diffraction. The third set of simulations was performed considering the fabricated multi-layer PC-OLED samples. In the analysis it was observed that the Bragg diffraction was the main factor behind the improvement in the efficiency. At a pillar height of 50 nm, the increase in the efficiency is considerable. The extent of this increase begins to decrease as the pillar height exceeds 100 nm. When the pillar height exceeds a certain value, the deeper metal pit causes random phased electromagnetic waves by such as multi-reflection and diffraction from metal surface and side walls and therefore at the plane of the observer the light out of glass interferes out. In addition, energy absorption by the surface plasmon from metal surface is another reason. These reduce the amount of Bragg diffracted light waves, resulting in less of an efficiency improvement.

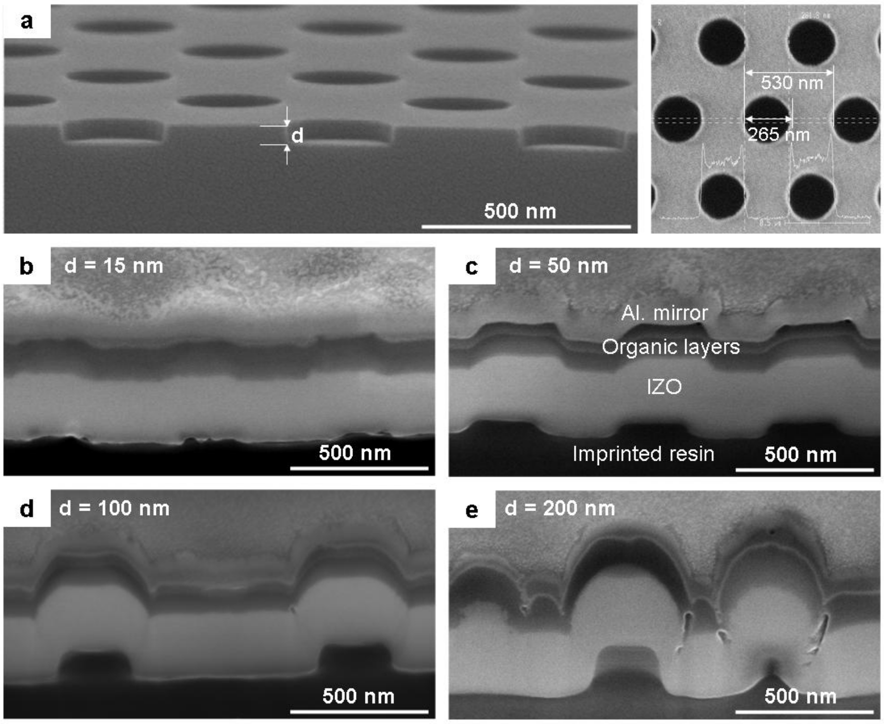

Fig.1: (a) SEM image of one of the stamps used in the UV-NIL process, and DB-FIB images of the cross sections of fabricated PoMPC-OLED samples; (b) 15 nm pillar height, (c) 50 nm pillar height, (d) 100 nm pillar height and (e) 200 nm pillar height

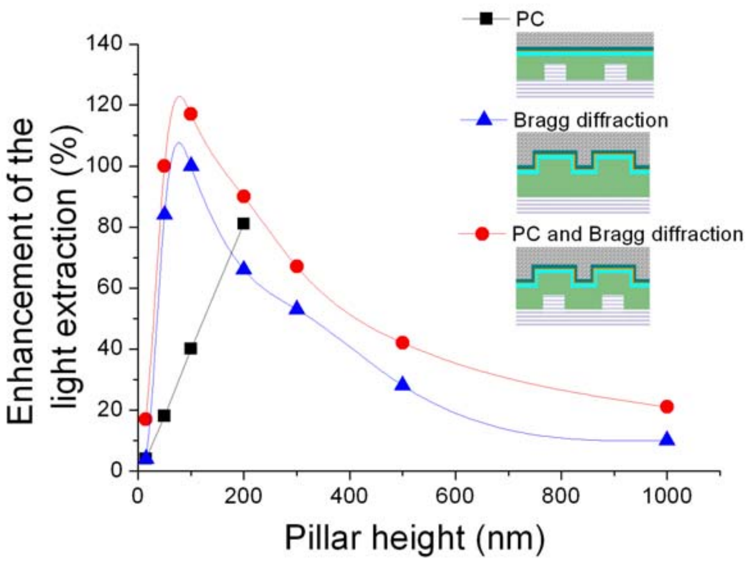

Fig. 2: Results of the FDTD analysis comparing the enhancement of the light extraction with respect to the pillar height