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Organic Ultraviolet Photodetectors with m-MTDATA:LiF Nanocomposite Layer

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Abstract

The organic ultraviolet (UV) photodetectors (PDs) with the m-MTDATA:LiF nanocomposite layer were, for the first time, fabricated and characterized successfully. With a 5 V applied bias, it was found that the leakage current of the fabricated PD with the m-MTDATA:LiF nanocomposite layer was 2.12×10^{-11} A. Furthermore, organic UV PDs with a m-MTDATA:LiF nanocomposite layer have a larger UVC-to-UVB rejection ratio. the NEP and D^* from the proposed UV PD were 2.49×10^{-10} W and 3.29×10^{8} cmHz$^{0.5}$W^{-1}.

1. Introduction

Ultraviolet (UV) photodetectors (PDs) is one of the most important optoelectronic devices in the application of scientific, industrial, medical, and astronomical fields because of its excellent high on/off ratio, fast response time, and a long lifetime [1]. However, different from inorganic semiconductors, organic materials are less stable [2]. The degradation mechanism in organic device is a result of the entrance of moisture and oxygen into the Device [3]. Grozea et al. reported that a thin LiF layer acts as an effective oxygen diffusion barrier in OLEDs [4]. Furthermore, LiF also acts as a effective surface passivation layer, preventing an Al electrode from being oxidized [5]. To maintain the conductive feature of m-MTDATA, m-MTDATA:LiF nanocomposites for the application of protective layer to UV PDs were proposed. In this study, we first developed the fabrication process and analyzed the characteristics of m-MTDATA-based UV PDs using m-MTDATA:LiF as a protective layer. For comparison, m-MTDATA-based UV PDs were also fabricated. The influence of inserting the m-MTDATA:LiF layer on performance of organic UV PDs was also examined.

2. Experimental

The organic UV PDs were fabricated on the clean silicon substrates, which were previously cleaned by acetone, isopropyl alcohol, and de-ionized water, subsequently, followed by baking at 110 ℃ for 10 min. Then, a m-MTDATA layer was deposited by thermal evaporation in a organic chamber. After that, the m-MTDATA:LiF composite layer was deposited by co-depositing m-MTDATA and LiF in the same chamber. Subsequently, a 100-nm-thick Al electrode was deposited using an interdigitated shadow mask. The interdigitated shadow mask was designed to have a finger width of 65 μm and a finger length of 1115 μm. The spacing between the neighboring fingers was kept at 85 μm. The active area of the devices was 2915×2300 μm^2. The device structure was m-MTDATA(60 nm)/m-MTDATA:LiF(20 nm)/Al(100 nm) (i.e., sample A) as shown in Fig. 1. For comparison, a m-MTDATA-based UV PD (i.e., sample B) consists of 80-nm-thick m-MTDATA and 100-nm-thick Al was also fabricated. The current-voltage (I-V) characteristics, spectral responsivities, noise power spectra of the fabricated devices were then measured and analyzed.

3. Results and discussion

Figure 2 shows the current-voltage (I-V) characteristics for UV PDs with and without m-MTDATA:LiF layers measured in the dark. When an 5V applied bias was administered, the measured dark current of the fabricated UV PDs with the m-MTDATA:LiF layers was 2.12 × 10^{-11} A. In contrast, the dark current of sample B was larger than that of sample A. In other words, the dark current can be further reduced by the insertion of the m-MTDATA:LiF layers. The lower dark from the fabricated UV PDs can be attributed to the fact that a m-MTDATA:LiF layer can provide better protection for the m-MTDATA active layer during deposition of the Al electrode and a better diffusion barrier for oxygen and moisture.

Figure 3 shows spectral responses measured from the fabricated UV PDs with and without the m-MTDATA:LiF layer. A sharp cutoff occurred at the range from 220 and 250 nm which was attributed to the absorption of the m-MTDATA layer. With incident light of 220 nm and 5 V applied bias, it was found that measured responsivities were approximate 0.16 and 0.25 mA/W for the UV PDs with and without a m-MTDATA:LiF layer, respectively. With the inserted m-MTDATA:LiF layer, photo-generated current should become lower again because the insulating nature of LiF. Although the lower responsivity can be measured from the UV PD with the inserted m-MTDATA:LiF layer, we can define the UVC-to-UVB rejection ratio as the responsivity measured at 220 nm divided by that measured at 280 nm. It is known that UV spectrum consist of UVA (310–420 nm), UVB (310–280 nm), and UVC (280–100 nm). According to this definition, the UVC-to-UVB rejection ratio of the UV PDs with and without a m-MTDATA:LiF layer was approximately 5.9 and 5.4, respectively, when biased at 5 V. Thus, the UVC-to-UVB rejection ratio for the sample A is larger than that for the sample B. As a result, we achieved a UV PD with a larger UVC-to-UVB rejection ratio with the insertion of a m-MTDATA:LiF composite layer.

Figure 4 shows the noise power spectra obtained from the fabricated PD with a m-MTDATA:LiF layer at a frequency range from 1 Hz to 1000Hz operating in various applied biases [6]. The noise power spectra can be described by the Hooge-type equation [7]:

$$S_n(f) = S_0 \frac{I_d^{\beta}}{f^{\alpha}} \tag{1}$$

where $S_n(f)$ is spectral density of the noise power, S_0 is a constant, I_d is the dark current, f is the frequency, and β and α are two fitting parameters. According to the measured curves, the determined α is nearly uniform throughout the measured frequency range. Then, the noise equivalent power (NEP) could be obtained from the following equation [8]:

$$NEP = \frac{\sqrt{<i_n>^2}}{R} \tag{2}$$

where R is the responsivity of a photodetector. In addition, the normalized detectivity (D^*) could be determined by $D^* = \sqrt{A}\sqrt{B}/NEP$, where A is the area of the photodetector and B is bandwidth. For a bandwidth of 100 Hz and a bias of 1 V, it was found that the NEP and D^* from the proposed UV PD were 2.49×10^{-10} W and 3.29×10^{8} $cmHz^{0.5}W^{-1}$, respectively, as shown in Fig. 4.

4. Conclusions

In summary, UV PDs with a m-MTDATA:LiF layers were proposed and successfully fabricated. It was found that we can achieve a low dark current and large UVC-to-UVB rejection ratio from the proposed devices with the m-MTDATA:LiF layer.

References

[1] H. L. Zhu *et al.*, Adv. Optical Mater **2** (2014) 1082.
[2] Y. Q. Zhao *et al.*, Appl. Phys. Lett. **91** (2007) 103109.
[3] M. Jørgensen *et al.*, Sol. Energ. Mat. Sol. C. **92** (2008) 686.
[4] D. Grozea *et al.*, Appl. Phys. Lett. **81** (2002)3173.
[5] A. Turak *et al.*, J. Electrochem.Soc. **154** (2007) H691.
[6] T. P. Chen *et al.*, IEEE Photonic Tech. L. **25** (2013) 213.
[7] E. Monroy *et al.*, Appl. Phys. Lett. **73** (1998) 2146.
[8] D. Kuksenkov *et al.*, Appl. Phys. Lett. 70 (1997) 2277.

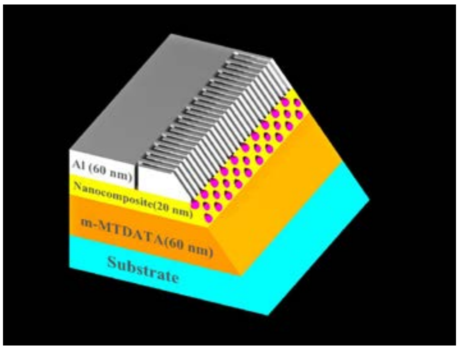

Fig. 1 The schematic structure of the m-MTDATA organic UV PD with a m-MTDATA:LiF layer.

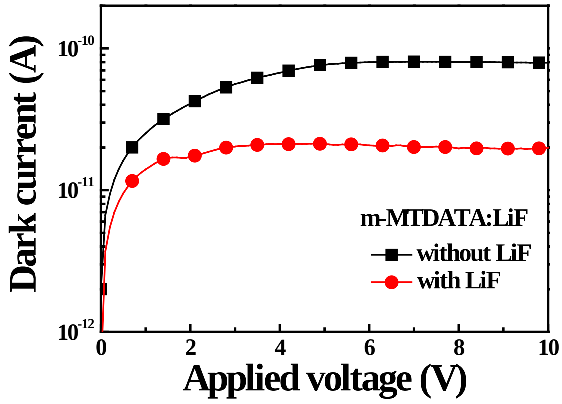

Fig. 2 I-V characteristics of the m-MTDATA Organic UV PD with and without a m-MTDATA:LiF layer.

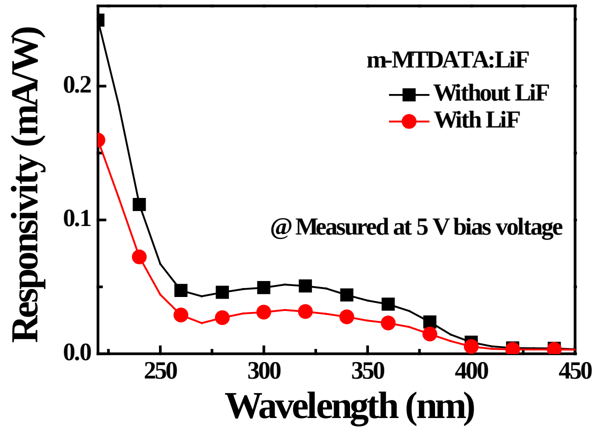

Fig. 3 Spectral responses of the m-MTDATA Organic UV PD with and without a m-MTDATA:LiF layer.

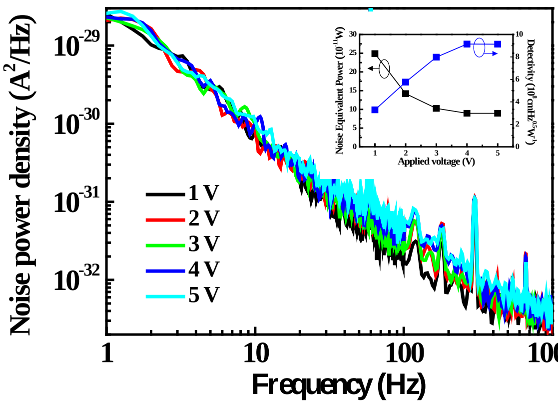

Fig. 4 Noise power density spectra of the m-MTDATA Organic UV PD with a m-MTDATA:LiF layer operating under applied biases. The inset is noise equivalent power and normalized detectivity of this PD.