Biuret doping is used to improve the performance of organic/inorganic photodetectors

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Abstract. The combination of inorganic semiconductor materials and perovskite materials can improve the performance and stability of photodetectors, and the photodiode prepared by combining Zinc oxide (ZnO) materials and perovskite materials can realize a wide spectrum detection from ultraviolet to near infrared. As the electron transport layer, ZnO film forming quality is very important to improve the performance of photodetectors. Therefore, in order to improve the film forming quality of ZnO, the surface passivation of ZnO films was prepared by doping Biuret into ZnO precursor solution, and its effects on the device working mechanism and device performance were studied. Studies have shown that doping Biuret improves the film forming quality of ZnO, and thus improves the electron transport capacity of ZnO. Meanwhile, the interface contact between ZnO film and perovskite film is optimized, and the film forming quality of perovskite is also improved. The light detection performance of the photodiode prepared by the combination of ZnO material and perovskite material is greatly improved, and the dark current of the device is obviously reduced, which is about 1/5 of the undoped Biuret device. Compared with undoped Biure device, the doped Biure device obtains the photoresponsivity (*R*) of 17740 mA/W, an increase of about three times. the specific detectivity (*D**) has been increased to 1.27×10^{13} Jones, an order of magnitude higher than before.

Keywords: ZnO; Biuret; Interface optimization.

1. Introduction

In optical information transmission and processing, photodetectors that convert optical signals into electrical signals are key devices, especially in optical fiber communication [1], night vision [2], infrared remote sensing [3], imaging [4,5], biomedicine [6], and spectrometers [7]. Photodiode as the most common photodetector, it can convert light energy into electricity. At present, the development of inorganic photodiode industry based on silicon, germanium, gallium nitride and other inorganic semiconductor materials has been quite mature. However, due to a series of unfavorable factors such as high preparation cost, low spectral response, poor compatibility of flexible substrate and inability to prepare large area, traditional inorganic wide spectrum detectors cannot meet the needs of a new generation of wearable intelligent optoelectronic products. Therefore, more and more new photodetectors have aroused people's research interest. ZnO has the characteristics of low film forming temperature and good film forming quality, in addition, it also has good photoelectric, piezoelectric, gas sensitive, pressure sensitive characteristics, which makes ZnO has been widely used in many fields such as ultraviolet photodiode, laser and so on. Lupan et al. [8] reported that Ag doped ZnO nanowires were prepared by electron beam deposition, which improved the performance of hydrogen sensor and UV detector of single ZnO nanowires. Tian et al. [9] used RF magnetron sputtering technology to grow high-quality ZnO films on quartz substrate, and prepared ultraviolet detectors on the films. The photoresponsivity of the photodetector is increased from 0.836 A/W to 1.306 A/W by sputtering metal Pt nanoparticles on the device surface.In this paper, we investigated the effect of doped biuret in ZnO precursor liquid on the performance of photodiodes prepared by ZnO materials combined with perovskite materials. The results show that, compared with undoped zno thin film devices, The biuret-doped device obtained the *R* of 17740 mA/W at a wavelength of 405 nm light and an optical power density of 0.01 mW/cm^2, and *D** increased to 1.27×10^{13} Jones.

2. Experiment

Two kinds of device with different structures were prepared, Device A : Ag/P-Si/ZnO/CH3NNH3PbI3/Au; Device B : Ag/P-Si/ZnO:B(X)/CH3NNH3PbI3/Au, Fig 1 is the structure of device A and device B. ZnO:B(X) in Device B represents the ZnO layer doped with Biuret, and the influence of biuret doping on the device performance is discussed. To prepare the Device A , the silver electrode was first vaporized on the back of P-Si, and then the perovskite film was prepared by coating ZnO precursor solution with a concentration of 0.8 mol/L on P-Si substrate and annealing at 350℃ for 1 hour. The precursor solution was coated with 0.75mol/L on the drying table and annealed at 100 degrees for 1 hour. The perovskite film was prepared on the upper side of the ZnO film, and the gold electrode was evaporated to complete the device preparation. The evaporation method of the gold electrode was similar to that of silver. When preparing Device B, the basic steps are the same as those of structure 1, but the difference lies in the preparation of doping solution: Biuret quality was weighed and added into 0.8 mol/L ZnO precursor solution to prepare doping solutions with Biuret concentration of 0.4mg/mL. The subsequent spin coating method and annealing time are consistent with the preparation methods of ZnO thin films.

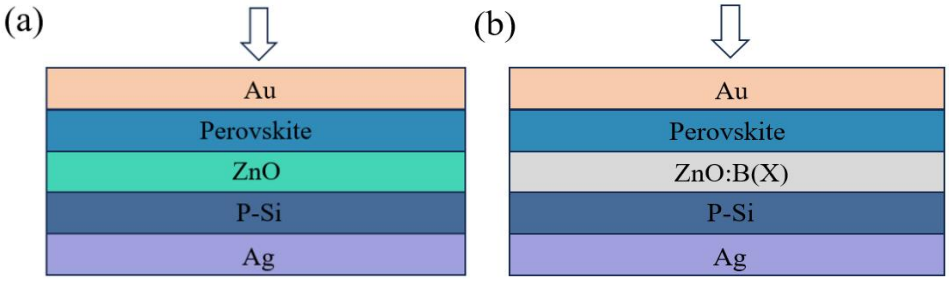

Fig. 1 The structure of devices (a) Device A : Biuret doped device; (b) Device B: Undoped biuret device

3. Results and discussions

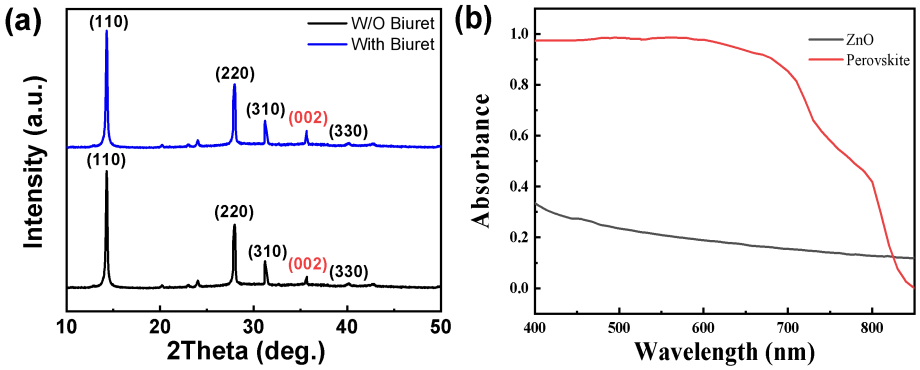

Fig. 2 (a) XRD of ZnO/$CH_3NH_3PbI_3$ thin films with or without Biuret doping; (b) Absorption spectra of ZnO and perovskite

Fig 2 shows the XRD characterization of ZnO/$CH_3NH_3PbI_3$ thin films with or without Biuret doping and the absorption spectra of the two materials. It can be seen from Fig 2 (a) that without new diffraction peak appears after Biuret doping, but the diffraction peak of ZnO (002) crystal surface is enhanced. This shows that ZnO films doped by Biuret have better crystal quality and smoother surface.

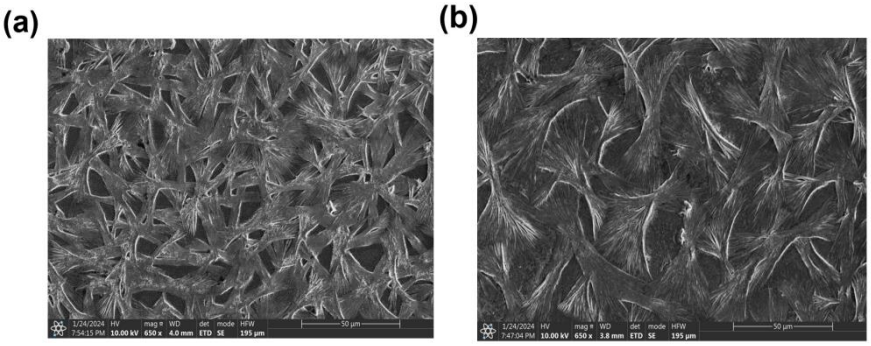

Fig. 3 (a) SEM image of undoped perovskite film; (b) SEM image of perovskite film doped with biuret

Fig 3 shows the scanning electron microscopy (SEM) images of perovskite film deposited on ZnO film with undoped Biuret and biuret doping concentration of 0.4 mg/ml. Compared with ZnO/$CH_3NH_3PbI_3$ films without Biuret doping, it can be clearly seen that the surface of perovskite films is more uniform and compact. The vacancy defects are significantly reduced, which can be attributed to the improved film forming quality of ZnO after biuret doping, and the smoother surface can be better used as a skeleton to support the subsequent perovskite film coverage, reducing the vacancy defects of perovskite films.

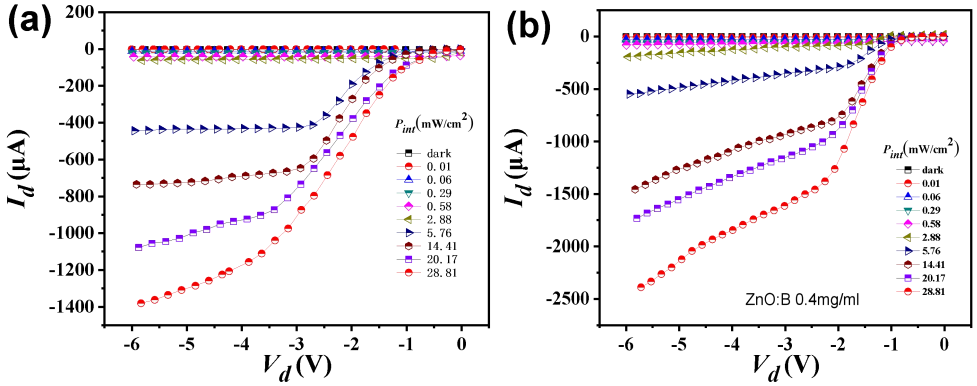

Fig .4 (a) I-V curve of device A at different optical power densities at 405 nm (b) I-V curve of device B at different optical power densities at 405 nm.

In order to more intuitively demonstrate the effect of biuret doping on device performance, we tested the device with a laser at 405nm wavelength.The undoped biuret and doped biuret devices are compared in terms of dark current, photoresponsivity and specific detectivity, and the comparison results are shown in Fig. 4. Fig. 4 (a) and (b) are the I-V curves of undoped and doped 0.4 mg/ml devicea. It can be seen from the comparison between the two figures that the optical power is the same. The photocurrent doped with biuret is much larger than that of the undoped one.

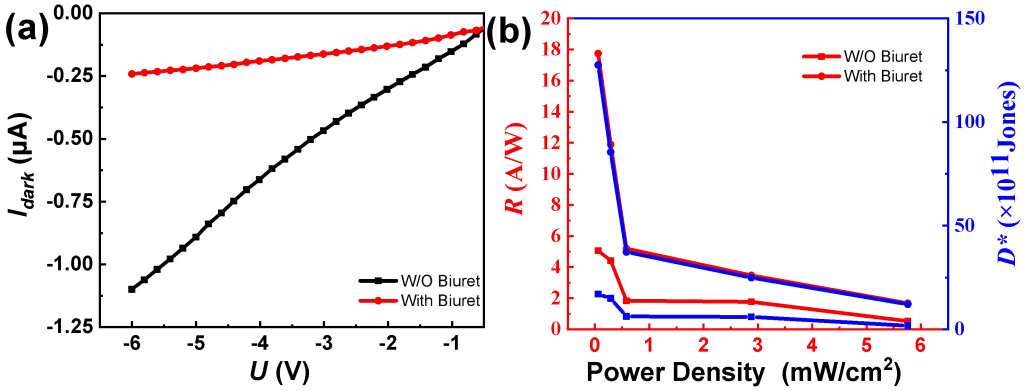

Fig .5 (a) Dark current comparison diagram of devices with or without biuret doping; (b) Relationship between photoresponsivity、specific detectivity and optical power density with or without biuret doping

As can be seen from Fig. 5 (a), after doping with biuret, the dark current decreases from 1.09 μA to 0.24 μA, and the dark current decreases significantly. As can be seen from Fig. 5 (b), the photoresponsivity increases from 5052 mA/W to 17740 mA/W, which is more than three times of the original; The specific detectivity has been increased from 1.70×10^{12} to 1.27×10^{13} Jones, an increase of about an order of magnitude. It can be seen from the above that doping Biuret in ZnO precursor solution can indeed improve the quality of ZnO film formation, thereby improving the contact interface between ZnO and perovskite films, and thus improving the performance of the device.

4. Summary

In conclusion, the organic/inorganic photodetectors with or without biuret were prepared and characterized. By comparison, it was found that the doped biuret effectively suppressed the dark current and increased the photocurrent at the same time, and the *R* increased by about three times compared with the undoped Biure devices. The *D** is an order of magnitude higher than the original, and the optical detection performance of the device is greatly improved.

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