High sensitive PbS QDs based Shortwave Infrared photodetector using ZnO NPs

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PbS SWIR photodetectors with and without ZnO NPs were fabricated and their current–voltage (I–V) characteristics were measured. The maximum on/off ratio of the former was 1.946 times that of the latter.

1. Introduction

Shortwave infrared (SWIR) sensors are currently used in various applications including environmental monitoring, military equipment, and medical devices. The fabrication of most of the widely used SWIR photodetectors involves metal organic chemical vapor deposition and two-dimensional epitaxial growth, and a cooling system is additionally required since the devices operate at low temperatures [1-3]. To overcome these disadvantages, we developed a PbS quantum dots (QDs) based SWIR photodetector and adapted zinc oxide (ZnO) nanoparticles (NPs) as an electron transport layer (ETL) to improve its sensitivity [4-6]. As the result, the maximum on/off ratio of the PbS SWIR photodetector with ZnO NPs was 1.946 times that of the PbS SWIR photodetector without ZnO NPs.

2. Experimental

Initially, to form the photo active layer, we coated the synthesized PbS QDs solution with an absorbance peak of 1400 nm on the ITO-patterned glass substrate, and heated the substrate for 30 min at 110 ℃ in vacuum oven.). To fabricate the PbS SWIR sensor with ZnO NPs, the ETL was formed by spin-coating ZnO NPs solution and annealed at 90 ℃ in a vacuum oven for 30 min (when fabricating the sensor without ZnO NPs, this process was omitted). Finally, Al cathode was deposited via thermal evaporation in high–vacuum by using a metal shadow mask. The Al electrode thickness exceeded 150 nm, the detecting area defined by the cross section between the Al cathode and the ITO anode was 9 mm^2.

3. Results and Discussion

To compare the performance of the fabricated PbS SWIR photodetectors, we measured their I–V characteristics. The dark current was measured when the IR light source was turned off, and the light current was measured when the light source was turned on. The voltage sweep range was –5 V to 5 V. Fig. 1 (a) and (b) show the I–V characteristics of the fabricated PbS SWIR photodetectors. The on/off ratio of the PbS SWIR sensor without ZnO NPs was 1.13 at the maximum current difference and the on/off ratio of the PbS SWIR sensor with ZnO NPs was 2.2 at the maximum current difference. In these results, PbS QDs can detect IR light and ZnO NPs can improve the sensitivity and current stability of the PbS SWIR sensor because of the ZnO NPs' high electron mobility and proper LUMO level.

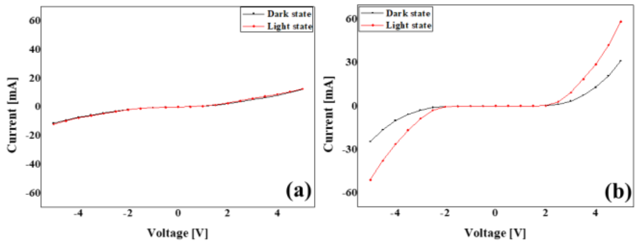

Fig. 2 I-V characteristics of the fabricated photodectector (a) without ZnO NPs, and (b) with ZnO NPs

4. Conclusions

A solution-processed PbS SWIR sensor was fabricated with ZnO NPs and compared to a PbS SWIR sensor without ZnO NPs. The on/off ratio of the PbS SWIR sensor with/without ZnO NPs were 1.3, 2.2, respectively, at the maximum current difference. These results confirmed that the on/off ratio of a PbS QDs SWIR sensor using ZnO NPs is 1.946 times higher than that of a PbS SWIR sensor without ZnO NPs.

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References

1. García, F.P. et al. *Nat. Rev. Mater.* **2**, 16100-16115 (2017).
2. Konstantatos, G. et al. *Nature* **442**, 180-183 (2006).
3. Wu, W. et al. *Appl. Phys. Lett.* **96**, 673-375 (2010)
4. Sargent, E.H. et al. *J. Mod. Opt.* **51**, 2797-2803 (2004).
5. Kim, O.S. et al. *IEEE Electron Device Lett.* **37**, 1022-1024 (2016)
6. Sun, D. et al. *J. Sol-Gel Sci. Technol.* **43**, 237-243 (2007).