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Supplementary information

High-performance $(Al_{0.4}Ga_{0.6})_2O_3/Al_{0.32}Ga_{0.68}N$-based UVC/UVB tunable dual-band photodetector

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1. Demonstration of AlGaN films

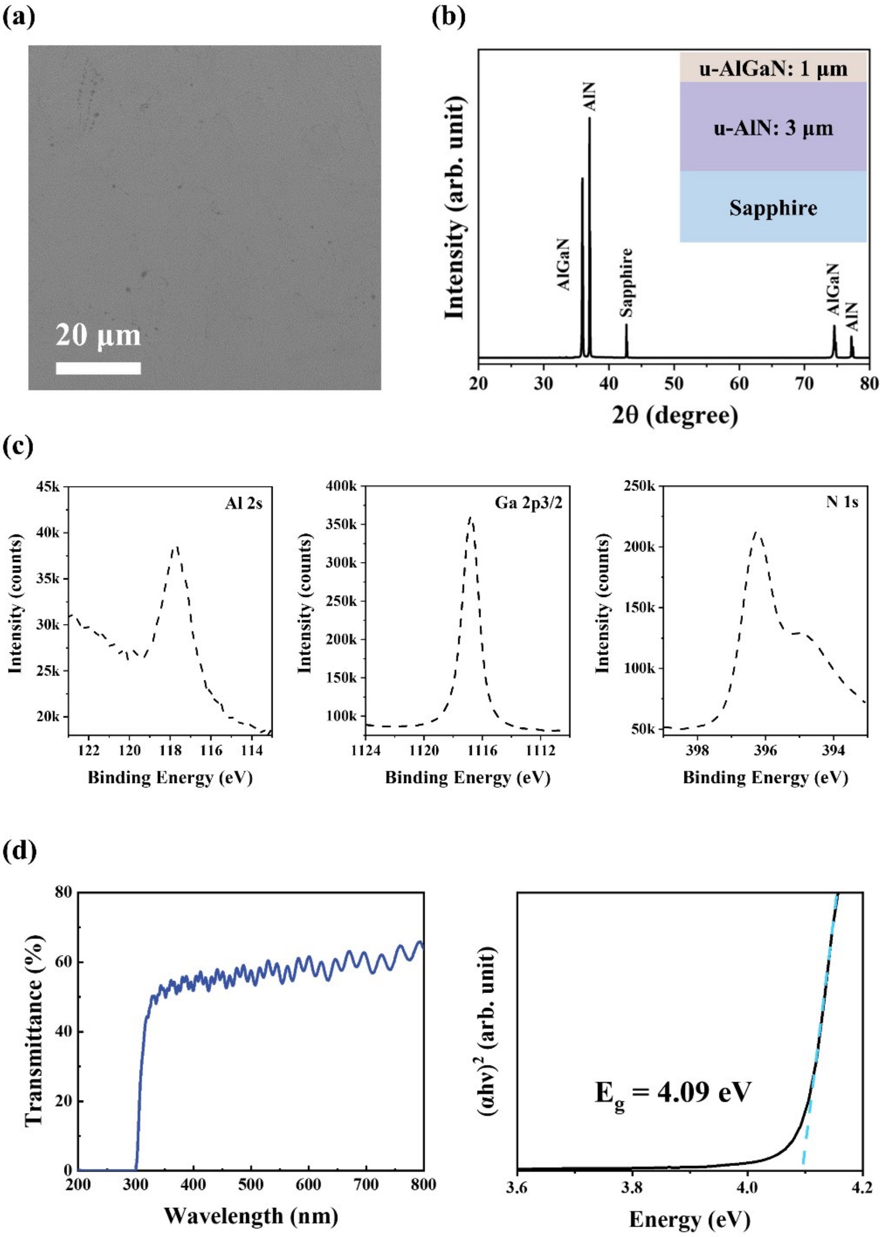

Fig. S1 (a) Surface morphology of the AlGaN films. (b) XRD pattern of the AlGaN films with the structural schematic diagram of the samples shown in the inset. (c) XPS core-level spectra of Al 2s, Ga 2p3/2, and N 1s photoelectron peaks of the AlGaN films. (d) Transmission spectrum of the AlGaN films and corresponding Tauc plot.

The stoichiometric information of AlGaN films is identified as $Al_{0.32}Ga_{0.68}N$, and the bandgap is calculated to be 4.09 eV.

2. Spectral responsivity of the photodetectors based on AlGaN films

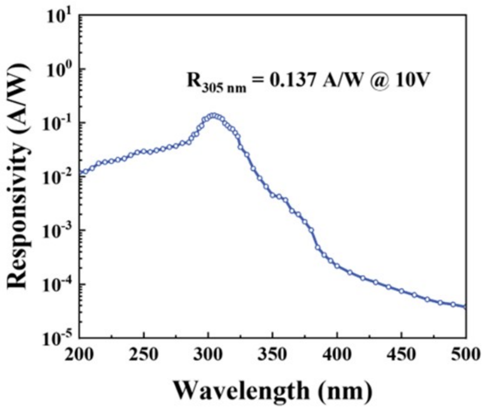

Fig. S2 Spectral responsivity of the PDs based on $Al_{0.32}Ga_{0.68}N$ films at 10 V bias.

PDs based on pristine $Al_{0.32}Ga_{0.68}N$ film with the same MSM structure have been fabricated, and the spectral responsivities at 10 V bias are measured as a control in order to investigate the origin of the UVB response. At 10 V bias, the spectral response of the PDs shows a responsivity peak of 137 mA/W at 305 nm.

3. Schematic energy band diagrams of the dual-band PDs based on $(Al_xGa_{1-x})_2O_3$/AlGaN heterojunction

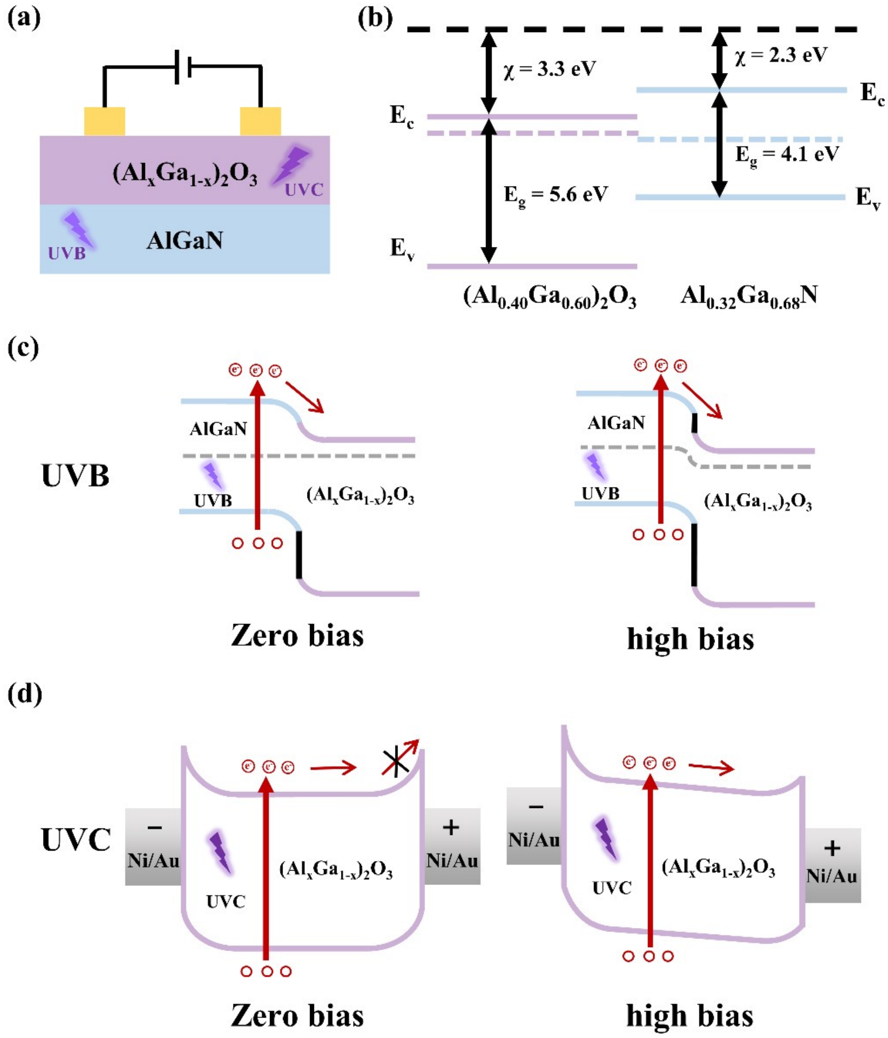

Fig. S3 (a) Schematic diagram of dual-band photodetection model. The schematic energy band diagrams of the PDs based on $(Al_xGa_{1-x})_2O_3$/AlGaN heterojunction: (b) before contact, (c) UVB response and (d) UVC response at 0 V and a high bias.

The band alignments of $(Al_{0.4}Ga_{0.6})_2O_3/Al_{0.32}Ga_{0.68}N$ with respect to vacuum level were obtained from previous reports [*Appl. Phys. Lett.*, 2001, **78**, 2503-2505; *AIP Adv.*, 2020, **10,** 125321], XPS and optical transmission spectroscopy analysis, exhibiting a type II band alignment. Fig. S3 demonstrates the possible mechanism of dual-band response based on our $(Al_{0.4}Ga_{0.6})_2O_3/Al_{0.32}Ga_{0.68}N$ heterojunction.

4. Noise characteristics of the $(Al_{0.4}Ga_{0.6})_2O_3/Al_{0.32}Ga_{0.68}N$ film-based PDs

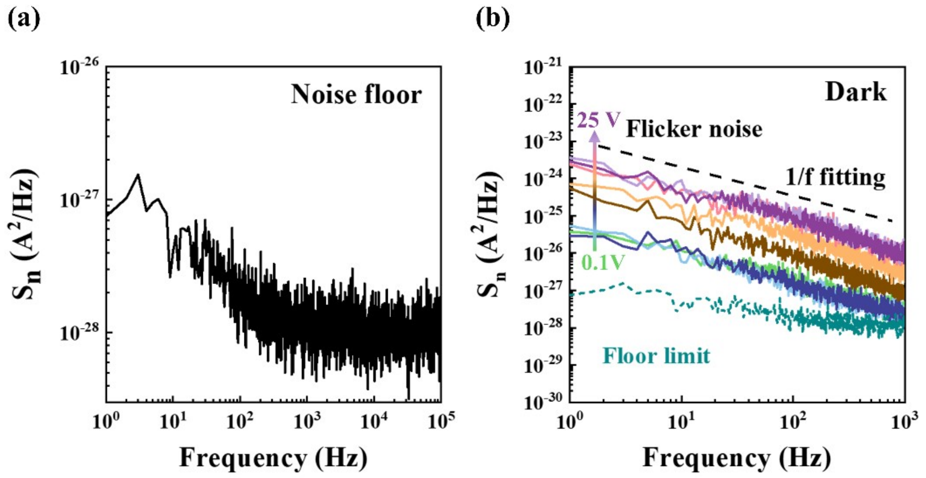

Fig. S4 (a) Instrument noise floor of the $(Al_{0.4}Ga_{0.6})_2O_3/Al_{0.32}Ga_{0.68}N$ film-based PDs. (b) Frequency-dependent noise power density at various bias voltages under dark condition.

It could be found that the noise power density spectrum can be well fitted with *1/f* function, indicating the dominant noise source is the flicker noise in the PDs.