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• Supplementary File •

32 × 32 β-Ga_2O_3 MOS solar-blind ultraviolet detector array and its properties

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Appendix A MOS Array Fabrication

Si-doped Ga_2O_3 film and Al_2O_3 layer were prepared by ALD. The metal sources were triethylgallium (TEG) and trimethylaluminum (TMA). Tris-dimethylamino silane (TDMASi) was the Si source and the O sources was all ozone (O_3). While the substrate temperature during deposition was fixed at 250°C. The base pressure of the vacuum chamber was kept below 0.5 Torr and the carrier gas was Ar (20 sccm). The applied ALD cycles of Al_2O_3 layer were 500 while the ALD cycles of Ga_2O_3 film were maintained at 2000 (20 out of the 2000 cycles were Si-doping cycles). The specific array preparation process is as follows. Si-doped Ga_2O_3 film with 100 nm thickness was deposited first on the SiO_2 substrate by ALD and changed into β-Ga_2O_3 by annealing at 900 °C for 10 min under nitrogen atmosphere. Then, the film was etched into isolated regions through wet etching with 60 wt% H_3PO_4. Subsequently, the first photolithography and evaporation of metal (Ti/Au (100/50 nm)) were performed, which was used to prepare the source/drain (S/D) electrodes as well as the row wires in the array. Then this Ti/Au metal layer was rapidly annealed to improve its Ohmic contact performance. Afterwards, an Al_2O_3 gate oxide layer with 50 nm thickness was grown by ALD and etched with 8 wt% HF. Finally, the second photolithography and evaporation of metal (Ni (150 nm)) were applied to prepare the gate electrodes (G) and column wires.

The single pixel unit size is 170 μm × 200 μm. The MOSFET has 100-nm-thick Ga_2O_3 channel layer and 50-nm-thick Al_2O_3 gate oxide. The length and width of channel are 30 μm and 90 μm, respectively. At the cross point of S/D and G electrodes in the array, 50-nm-thick Al_2O_3 layer acts as the electrical isolation layer.

Appendix B Basic photoelectric characteristic

The characteristics of the MOSFET array were measured by Keysight B1505A semiconductor analyzer. A UV mercury lamp with a wavelength of 254 nm was used for photo response measurements.In the text, the parameter τ_r is defined as the time for the photocurrent to increase from 10% to 90% of its maximum value, and decay time τ_d is defined as the time for the photocurrent to decrease from 90% to 10% of its maximum value. τ_u and τ_f are defined similarly.

Fig.B1 shows I_D-V_G curve at V_D = 2 V. The semi-logarithmic curves are shown in the inset of Fig.B1, which exhibits a gate modulation of approximately 10^4 of device in the dark case. Fig.B2(a) shows the current-time (I-T) curves of the device when both V_G and V_D = 2 V under P of 1250 μW/cm^2, which shows that the device has good reproducibility in photo response. Fig.B2(b) shows the variation of the device output curves as P increases from 500 to 1800 μW/cm^2 at V_G = 2 V. I_D increases with P because a larger P generates more photo-generated carriers. Fig.B2(c) shows the I-T curves in the case of V_G = 2 V/V_D = 2 V under different P. The growth trend of I_D with increasing P is consistent with Fig.B2(b). Note that the device exhibits stable transient response characteristics. As P increases from 500 to 1800 μW/cm^2, I_D are 0.84, 1.07, 1.24 and 1.60 μA, respectively.

Appendix C The gate voltage regulation

Fig.C1 shows the energy band diagram of the gate oxide layer and β-Ga_2O_3 film when $V_G < 0$. When a negative VG is applied, the energy band of the Ga_2O_3 film bends upward near the contact interface with the Al_2O_3 layer. Since the majority carriers of β-Ga_2O_3 as an N-type substrate are electrons, the negative gate voltage repels electrons. This results in a decrease in the surface electron concentration and the device being in an off state, which contributes to the suppression of the I_D. By extension, this technique can be used to act as electronic shutter. To be more specific, gate can actively turn off the optical response function of the device during continuously UV light irradiation. The faster the gate-controlled response speed, the more multiple images can be collected within a unit of time.

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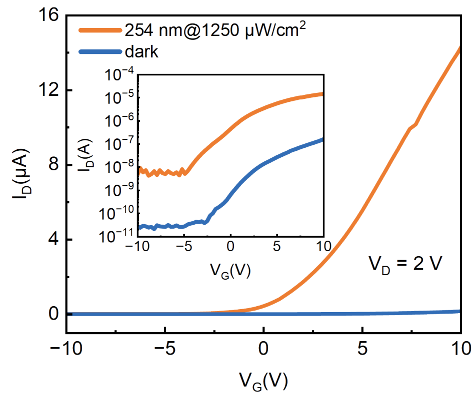

Figure B1 I_D-V_G curves measured under dark and 254 nm UV conditions. The inset shows the I_D-V_G curves in semi-logarithmic coordinate.

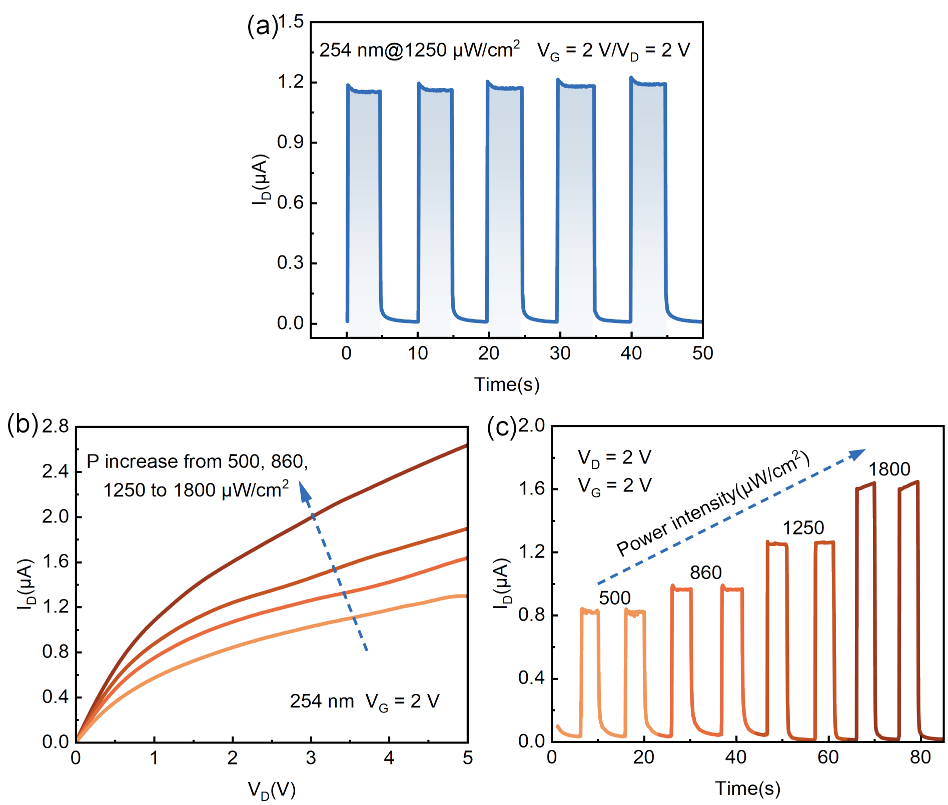

Figure B2 (a) I_D-T curves when V_G = 2 V/V_D = 2 V under P of 1250 μW/cm^2. (b) I_D-V_D curves under different P when V_G = 2 V. (c) I_D-T curves under different P when V_D = 2 V/V_G = 2 V.

Fig.C2(a) shows the array imaging system composed of a UV light source, lens, mask and data collection system. The 254 nm UV beam illuminates a 0.4 mm wide strip spot pattern on the array through the mask.Fig.C2(b-e) show the imaging results of 10 × 10 pixels of array of different V_G under V_D = 2 V. The imaging results show a non-monotonic trend in the PDCR with increasing V_G. When V_G = 1 V, the PDCR is approximately 2.3 × 10^3. When V_G = 2 V, the PDCR improves to 3 × 10^3. However, when V_G continues to increase to 3 V and 4 V, PDCR decreases to about 1.5 × 10^3 and 1.4 × 10^3, respectively. The imaging results obtained at V_G = 2 V exhibit superior clarity compared to other V_G conditions. This phenomenon can be attributed to the effective regulation of the gate voltage on the conductive channel state. Signal-to-noise ratio (SNR) can characterize the intensity ratio of the useful signal to the background noise. Based on the discussion above, a moderate V_G can enhance the photo-generated carrier concentration while to suppress the dark current, which can also improve SNR significantly.

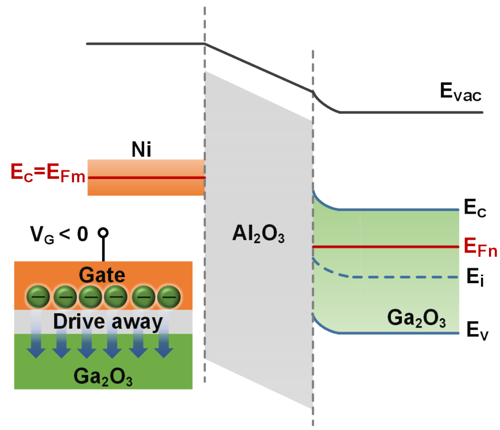

Figure C1 Energy band diagram of gate oxide layer and β-Ga_2O_3 film under $V_G < 0$.

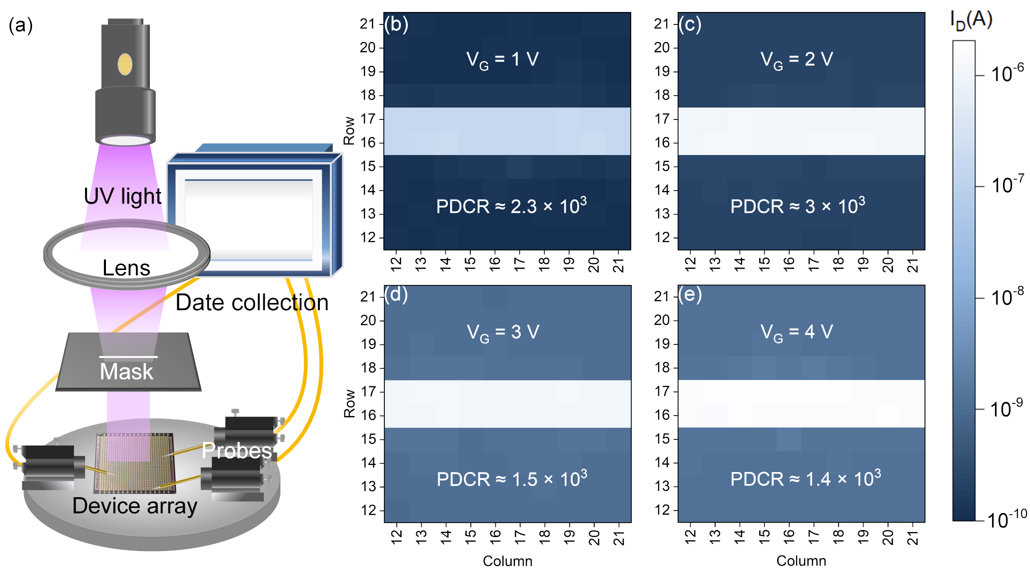

Figure C2 (a) Schematic of imaging system; Comparison of imaging results with different V_G under P of 1250 $\mu W/cm^2$ under V_D = 2 V: (b) V_G = 1 V; (c) V_G = 2 V; (d) V_G = 3 V; (e) V_G = 4 V.