Electronic Supporting Information

Highly sensitive detection and imaging of ultraviolet-B light for precisely controlling vitamin D generation in the human body

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Electronic Supplementary Information Included:

Table S2. Photoresponses of different materials for UV-B photodetection
Figure S7. The photograph of as-fabricated 10 × 12 ZGO MPs image sensor on glass substrate

1. Experimental details

1.1Synthesis of ZGO truncated octahedrons and ZGO octahedrons

First, a rectangular gallium oxide target (>99.99%) and a rectangular zinc target (>99.995%) were polished with an emery paper. The zinc target was ultrasonically rinsed with ethanol for 10 min, and then both washed with deionized water.

The precursors of ZGO truncated octahedrons were provided by dual-beam LAL. The spliced target made up of rectangular Zn and Ga_2O_3 targets were then placed in the bottom of a quartz vessel filled with 60 mL deionized water. Subsequently, the ablation laser beam was emitted by a Q-switched Nd: YAG laser (wavelength = 1064 nm, pulse duration = 7 ns). A polarizing beam splitter was used to obtain two laser beams. Two laser beams energy were adjusted to 70 mJ and 100 mJ by prism and mirror, and then two laser spots were focused on the surface of the Ga_2O_3 target and Zn target on both sides of target seam, respectively. The colloidal solution of ZGO truncated octahedrons was obtained after 40 min ablation.

The precursors of ZGO octahedrons were provide by single-beam LAL. The cleaned Ga_2O_3 target was immersed in the bottom of a quartz vessel filled with 60 mL deionized water. Subsequently, the target was ablated for 90 min by using a fundamental (1064 nm) Nd: YAG pulse laser with 10 Hz pulse repetition rate, 7 ns pulse duration, and 70 mJ pulse energy density. After ablating the Ga_2O_3 target, it was replaced with Zn target and the Zn target was ablated with the same laser for 25 min. Then the colloidal solution of ZGO octahedrons was obtained.

After ablation, the both generated colloidal solution was immediately collected for subsequent hydrothermal reaction. In sequence, 0.2 mL acetate (>99.9 wt%) and 5mL ammonia solution (30 wt%) was added to the as-prepared solution under continuous stirring for 5 min at room temperature. Then, the mixture was transferred into a 100 mL Teflon-lined stainless steel autoclave

with the hydrothermal treatment performed at 200 °C for 15 h and cooled down to room temperature naturally. Finally, the white products of ZGO truncated octahedrons and ZGO octahedrons were washed several times with deionized water and ethanol and then dried in a vacuum.

1.2 Synthesis of spherical ZGO MPs

2 mmol $Ga(NO_3)_3$, 1 mmol $Zn(Ac)_2$ and 4 mL ammonia solution were added into 60 ml deionized water and stirred for 5 min. The precursor was transferred into a 100 mL Teflon-lined stainless steel autoclave with the hydrothermal treatment performed at 200 °C for 15 h and cooled down to room temperature naturally. Finally, the white products were washed several times with deionized water and ethanol and then dried in a vacuum.

1.3 Fabrication of UV-B PD

The interdigital Au/Cr electrodes were deposited on SiO_2/Si substrate by a thermal evaporation method. 1 mg ZGO was first ultrasonically dispersed in water/ethanol solution with a volumetric water to ethanol ratio of 1:1. Then ZGO were deposited on interdigital electrodes by the centrifugal-casting method with the centrifugal parameter of 10000 rpm and 1 min.

1.4 Fabrication of ZGO MPs image sensor

First, an ITO electrode layer is made by similar photolithography, magnetron sputtering, and lift-off process. Then, PMMA (polymethyl methacrylate with 15 wt%) was spin-coated on the glass substrate with ITO electrode layer at 3000 rpm for 40 s as the insulating layer after being heated under 50 °C for 10 min. The PMMA layer was afterwards wiped off by a dustless cloth with acetone except for all the intersection region of two vertical cross line electrodes on the ITO electrode layer and Au/Cr electrode layer (would be deposited later), respectivly. Eventually, ten Au/Cr line electrodes vertical to the interdigital electrodes were deposited to connect with another

half of the interdigital electrodes as another half of the external electrodes to form the second electrode layer (60 nm) which is used to connect with the ITO electrode layer The ZGO MPs image sensor with a resolution ratio of 10 × 12 pixels was successfully fabricated on the glass substrate.

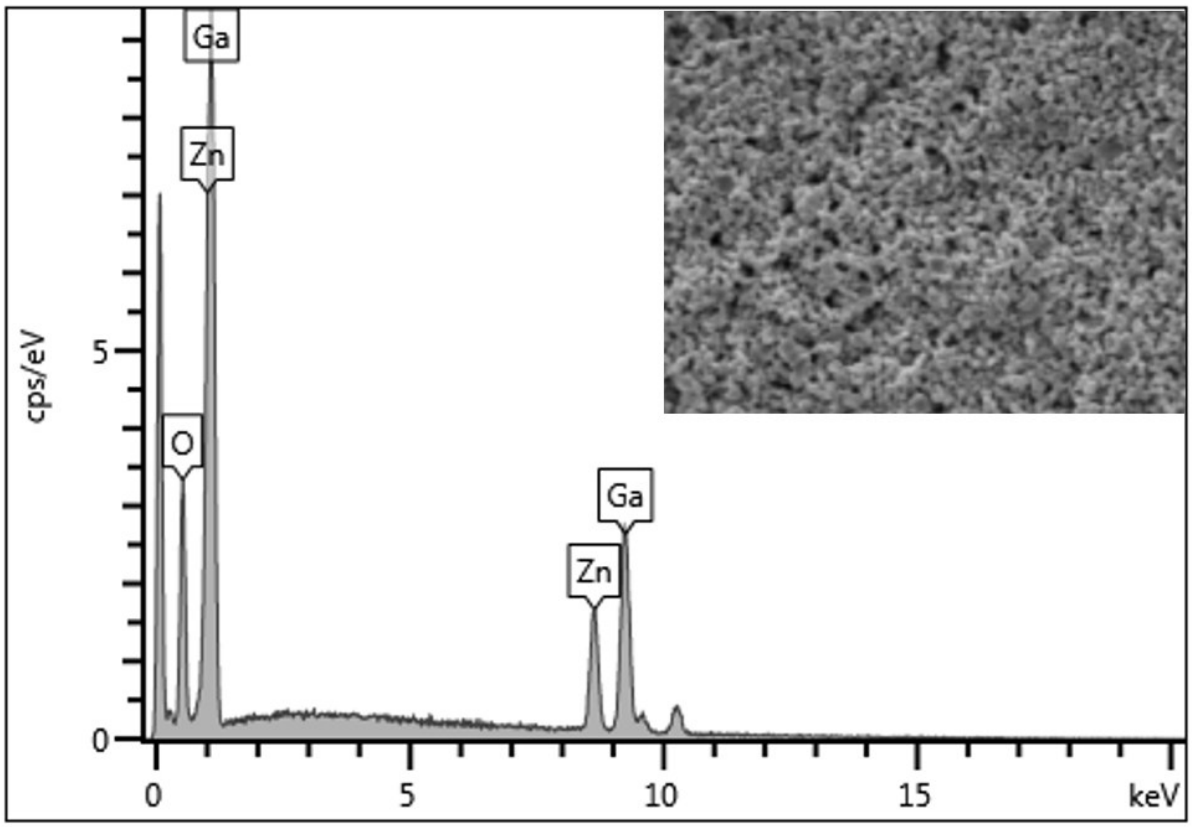
1.5 Characterizations and measurements

The SEM images of ZGO and UV-B PD surface were characterized utilizing a Quant 250 FEG SEM instrument. XRD patterns of ZGO were recorded by a Bruker D8 Advance XRD system using Cu K radiation. The absorption spectrum of ZGO powder was measured by a Shimadzu UV-3600 UV/VIS/NIR spectrophotometer. The photoelectric response measurements were studied by Zolix DSR101UV-B UV detector spectral responsivity measurement system. The 266 nm light source was chosen to be FQCW266 of Crylas. The effective area is determined by the spot size of the light source and estimated as 3.14 mm^2. The power of the incident light was measured by an Ophir NOVA power meter.The measurements of *I-V* (current-voltage) curve and *I-t* (current-time) curve of the UV-B PD were carried out by a Keithley 6487. The noise current was extracted from the dark current which is recorded by Agilent B1500A with a current amplifier. A Fourier transform was applied. The rise and decay time were obtained by an oscilloscope with a chopper controlling the frequency of light source. The trap density was collected from impedence measurement by CHI660E electrochemical work station. The EIS experiments were performed at a constant temperature of 25 °C in the dark. The data was recorded with frequencies ranging from 0.01 Hz to 1 MHz, the oscillation potential amplitudes being adjusted to 50 mV. The photoresponses of the ZGO MPs image sensor were measured by the Keithley 2400 linked with a probe station and a power-adjustable xenon lamp (CEL-HXUV300) containing a monochromator were used as the illumination sources.

2. Supplemental tables and figures

Table S1. Optical bandgap in ZGO with different morphology

Morphology	Diameter /μm	Bandgap /eV	Ref.
Truncated octahedron	1.3	4.25	This work
Octahedron	0.8	3.85	This work
Sphere	1.9	4.23	This work
Rod-like particles	several micrometers	4.75	1
Spherical nanoparticles	0.03	4.77	1
Spherical nanoparticles	< 0.03	4.37	1
Microflowers	0.8-1	4.8	2
Microspheres	1	4.65	2
Irregular particles	> 10	4.5	2



Element	wt%	Amount (at.%)
O	30.94	65.66
Zn	21.63	11.24
Ga	47.43	23.10
Total	100.00	100.00

Figure S1. The EDS pattern of the ZGO MPs.

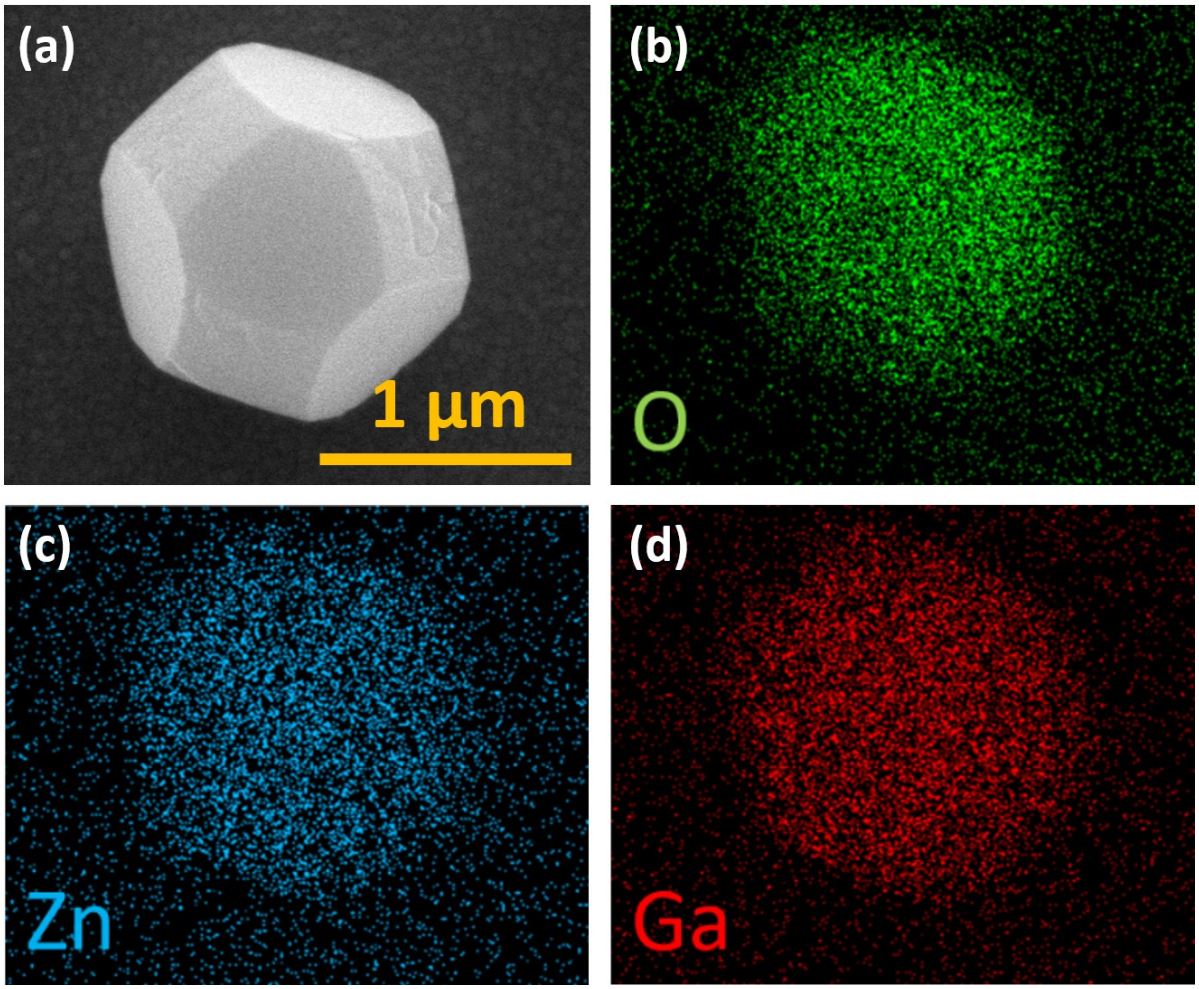


Figure S2. The SEM image of a typical single ZGO MP (a) and the EDS element mapping on a typical single ZGO particle: (b) O; (c) Zn; (d) Ga.

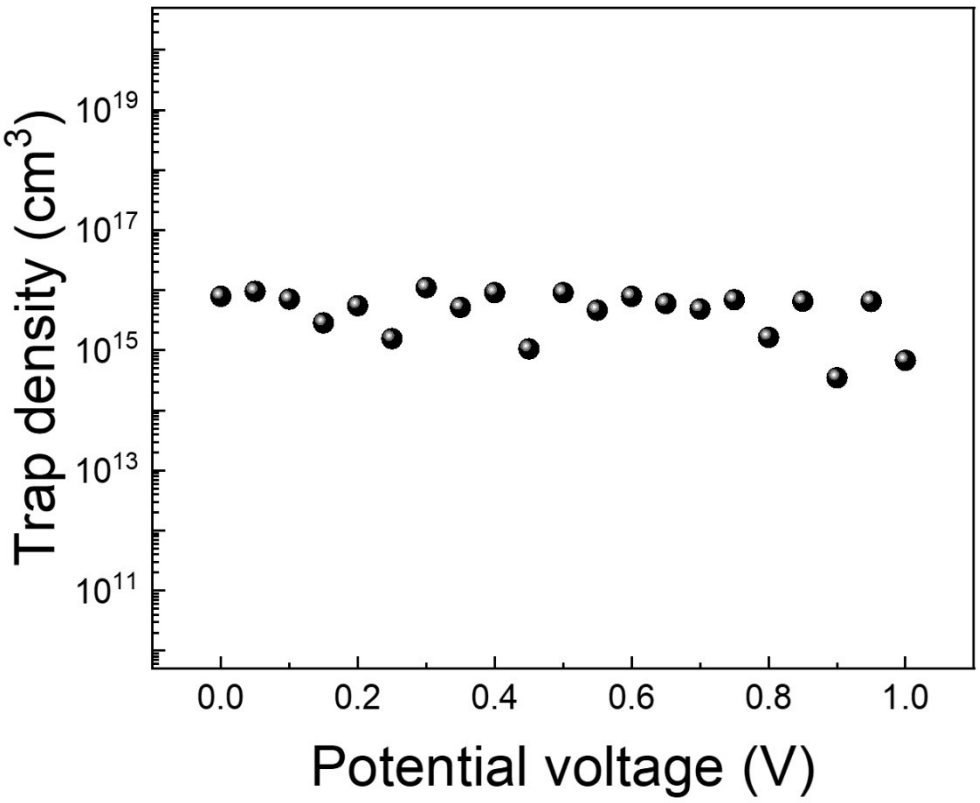


Figure S3. The trap density in UV-B PD from the capacitance-voltage measurement.

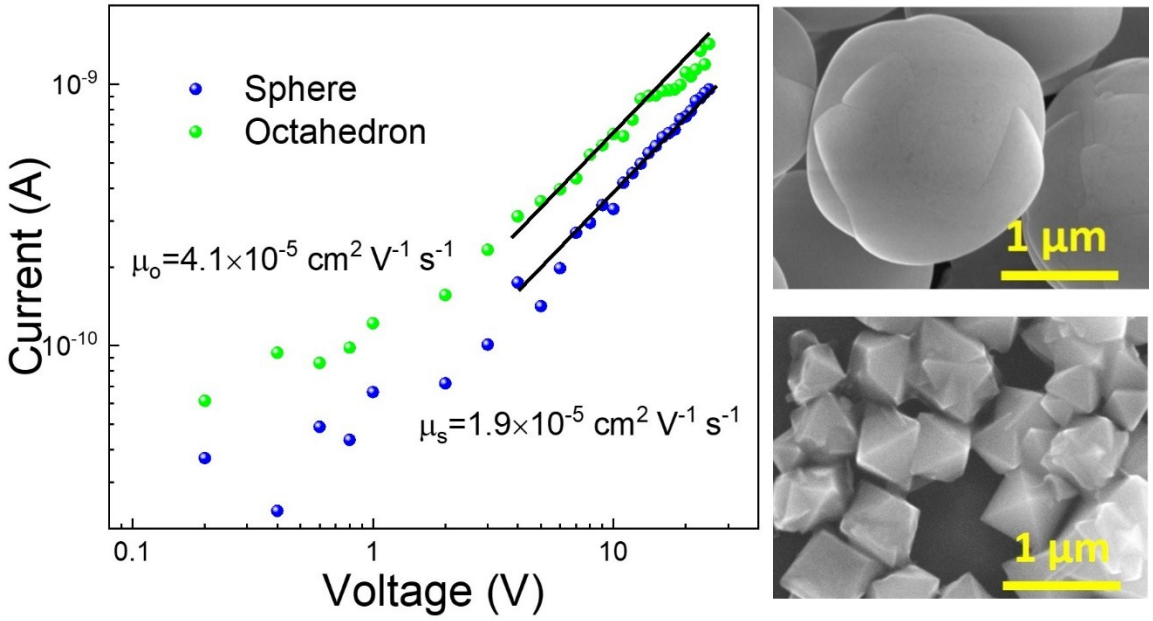


Figure S4. The space-charge limited current (SCLC) of the ZGO sphere and octahedron film.

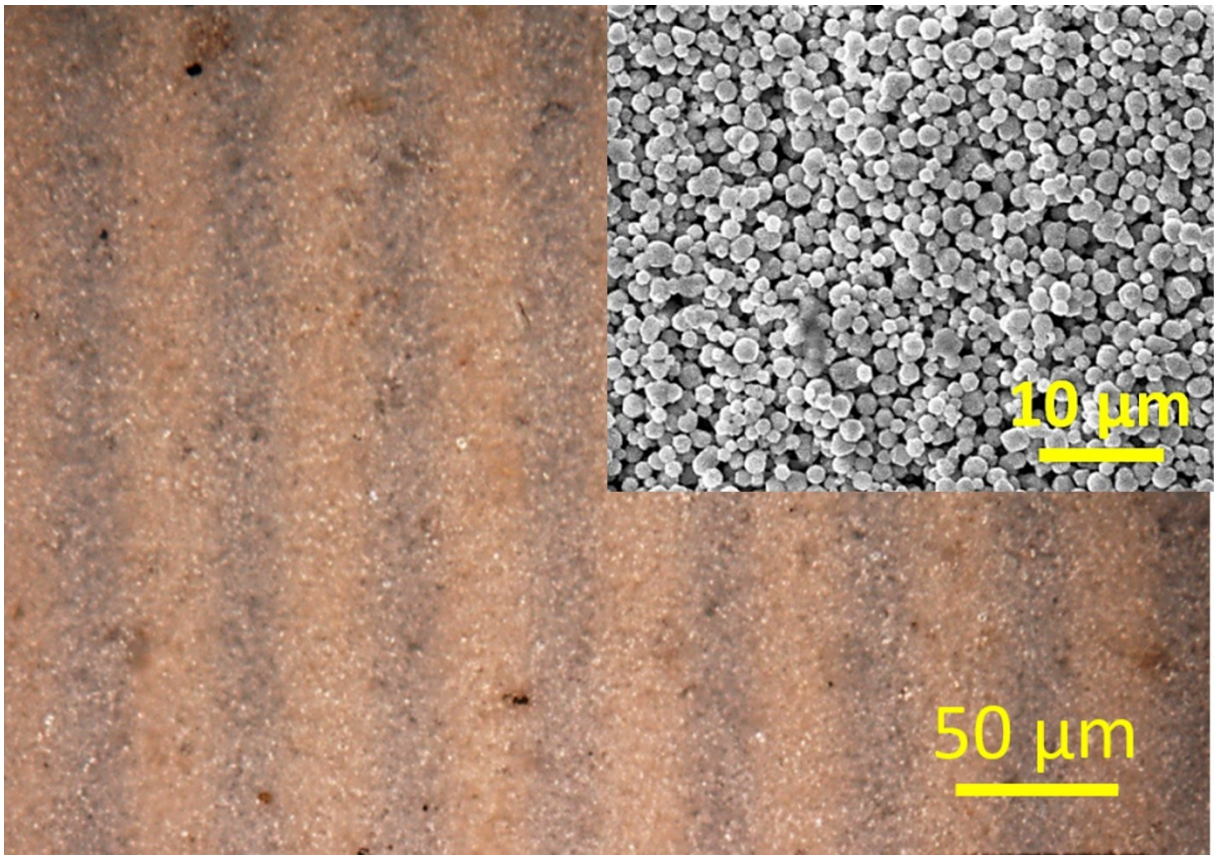


Figure S5. The optical micrograph of the ZGO assembled-film and the inset shows SEM image of the film.

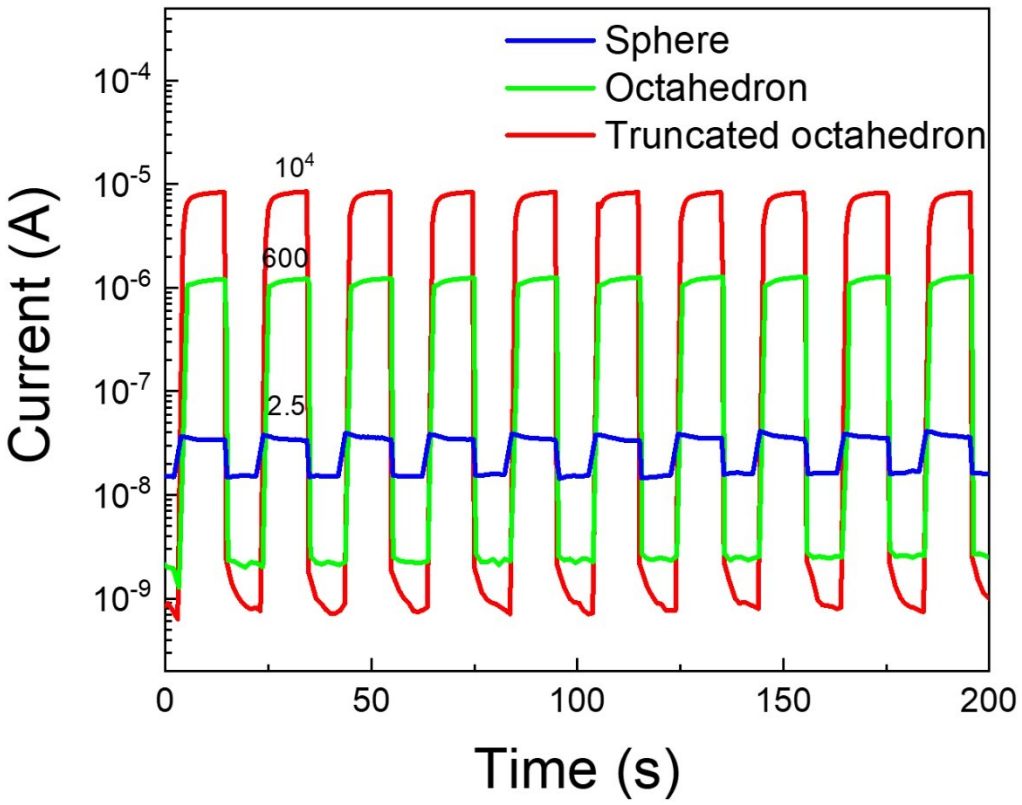


Figure S6. *I-t* curves of the three types based UV-B PDs under 3.18 mW/cm^2 irradiation at the wavelength of 266 nm.

Table S2. Photoresponses of different materials for UV-B photodetection.

Active material	I_{on}/I_{off} ratio	Bias voltage /V	Rise time/s	Decay time /s	Wavelength /nm	Detectivity /Jones	Minimum irradiation /W cm^{-2}	Ref.
$ZnGa_2O_4$ micro-particles	1.14×10^4	20	0.039	0.021	266	4×10^{14}	2.18×10^{-8}	This work
$ZnGa_2O_4$ nanowires	117	30	~2	＜1	254	—	—	3
$ZnGa_2O_4$ nanowires	130	5	15	10	350	—	0.18	4
$ZnGa_2O_4$ microflowers	1105	0	0.2	0.3	254	—	2.84×10^{-5}	2
Zn_2GeO_4 nanowires	200	8	12	0.6	245	—	5×10^{-5}	5
AlGaN films	10^4	5	—	—	—	—	—	6
n-MgZnO/p-Si	100	3	—	—	254	—	—	7
MgZnO films	200	150	—	—	254	—	—	8
MOS-structured MgZnO	2	5	—	—	366	—	—	9
AlGaN films	10^2-10^3	5	—	—	266	—	4774	10
MgZnO films	110	1	0.1	—	—	—	—	11
W- MgZnO films	100	0	—	—	—	—	—	12

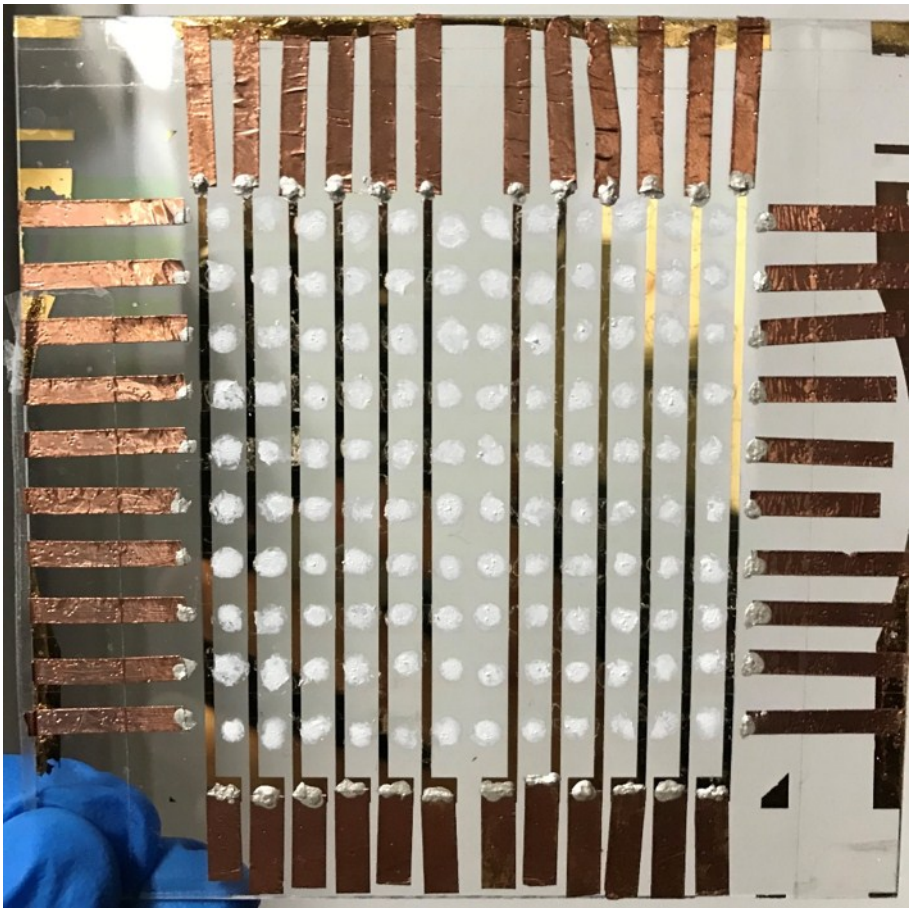


Figure S7. The photograph of as-fabricated 10 × 12 ZGO MPs image sensor on glass substrate.

References

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