Supporting Information

Liquid-Metal Synthesized Flexible a-IZTO Ultrathin Films for Electrical and Optical Applications

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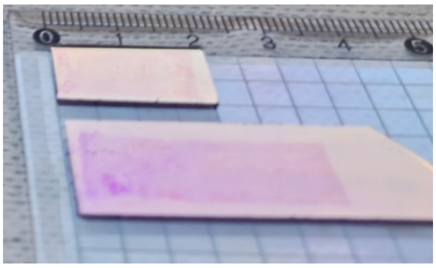

Figure S1. Photograph of a centimeter-sized 2D a-IZTO thin film on the SiO_2/Si substrate.

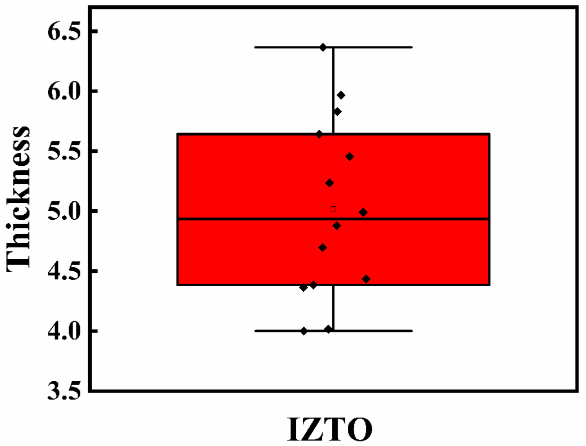

Figure S2. A statistical chart of the thickness (7 samples, two points for every sample).

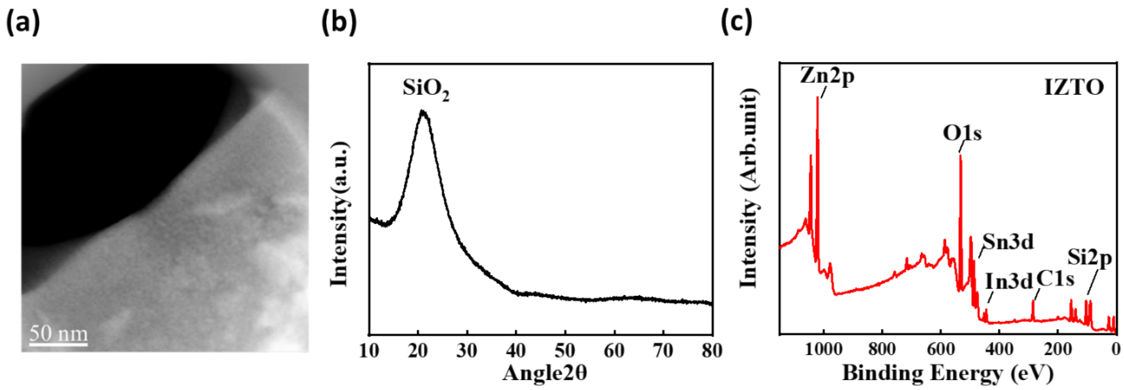

Figure S3. a) TEM image of the EDX element mapping in Figures 2e. b) XRD image of a-IZTO films annealed at 300 °C. c)XPS wide scan results for the a-IZTO thin films.

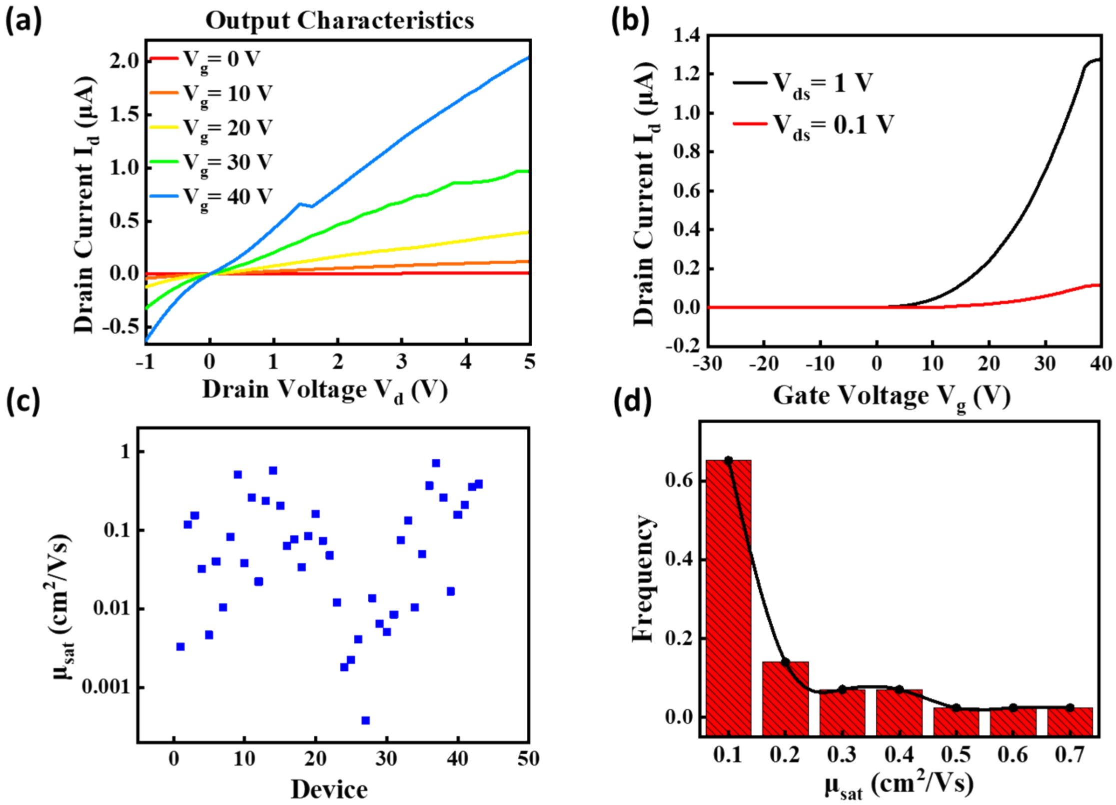

Figure S4. a) I_{ds} - V_{ds} curves of the IZTO-based FET from -30 V to 40 V. b) I_{ds} - V_g curves of the IZTO-based FET under different V_{ds}. c,d) Scatter plot and histogram of the mobility of 43 different devices.

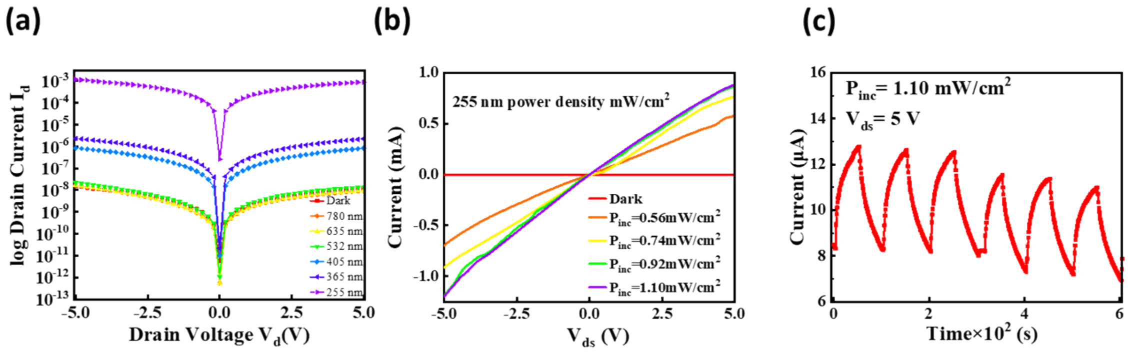

Figure S5. a) The I_{ds} - V_{ds} curves of the device in the dark and 255 nm - 780 nm light sources. b) The I_{ds} - V_{ds} curves of the device in the dark and under 255 nm light with various light illumination intensity at Vg = 0 V. c) Stability and repeatability of the current for the photodetector under the irradiation of 365 nm wavelength.

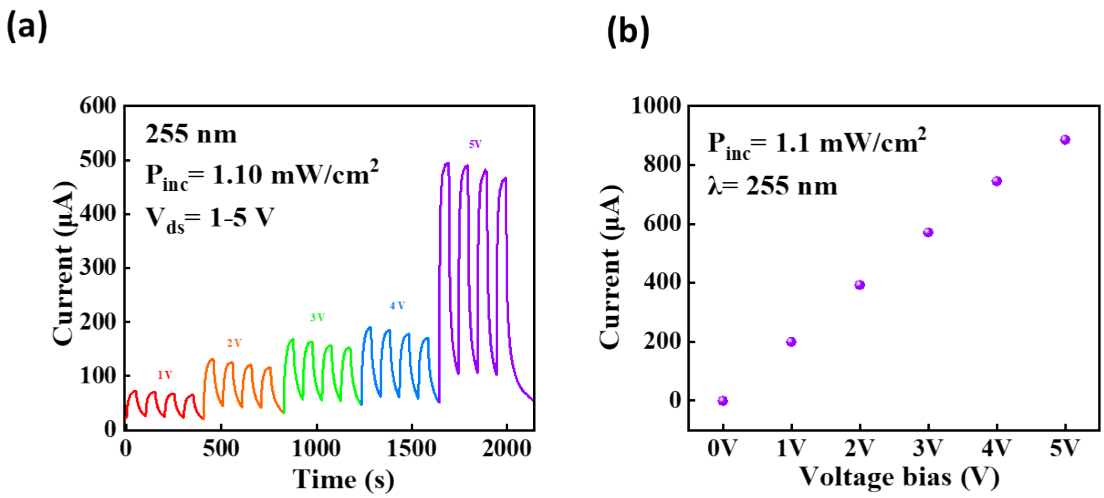

Figure S6. a, b) I - T curves and current obtained with various V_{ds} under an excitation wavelength of 255 nm and a P_{inc} of 1.1 mW cm^{-2}.

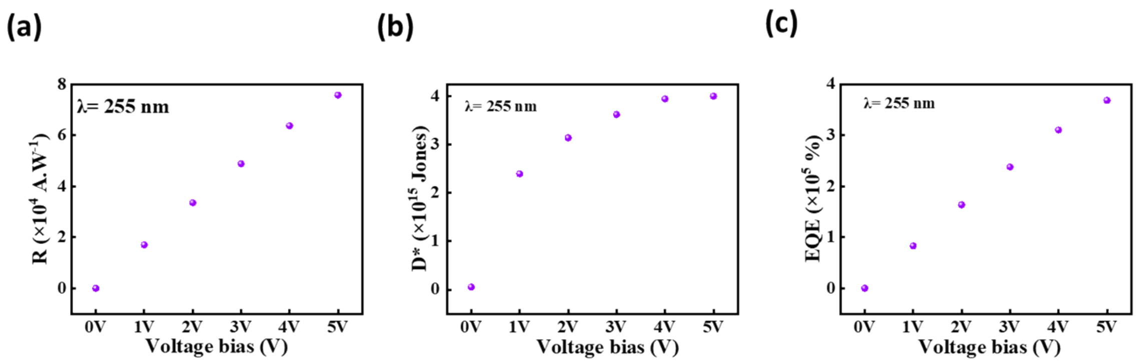

Figure S7. a-c) R, D* and EQE as functions of varying V_{ds} under 255 nm (1.1 mW cm^{-2}) illumination.

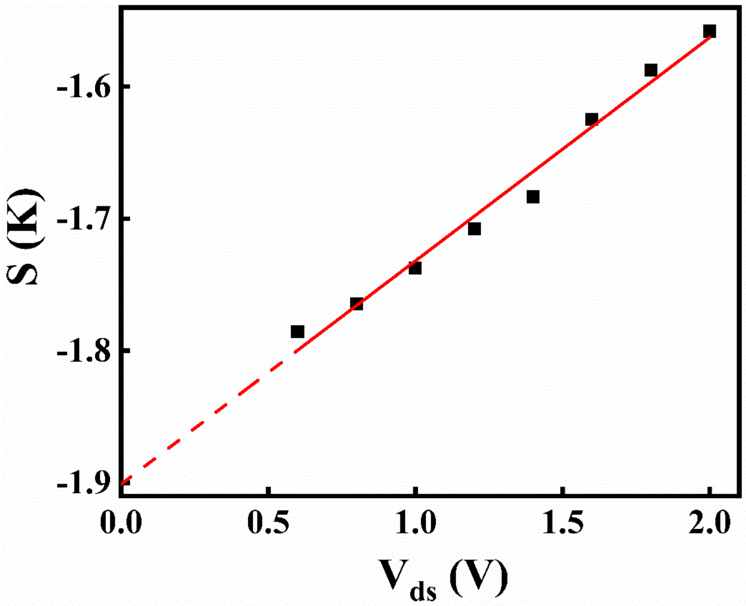

Figure S8. Fitting curve of slope S-V_{ds}. First, the variable temperature output characteristic data (I_{ds} - V_{ds}) of the device is obtained (Figure 4g). Then, draw Arrhenius curve and calculate the slope value: The classical Arrhenius curve is drawn with 1000/T as the horizontal axis and ln (I_{ds}/T^2) as the vertical axis. However, the classical Arrhenius formula is developed from the contact between 3D semiconductor and metal. For the contact between 2D semiconductor and metal, ln ($I_{ds}/T^{3/2}$) is used instead of ln (I_{ds}/T^2) as the vertical axis. Therefore, with 1000/T as the horizontal axis and ln ($I_{ds}/T^{3/2}$) as the vertical axis, multiple curves under different V_{ds} were drawn. And find the slope of each curve S. Finally, The S - V_{ds} curve was fitted to obtain the Schottky barrier: according to a series of S - V_{ds} values, linear fitting was carried out to obtain the ordinate intercept S_0 = -1.9 K. The Schottky barrier Φ_B could be obtained as 163.8meV, according to the formula. [1]

$$S_0 = \frac{q\Phi_B}{1000K_B}$$

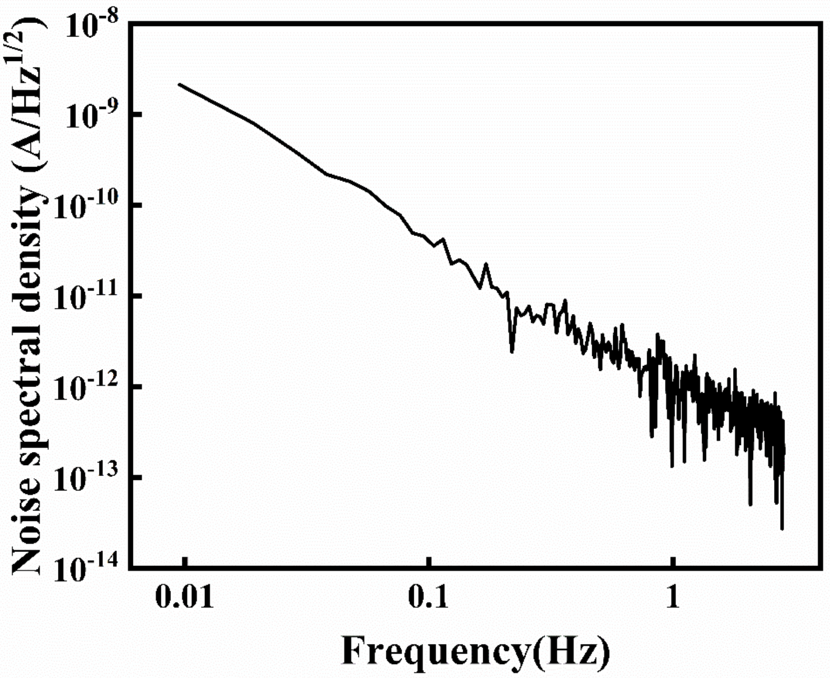

Figure S9. The noise spectral density of a-IZTO film.

Calculation of the D*

Since the illumination state is maintained during measurement, we believe that the frequency independent shot noise dominates the total noise of the device under this condition. According to Schottky's theorem, the spectral density of shot noise is defined as

$$S_I(f) = 2q\langle I\rangle \qquad (1)$$

where $\langle I\rangle$ is the average value of the electrical current. [2] Under this assumption, the current noise power spectral density in dark at 1 Hz bandwidth (PSD) is proportional to the square root of the dark current,

$$D^* = \frac{\sqrt[2]{2A\Delta f}}{NEP} \qquad (2)$$

and can be written as formula (3). [3]

$$D^* = \frac{\sqrt[2]{A}R}{\sqrt[2]{2eI_{dark}}} \qquad (3)$$

where A is the device area, Δf is its bandwidth, NEP is the minimum illumination power that delivers a unity signal-to-noise ratio at 1 Hz band width, R is responsivity of device, I_{dark} is the dark current. According to our measurements and calculations, A is about 657.96 μm^2, R is 7.57×10^4 A/W, I_{dark} is 12.2 nA. D* is calculated as 4.00×10^{15} Jones.
However, the electrical noise of photodetectors includes thermal noise, shot noise, generation-recombination noise, and 1/f noise. [2,4] In order to consider the influence of frequency related noise, we calculate D* with Formula 3. Firstly, we measured the current of the device for 108 seconds in the dark, and obtained the noise spectrum density of the device by Fourier transform, [5]the noise spectral density of a-IZTO film is shown in Figure S9. According to the calculation results, PSD is calculated to be about 2.09×10^{-12} A Hz$^{-1/2}$, PSD is the noise level per unit bandwidth (1 Hz) of the detector. According to the formulas

$$D^* = \frac{\sqrt[2]{2A\Delta f}}{NEP} \qquad (2)$$

and [6]

$$NEP = \frac{PSD}{R} \qquad (4)$$

according to our measurements and calculations, A is about 657.96 μm^2, Δf is 1 Hz, PSD is 2.09×10^{-12} A $Hz^{-1/2}$, R is 7.57×10^4 A/W. D* is calculated as 3.37×10^{15} Jones, which is slightly smaller than the previous results.

1. S. Lee, A. Tang, S. Aloni and H. S. Wong, *Nano Lett*, 2016, **16**, 276-281.
2. N. Huo and G. Konstantatos, *Adv Mater*, 2018, **30**, e1801164.
3. V. Krishnamurthi, T. Ahmed, M. Mohiuddin, A. Zavabeti, N. Pillai, C. F. McConville, N. Mahmood and S. Walia, *Adv. Opt. Mater.*, 2021, **9**.
4. Y. Chen, Y. Wang, Z. Wang, Y. Gu, Y. Ye, X. Chai, J. Ye, Y. Chen, R. Xie, Y. Zhou, Z. Hu, Q. Li, L. Zhang, F. Wang, P. Wang, J. Miao, J. Wang, X. Chen, W. Lu, P. Zhou and W. Hu, *Nat. Electron.*, 2021, **4**, 357-363.
5. L. B. Luo, D. Wang, C. Xie, J. G. Hu, X. Y. Zhao and F. X. Liang, *Adv. Funct. Mater.*, 2019, **29**.
6. M. Buscema, J. O. Island, D. J. Groenendijk, S. I. Blanter, G. A. Steele, H. S. van der Zant and A. Castellanos-Gomez, *Chem Soc Rev*, 2015, **44**, 3691-3718.