Electronic Supplementary Material (ESI) for Materials Advances.

SUPPLIMENTARY INFORMATION

Title: Investigation of transient photo-response and switching window in Al/Indigo/Al device : Unveiling negative photoconductivity and photo-enhanced memory window

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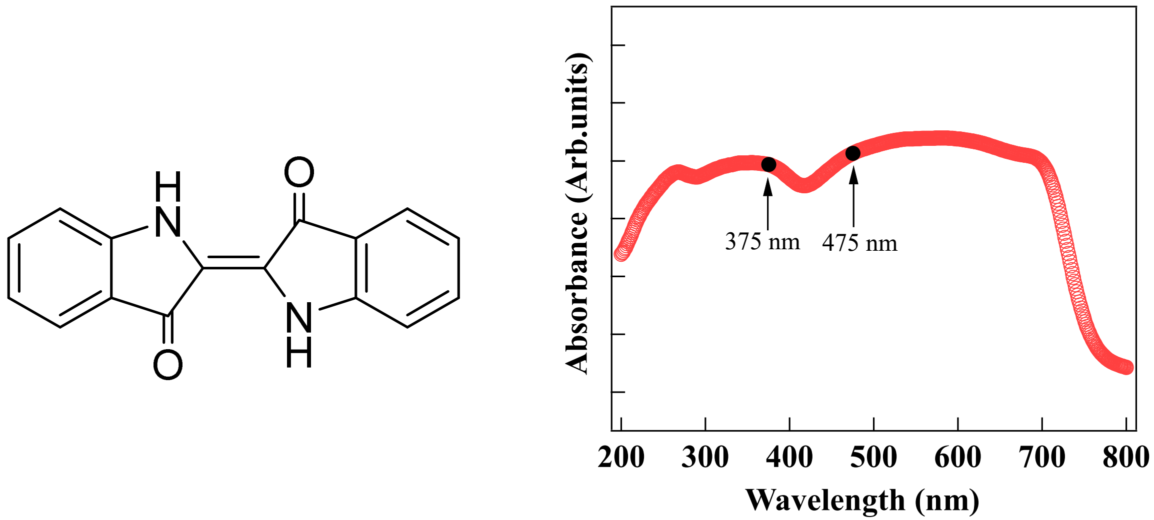

Figure (S1). (a) The structure of Indigo molecule (C_{16} N_{10} H_2O_2). (b) The absorbance spectra of Indigo molecular layer showing the higher absorbance in large wavelength range.

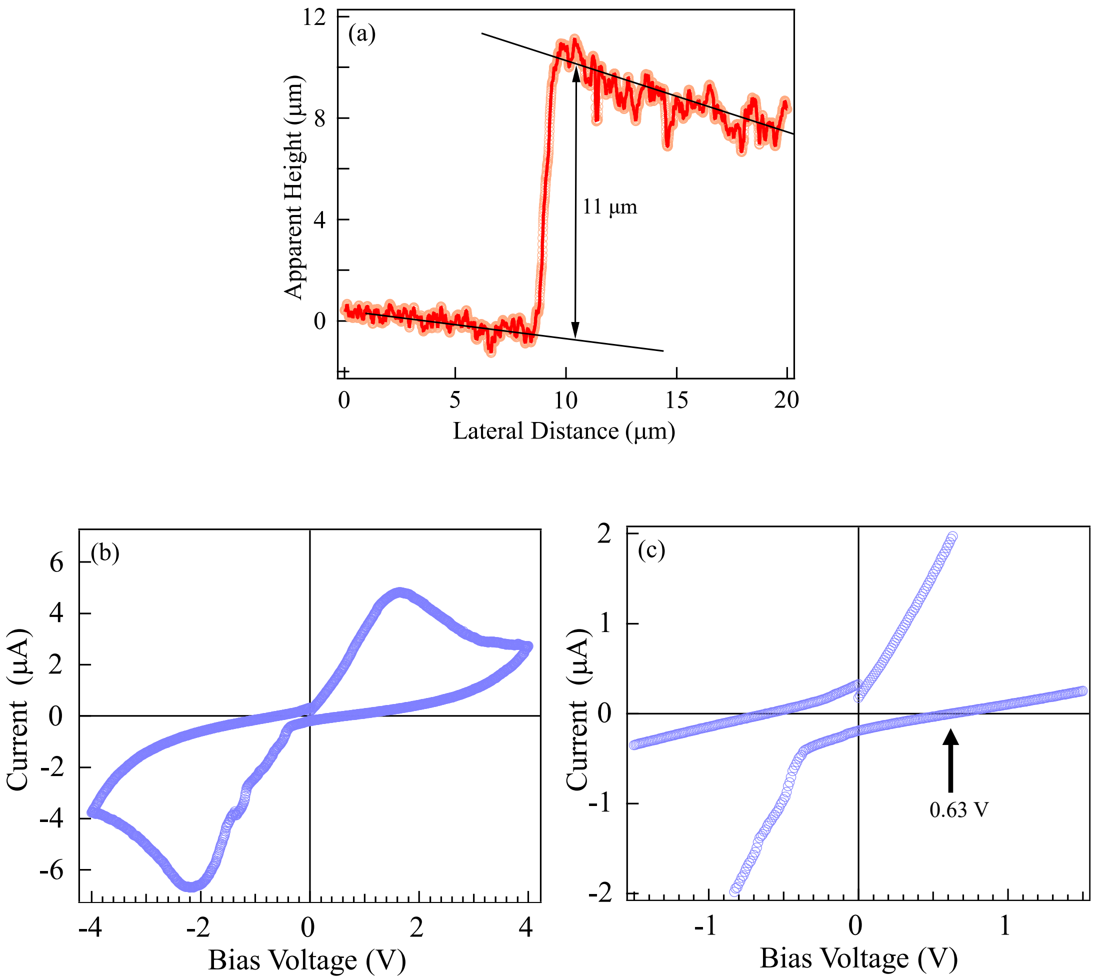

Figure (S2). (a) Apparent height of the interdigitated electrodes used in the device fabrication. The height of the electrodes are about 11µm. The electrode to electrode distance is about 125 µm. (b) The current – voltage measurement done in dark. The bias range is ± 4 V under (c) zoomed version of current-voltage curve indicating non-crossing characteristics. The current crosses the x-axis at 0.63 V in the first quadrant.

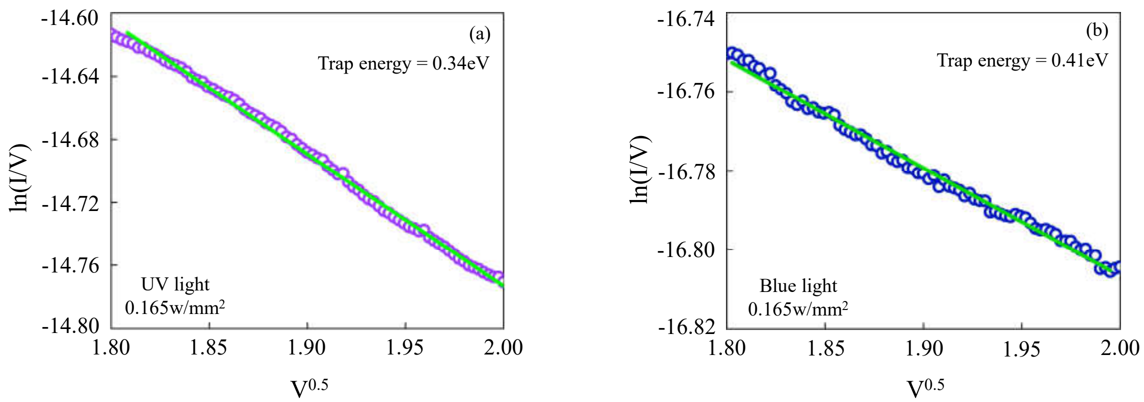

Figure (S3). Trap energy calculation from P - F conduction plot. The current – voltage measurement was done with range ± 4 V under (a) UV illumination and (b) Blue light illumination, with same intensity of $0.165 w/mm^2$.

Trap energy calculation

The electrical conductivity of semiconductors in the presence of high electric field is, $\sigma = \sigma_o e^{(\alpha E)}$ [Poole's law], where σ_o is the zero-field electrical conductance, α is a constant and E is the applied electrical field.

And the height of the potential barrier reduces by, $\Delta U = qEr_o + \frac{q^2}{4\pi\epsilon r_o}$, where q is the elementary charge and ϵ is the permittivity. The first term in this equation is due to the applied electric field and the second term is due to the electrostatic attraction between the ionic trap states and the electron.

The potential has a maximum at a distance of r_o from the coulomb trap centre. That is $\frac{q^2}{4\pi\epsilon r_o} = qE$ and $r_o = \sqrt{\frac{q}{4\pi\epsilon E}}$. So the height of potential barrier can be written as $\Delta U = q\sqrt{\frac{qE}{\pi\epsilon}}$.

The number of thermally ionised electrons without any electric field is proportional to $e^{\frac{-q\phi_B}{K_B T}}$, where ϕ_B is the voltage barrier in zero applied electric field, K_B is the Boltzmann's constant and T the temperature.

Therefore $\sigma = \sigma_o \exp\left[\frac{q\sqrt{\frac{qE}{\pi\epsilon}}}{K_B T}\right]$ and the current density $J = \sigma E$

The current density due to pool-Frenkel emission is,

$$J = q\mu N_c \mathrm{E}\exp\left[\frac{-q(\varphi_T - \sqrt{\frac{qE}{\pi\varepsilon}}}{KT}\right]$$

This equation can be rearranged into linear equation $y = mx + c$.

$$ln\left[\frac{J}{E}\right] \propto -\frac{1}{KT}\sqrt{\frac{q}{\pi\varepsilon}}\sqrt{E} - \frac{q\varphi_T}{KT}$$

Where, $q\varphi_T = \Phi_T$ is the trap energy. And μ is the electronic drift mobility, N_C is the density of states in the conduction band ε is the permittivity of active material.

$$ln\left[\frac{I}{V}\right] \propto -m\sqrt{V} - \frac{q\varphi_T}{KT}$$

A plot of ln(I/V) versus $V^{0.5}$ is linear for Poole-Frenkel emission. The intercept of the P - F plot can be used to calculate the trap energy, $\Phi_T = Y_{intercept} \times KT$

[1] Frenkel, J., On pre-breakdown phenomena in insulators and electronic semi-conductors, Physical Review, 1938. 54(8), 647.
[2] Simmons, J. G., Poole-Frenkel effect and Schottky effect in metal-insulator-metal systems, Physical Review, 155(3), 657.
[3] Chiu, F. C., A review on conduction mechanisms in dielectric films, Advances in Materials Science and Engineering, 2014, 2014(1), 1.

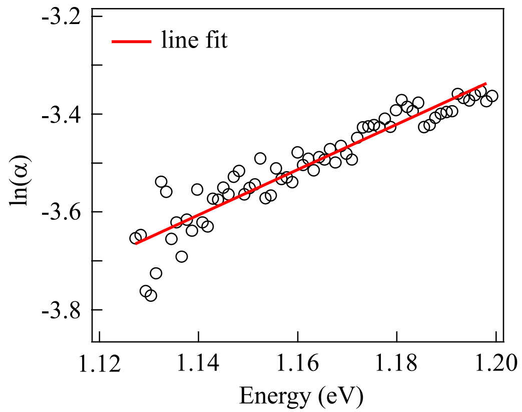

Figure. (S4) : Urbach energy calculation. The extent of conduction band tail correspond to the Urbach energy. This is calculated from the slope of the ln(α) vs Energy (eV) by making use of UV-vis spectra. From the slope, the Urbach energy is ~ 0.216 eV which matches very well with the calculated defect states.

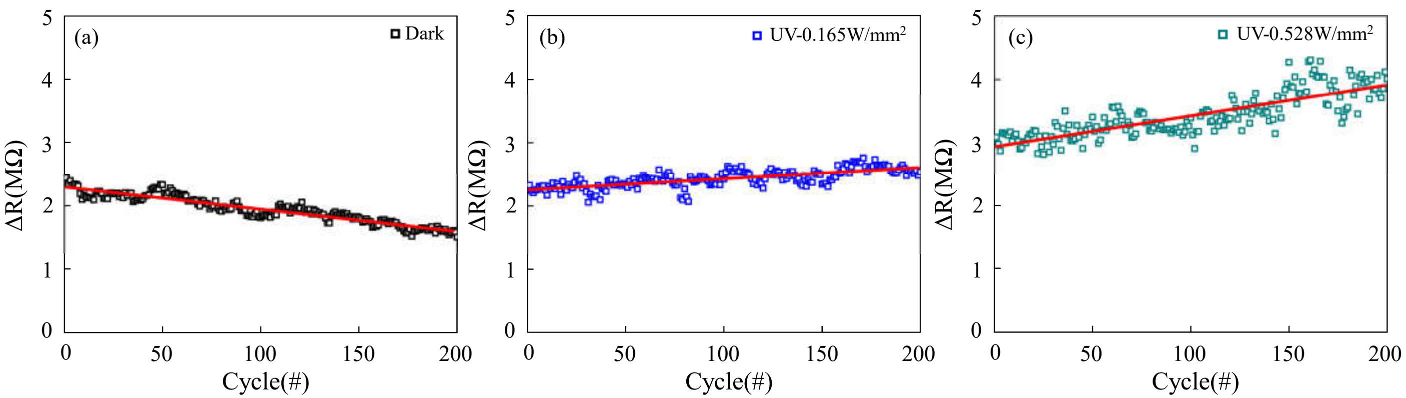

Figure (S5). The memory window enhancement with UV radiation (V_{read} = 0.9 V, V_{write} = -4 V, V_{Erase} = 4 V). The memory window $\Delta R = R_{HRS} - R_{LRS}$ (a) in dark, (b) Under UV illumination with intensity 0.165W/mm^2 and (c) Under UV illumination with intensity 0.528W/mm^2.