Visible Light Enhanced Resistive Switching Behaviour in Two-Dimensional Janus MoSSe

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Introduction: Resistive random-access memory (RRAM) is now being considered as one of the standout emerging memory technologies [1]. Artificial synapses mimicking the human brain can be easily implemented using RRAM devices [1,2]. Traditionally, for RRAM devices, various oxides have been used tactfully to employ the available oxygen vacancies to form the conductive filament and thereby achieve various resistance states. In this work, we propose to use a 2D Janus ternary material, MoSSe, in lieu of oxides. As Se or S vacancies offer more stability, better charge transfer capability, and easy controllability during the material synthesis, the proposed device is expected to offer better performance metrics [3]. As the Se or S vacancies help easier charge separation and transport properties, external photoexcitation would improve the all-important R_{OFF}/R_{ON} ratio. Typically, the band-gap (E_g) of MoSSe ranges ~ 1.9 eV [3], which indicates that a visible photoexcitation around 652 nm will improve the R_{OFF}/R_{ON} ratio.

Results and Discussions: MoSSe material characterization can be carried out using standard techniques such as XRD, XPS, and UPS. The XRD spectra of MoSSe reveal its hexagonal crystal structure with a dominant presence of the 1T phase, with a little presence of the 2H phase [3]. Similarly, the XPS analysis confirms the formation of MoSSe via the hydrothermal reaction. The UV-Vis absorption study and UPS measurements estimate the E_g and work function of the synthesized MoSSe to be 1.81 eV and 4.68 eV, respectively.

Various electrical characteristics of the prototype device were carried out using a Keithley 2601B pulse source meter unit connected via an RF probe station. In the absence of the 685 nm photoexcitation, the measured R_{OFF}/R_{ON} ratio is approximately 0.12. As MoSSe is sensitive to 685 nm photoexcitation, Se and S vacancies offer better charge separation, which aids in the formation of the conduction bridge, and thereby the R_{OFF}/R_{ON} ratio improves to 3.88 with a butterfly-shaped I-V profile. Interestingly, the overall device current reduces in this condition, which enables the proposed device to be utilized as a light-gated inverted transmission gate. The charge conduction mechanism can be explained by the trap-assisted SCLC theory. Additionally, the bipolar resistive switching (BRS) behaviour can be explained using the conduction bridge formation (CBF) due to the dual active electrodes in the device. The stability property of the BRS in the Ag/MoSSe/Ag device was recorded at room temperature, and the results show that consecutive 100 switching cycles almost overlap with each other, validating the stability of the device. Similar to biological neurons, the proposed device gives rise to stable voltage spiking in the presence of any change in the input current.

References

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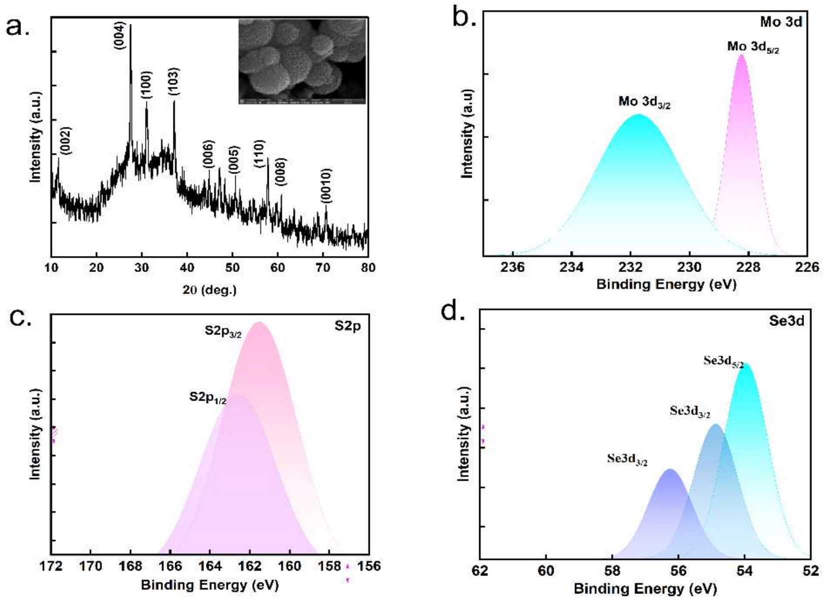

Fig. 1: Material characterization of synthesized MoSSe: (a) XRD pattern, (Inset: nano flower surface morphology of MoSSe), (b)-(d) core-level deconvoluted XPS spectra validating the synthesized MoSSe.

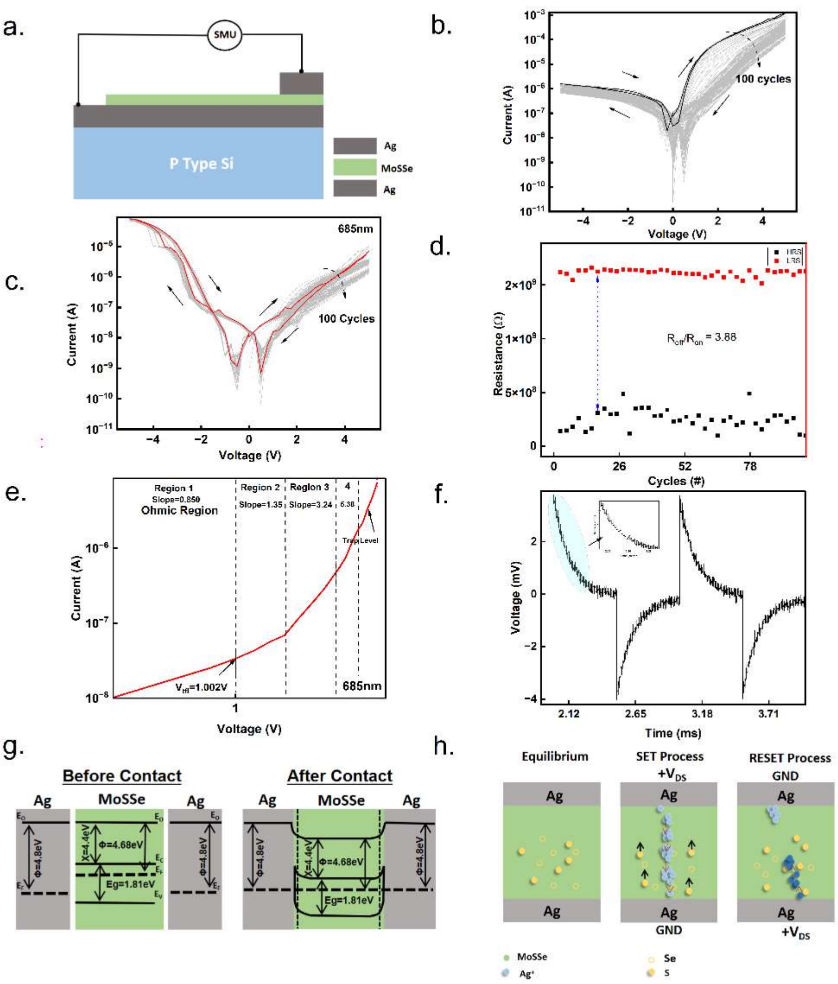

Fig 2: Schematic & electrical characterization of the proposed device: (a) cross-sectional device schematic, (b)-(c) measured I-V characteristics in dark condition & at 685 nm photoexcitation, (d) variation in R_{off}/R_{on} ratio for consecutive 100 cycles, (e) conduction mechanism explanation via SCLC theory, (f) measured spiking, (g) energy-band diagram of the device, (h) schematic illustrating the CBF in the active region of the device under different bias conditions confirming the BRS behaviour of the proposed device.