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Development of organic–inorganic halide perovskites (OHPs) based memristors

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Abstract

Organic – inorganic halide perovskite (OHP) has drawn researcher's attention working in the field of optoelectronics from last ten years due to its remarkable optical properties such as adjustable band gap, ambipolar charge transport, high optical absorption coefficients, and extended carrier diffusion lengths. OHP based memristors (memory + resistors) are newly introduced passive two-terminal, nonlinear device used for information storage. In this work we have fabricated methyl ammonium lead iodide (MAPbI3) crystals-based device (Figure 5) from MAPbI3 crystals (Figure 1). The crystals have been developed by simple solution process-based method. Developed crystals have shown highly porous geometry and trap charges across these pores facilitates higher conductivity. The fabricated device exhibit ~2.7 milli second response recovery time (Figure 7) which enable elevated speed and shown hysteresis in the I-V characteristics (Figure 8) thus demonstrated superior storage capacities. Hence developed device has been the potential candidates for next-generation non-volatile memories.

1. Introduction/Objective

MAPbI3 has been the well known OHP in the field of thin film-based photovoltaic device (PVD). However, shape and size of crystals have profound impacts on electrical and optical properties. Hence lower dimension (zero-dimension, one dimension) OHP crystal structure provide particular set of advantages such as large surface to volume ratio, better charge separation and conductivity makes OHP very useful in optoelectronics application other then PVD. The morphological, and structural properties of the one-dimensional perovskite micro-rods have been examined using SEM and XRD characterization techniques. Memory resistors has been fabricated using micro-rods . Current – Voltage (IV) characteristics has been studied to examine charge conduction behavior of the device

2. Hypothesis

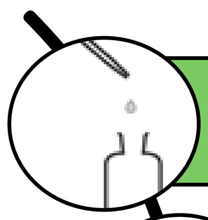
If one-dimensional $MAPbI_3$ perovskite micro-rods has been obtained by solution-based facile synthesis of, non-volatile memory may be improved further.

3. Materials and Equipment

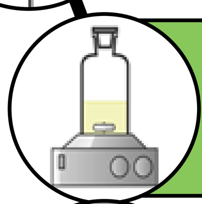
Materials Required	Equipment to be Used
1. Lead (II) iodide	1. Heater with stirrer
2. methylammonium iodide	2. Ozone cleaner
3. Dimethylformamide (DMF)	3. Dry nitrogen blow dryer
4. isopropanol (IPA)	4. Magnifying glass
5. ITO coated glass	5. FESEM
6. Silver Paste (Ag)	6. Solar Simulator with Keithley 2400 SMU
7. Acetone, Methanol, Hellmanex III solution.	7. XRD machine
	8. Ultra sonicator
	9. Kickstart software

4. Methods

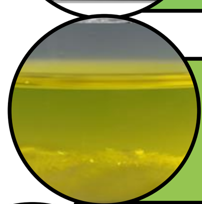
4.1 Crystal Synthesis:



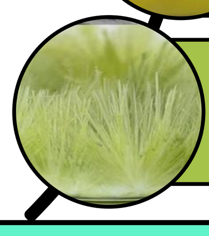
1M solutions of PbI_2 and MAI were prepared separately in DMF and IPA



PbI_2 and MAI solutions were mixed in the 2:1 volumetric ratio then simultaneous heating and stirring at 70 °C gives a clear yellow solution of the $MAPbI_3$



The solutions of $MAPbI_3$ was left to cool down slowly at a very slow rate of 10°C /HR)



The growth of the micro-rods were observed after many hours of cooling down solution to room temperature.

4.2 Device Fabrication:

ITO coated glass substrate has been cleaned using Acetone, Methanol, and Hellmanex-3 cleaning solution under ultrasonication sequentially

After drying under nitrogen each MAPbI3 has place at ITO substrate

silver (Ag) paste has been used to connect both the ends to complete Ag-MAPbI3-Ag device

Current-voltage (I-V) characteristics of the device has been measured under dark and 1 Sun

5. Results and Analysis

Figure 1: MAPbI3 crystals grown in the DMF solution.

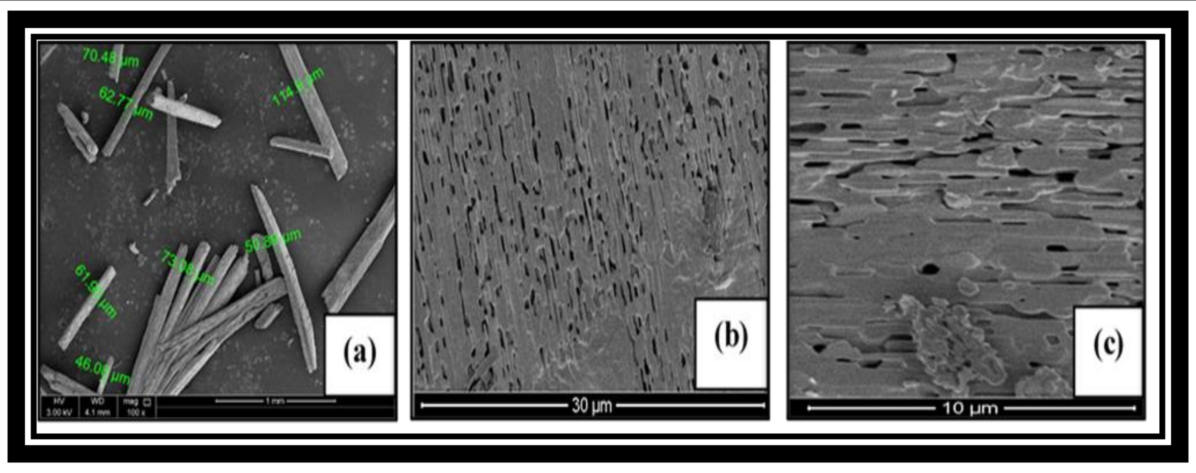


Figure 2: FESEM images of $MAPbI_3$ micro-rods taken at different magnification. (a, b and c).

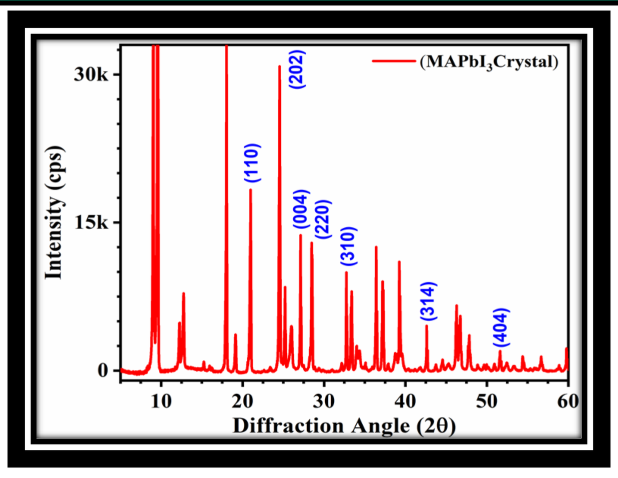


Figure 3: XRD results of $MAPbI_3$ micro rods.

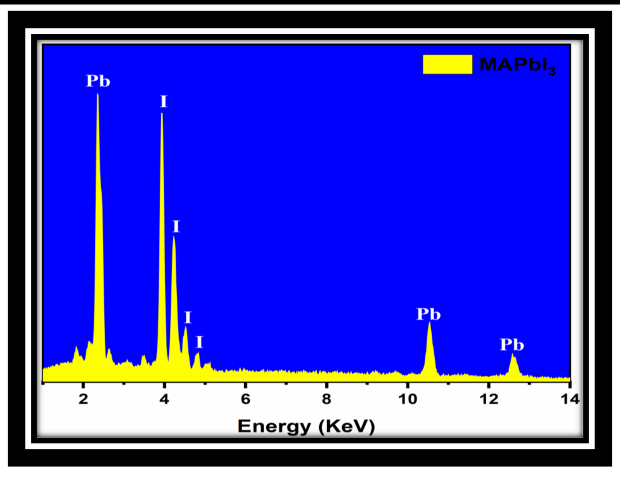


Figure 4: EDS spectra of the $MAPbI_3$ micro-rods.

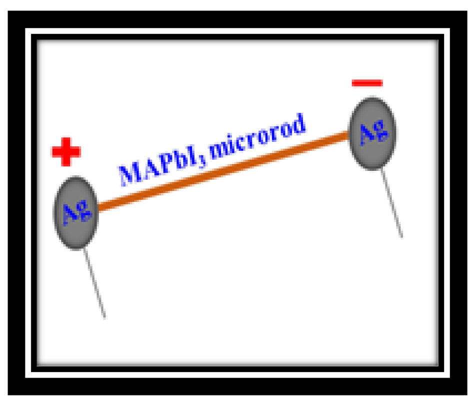


Figure 5: Device Structure of Ag/MAPbI3/Ag based photo-induced memory resistor.

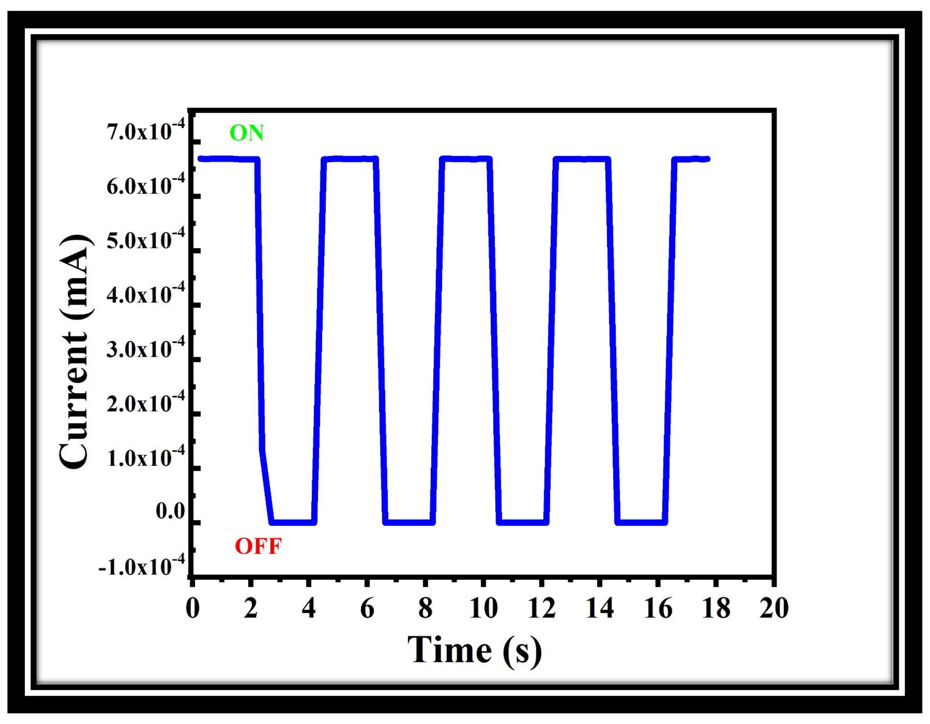


Figure 6: ON/OFF behaviour of Ag/MAPbI3/Ag based memory resistor .

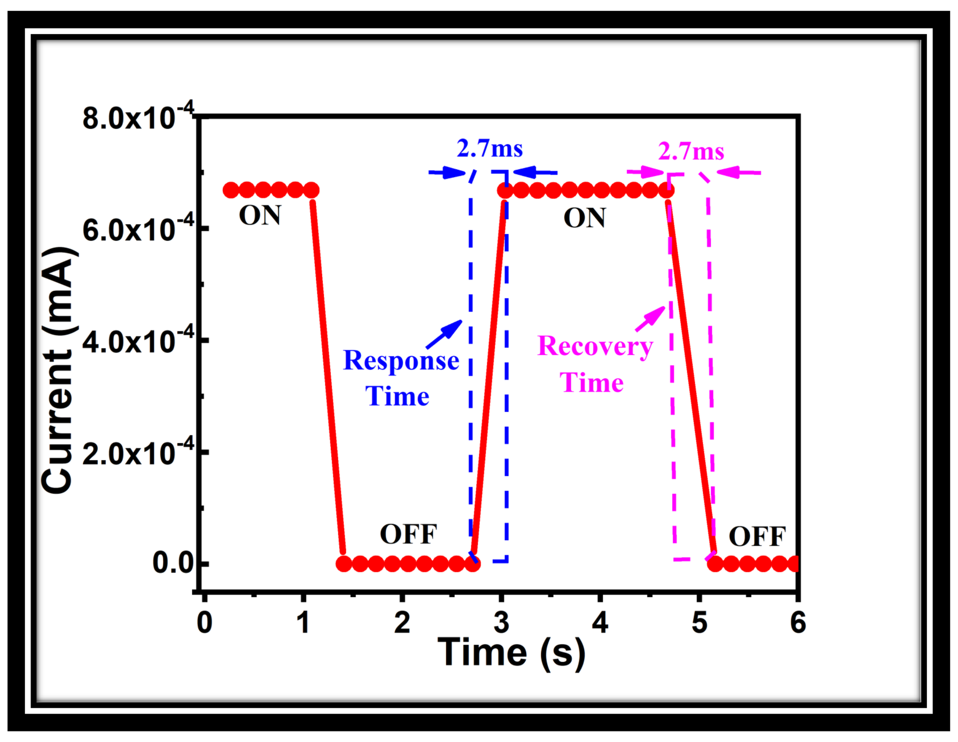


Figure 7: Response and recovery switching cycles of device.

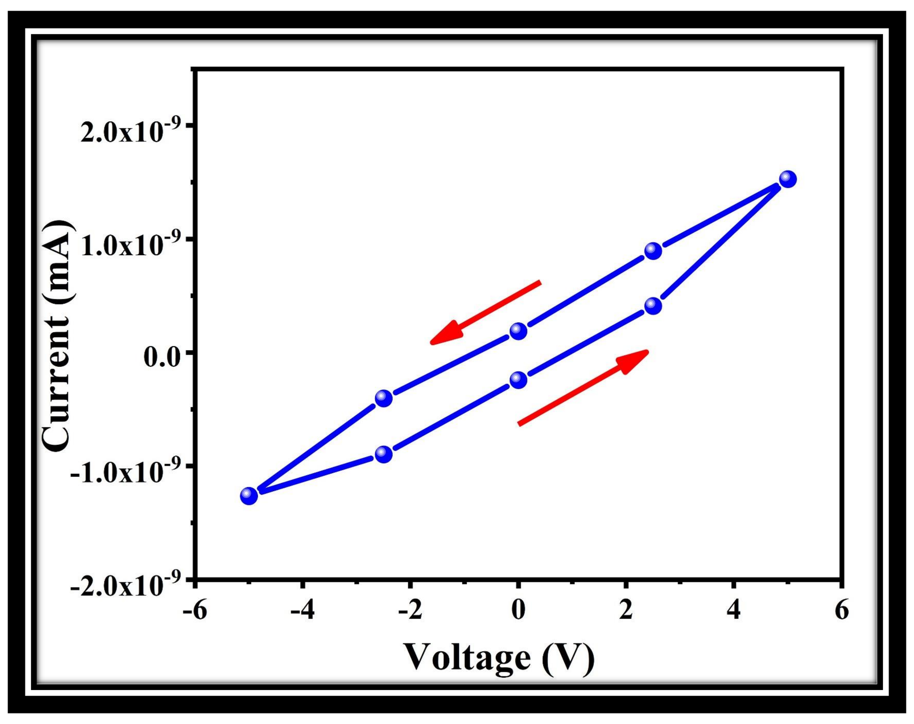


Figure 8: Hysteresis plot for Ag/MAPbI3/Ag based device.

5. Concluding remarks

- X-ray diffraction and EDs analyses confirm phase purity and high crystallinity of the developed micro-rods. The morphological studies (SEM) confirm crack free morphology of $MAPbI_3$ micro-rods with porous structure. Developed crystals have shown highly porous geometry and trap charges across these pores facilitates higher conductivity.
- The fabricated device exhibit ~2.7 ms response recovery time which enable elevated speed and shown hysteresis in I-V scan thus demonstrated superior storage capacities. Hence developed device has been the potential candidates for next-generation non-volatile memories.

6. References

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