

Redox-gated 3-terminal organic memory devices: Performance with future prospects

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Redox gated 3-terminal organic memory device is a potential candidate with existing alternative non-volatile memory (ANVM) technologies. The device architecture and operation mechanism of this is remarkably different than all reported ANVM in literature. Even structure of this is similar to OFET but operation is certainly different. Survival of generated polarons makes major difference on operation. Device is prepared using a thin solid polymer electrolyte as gate dielectric on a ~30 nm thick conducting polymer (CP) layer as channel. Order of resistance change between low & high conducting states remain $>10^4$. Raman spectroscopy during device operation has shown the direct evidence of polaron formation in conducting polymer layer. Multi-state memory application is also possible with this memory device. Environmental conditions and temperature has big influence on device speed. Flash memory devices require 17–1100 nJ/byte for operation. The energy consumption for this memory cell with dimension (100×100) nm has estimated as <10 pJ/byte which is much less than the energy required for “flash” memory [1]. Further research will give us the opportunity to design memory cell with low energy cost per bit using this technology.

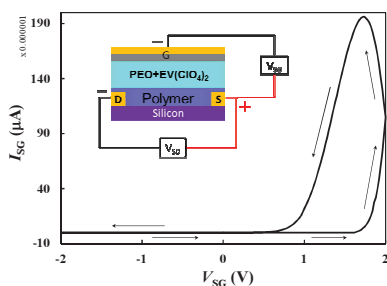


Figure 1: Source-Gate I-V curve for Au/P3HT/PEO-EV/e-C/Au memory devices with drop-cast electrolyte. Increase in I_{SG} current around $V_{SG} = \pm 2.0$ V is due to oxidation of P3HT accompanied by ethyl viologen (EV) reduction. Inset shows the schematic of experimental devices under investigation

Figure 1 shows an $I-V$ curve for a three-terminal Au/P3HT/EV(ClO_4)₂+PEO/e-C/Au device scanned between $V_{SG} = -2$ and $+2$ V. Polarities of bias potential and layer constituents of the device are shown in the inset in Figure 1, and the arrows show the direction of sweep starting from $V_{SG} = 0$. An asymmetric $I_{SG}-V_{SG}$ is appeared with more current when S is biased positive with respect to G and an asymmetry ratio of $\sim 10^3$ for $|V_{SG}| = 2$ V. When S is biased positive beyond a certain

threshold (~ 1.5 V in the present case), P3HT is oxidized to its conducting polaron (P3HT⁺) and EV⁺² is reduced to EV⁺ at G. Under reversed polarity with V_{SG} , current through the SG circuit is small because P3HT is now reduced and its conductivity is low. Further support for the redox mechanism is provided by in situ Raman spectroscopy of the three-terminal device under different V_{SG} conditions [2].

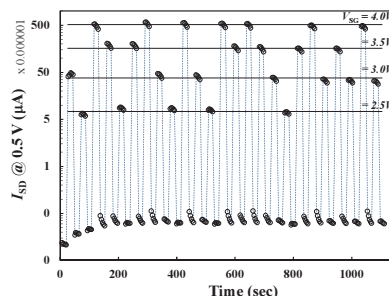


Figure 2: Multilevel W/R/E/R cycles using random $V_{SG} = \pm 2.5, 3.0, 3.5,$ and 4.0 V with pulse duration of 1 sec for a P3HT/PEO-EV device under vacuum ($<1 \times 10^{-5}$ Torr). After each write or erase pulse, five I_{SD} values were recorded at 2 sec intervals when $V_{SD} = +0.5$ V

It was clarified from our research that the conditions and materials necessary for redox-gated ANVM devices based on conducting polymers and the performance affecting parameters, particularly W/E speed, retention, and cycle life. For control experiments, we have used different polymers from conducting to inert and also investigated electrolytes with and without an electron acceptor. It was shown that both speed and cycle life was strongly affected by environmental conditions which affect ionic conduction. The results are valuable for designing and assessing the performance and commercial viability of redox-gated polymer memory devices. This phenomenon may also lead to an application of redox gating to “multistate” memory cell design, as illustrated in Figure 2 [3]. At least in principle, the number of bits available in one device could be increased by a factor of 4 using this approach.

References

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3. Das BC, Pillai RG, Wu YL, McCreery RL. 2013. ACS Appl. Mater. Inter. 5:11052-11058.