Organic charge storage materials for high performance non-volatile organic transistor memory device

Due to increasing interest in consumer electronics, there is great demand for high-density, high-speed, long retention time (non-volatile) and low power consumption memory devices. Organic Field-Effect Transistor (OFET) memory devices have been considered to be promising candidates for next-generation non-volatile memory devices due to their non-destructive read-out properties, single transistor realization, and excellent compatibility with integrated circuits. The device shown in Fig. 1a incorporates an additional charge-trapping layer, such as metallic nanoparticles, a planar metallic sheet or polymer electrets, between the semiconductor layer and the gate dielectric layer. Fig. 1b shows the operation principle of p-type OFET memory. The p-type OFET memory is operated by applying a negative gate bias between the gate and the source electrode, where holes from the semiconductor channel tunnel through a potential barrier into the charge storage layer. The trapped charges affect the distribution of carriers in the semiconducting channel, thus resulting in shifts of threshold voltage (VTH), corresponding to the programming (PGM) or erasing operation (ERS). As a result, the digital "0" and "1" signals in one bit are determined by the erasing and programming operations, corresponding to low and high drain currents, respectively.

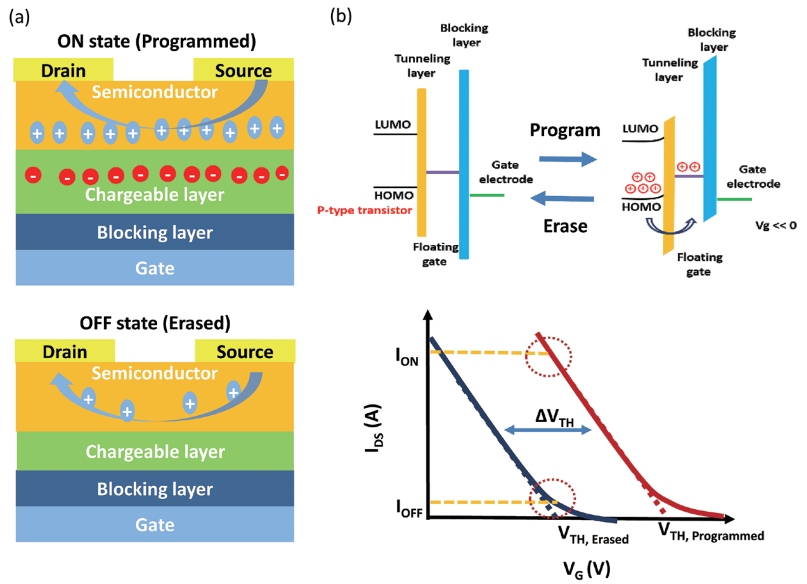

Figure 1. (a) Device structure of OFET memory; (b) Charge trapping mechanism of floating gates and I-V curve shifting in the OFET memory. (Reproduced from C. C. Shih, W. Y, Lee, W. C. Chen, Mater. Horiz., 2016, 3, 294 with permission from The Royal Society of Chemistry)

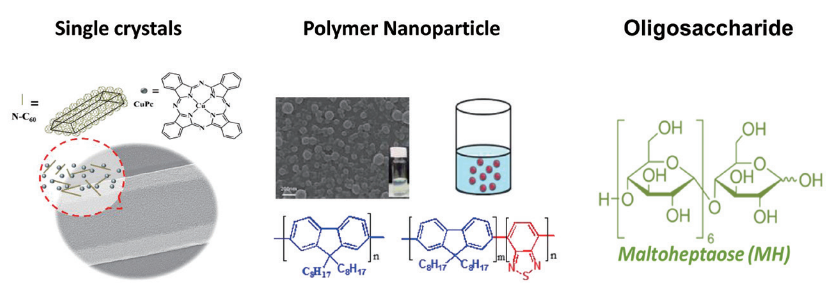

Figure 2. Three chargeable layers (nanofloating gates and renewable dielectric) developed for high-performance non-volatile memory. (Reproduced from Ref. 1, 2 and 3 with permission from John Wiley and Sons)

Precise control of the amount of charge stored in the specific floating-gate could potentially solve the fundamental scaling-down issues and meet the requirements for high-density memory devices. Recently, Prof. Wen-Chang Chen, Dr. Chien-Chung Shih, and Dr. Yu-Cheng Chiu of National Taiwan University, Prof. Wen-Ya Lee of National Taipei University of Technology, Prof. Cheng-Liang Liu of National Central University, and Dr. Redouane Borsali of CNRS, France, employed nanostructured floating gates or renewable oligosaccharide dielectrics as charge storage layers to achieve high-performance non-volatile organic transistor-type memory, as described in the following (Fig. 2). (1) The concept of double floating-gates, bipolar charge trapping, and discrete trapping sites is first combined to develop high-performance non-volatile OFET memory. The studied double floating-gate memory could simultaneously store holes and electrons on copper phthalocyanine (CuPc) nanoparticles and needle C_{60} single crystals, respectively, leading to a broad memory window (~4.4 V), low power consumption (±5 V), long data retention time (~10^4 s), and good writing/erasing endurance (over 100 cycles). (2) A molecular nano-floating gate (NFG) consisting of pentacene-based transistor memory devices is developed using conjugated polymer nanoparticles (CPN), such as polyfluorene (PF), as the discrete trapping sites embedded in an insulating polymer, poly(methacrylic acid) (PMAA). By inserting PF nanoparticles as the floating gate, the transistor memory device reveals a controllable threshold voltage shift, indicating effective electron-trapping by the PF CPN. (3) Renewable oligosaccharides are employed as the charge storage layer in the OFET memory device because the charged hydroxyl groups facilitate the formation of strong hydrogen bonding to stabilize trapped charges and remain stable in a high-conducting state, even after successive stresses of reverse gate biases. This is the first example of employing renewable sugar-based materials as a charge storage layer that exhibit a WORM (write-once-read-many-times) memory characteristic with an ON/OFF current ratio larger than 10^6. The above results can meet the requirements for next-generation organic non-volatile transistor-type memory devices.

References

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Professor Wen-Chang Chen
Department of Chemical Engineering
chenwc@ntu.edu.tw

A novel intraocular lens device

The optical and biofunctional properties of anintraocular lens are customizable

The research team of Professor Hsien-Yeh Chen (Department of Chemical Engineering) at National Taiwan University has demonstrated an innovative intraocular lens (IOL) device (PPX-IOL) that is fabricated via chemical vapor deposition (CVD) encapsulation of func-tionalized poly-p-xylylenes (PPX).

The novel design of PPX-IOL provides customiza-ble parameters for both its optical and biological proper-ties. As an excellent optical device, it provides a high re-fractive index and a tunable effective focal length that is realized by manipulating the wetting properties of liquids. The device also offers protec-tion from UV radiation. As a key medical device, it exhibits excellent biocompatibility and reduced postoperative calci-fication due to the intrinsic properties of PPX. In addition, these synergistic functions provide precise surface chemistries for the placement of eye epithelial cells via guided attachment or repel-lent properties, which is very important in preventing de-vice-associated