Promising Investigations into Organic Nonvolatile Flash Memory

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Summary for RSS Feeds: Anri Nakajima and Daiki Fujii investigate polymers containing C_{60} or a closely related derivative in order to gauge the retention times and programming capability these materials have. Promising results are obtained, with a C_{60}-containing polymer holding information for hours while only being powered for a time on the order of tenths of a second.

Anri Nakajima and Daiki Fujii have performed investigations on gate insulating polymers containing fullerene molecules for the purposes of application in flash memory devices. They themselves refer to these materials as simply "nanocomposites." They take a detailed look a capacitance-voltage response curves obtained from materials they chose and demonstrated that these organic materials are capable of retaining programmed information for long periods of time (on the order of hours), after applying -4V for a period of 150 seconds. The specific data is linked to how they believe the charge carriers are moving around in the material and they have made predictions about how their materials can be improved.

Conventional flash memory devices are not exactly stable when it comes to the retention of information. The information can decay, and processes such as reading or writing can speed up the process of decay. When reading from the same flash memory cell over and over, the surrounding cells can be accidentally altered. This problem is typically solved by moving the information to a new location and erasing an entire cell block in order to refresh it. Flash memory devices come with an estimated amount of times that one can program and erase a cell block before the capacity of the material to retain information begins to degrade. Clever methods of extending the life of a flash memory device that suffers from this degradation already exist. An important measurement that is used when evaluating new flash memory devices is retention time. Charge can leak from/into components due to the fact that the components themselves are not perfectly ideal. This charge leakage, over time, destroys the information. The problem that Anri Nakajima and Daiki Fujii are focused on is the fundamental scaling limitation that causes a tension between trying to make low power devices and also maintaining retention time.

The authors do not think that inorganic floating dots are a promising alternative to conventional flash memory because they are hard to create and it is difficult to control their size and density. They have used organic materials containing fullerenes such as spherical C_{60} and a derivative of it to explore they are retention times and programming capability. Attention was drawn to these materials when Hyuk Joo Kim's group, in the paper "Electrical Properties and Operating Mechanics of Nonvolatile Organic Memory Devices Fabricated Utilizing Hybrid Poly (N-vinylcabazole) and C_{60}", showed via the capacitance-voltage characteristics that there was a hysteresis effect that indicated the potential for organic nonvolatile memory. Nonvolatile, in this case, means that the device stores the information for some time even without an external power source.

In Nakajima and Fujii's paper, "Memory operation mechanism of fullerene-containing polymer memory", they use nanocomposites containing specifically spherical C_{60} as well as PCBM, a derivative of C_{60}. They consider the electrons to be stored in the LUMO (lowest unoccupied molecular orbital) levels of the nanocomposites. They get HOMO (highest occupied molecular orbital) and LUMO levels from the literature. The results of their analysis of the capacitance-voltage characteristics led them to conclude that both C_{60}-containing and PCBM-containing nanocomposites have excellent and very promising memory retention and programming capability.

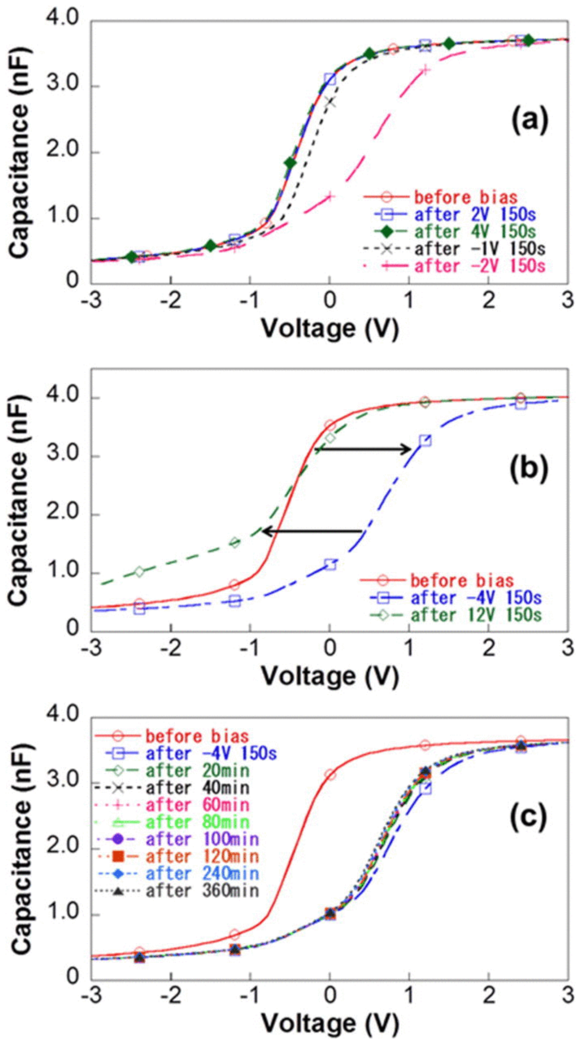

Figure 1: Characteristics of the C60-containing nanocomposite gate.

They saw that after 6 hours, 85% of the flat band remained after just 150 seconds of exposure to -4 volts. Similar results were obtained for the PCBM-containing nanocomposite, under the same circumstances, although there were characteristic differences in their response. They conclude that for both nanocomposite materials, electrons are injected and stored in the HOMO and LUMO levels. Electrons are injected near the Al gate with just a small programming voltage because the Fermi energy of the Al gate and the LUMO of the nanocomposite are very close.

In conclusion, the relationship between the levels of the nanocomposite material that actually store electrons has a relationship with the Al gate such that the electrons are easily injected. In the future, Nakajima and Fujii wish to hand-select a more appropriate metal for the gate electrode that would be more effective in decreasing the magnitude of writing/erasing voltages.