Novel Technology Shines Light on the Promising Future of Computer Memory

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The computer memory technology that we currently rely on is either fast, when it comes to writing and reading programmed states, yet volatile (i.e. it loses its programmed state if power is not being supplied to it), or non-volatile yet slow in terms of write operations and facing issues with further scaling (reduction in size). It should then be obvious that finding a replacement for the above is an important task, as volatility is an undesired trait that implies power consumption, and slow and non-scalable devices are inevitably going to become a bottleneck for new, high performance systems. Multiple new technologies have been proposed, yet a common opinion seems to be that resistive random-access memory (RRAM) is the most promising alternative for the future of computer memory.

To comprehend the benefits of RRAM a good approach is to first understand how it works, and only then draw conclusions about its implications for the current state of memory applications. Imagine the task of having to make a stream of water pass through a patch of compact soil. The latter, in its pristine state, will impose a high resistance to water flow, as no paths are available in it for water to cross it. However, if a high enough water inlet pressure is applied, the soil will eventually reshape and a conductive path will arise. Subsequently, one could use a shovel to pat on the soil and cause one end of the patch to become compact again, and after that apply a high pressure to reopen the path for facilitated water flow. That is, one can switch between high and low water conductivity by applying appropriate stress on the soil. If we now think of the soil as an insulator, of the water as electrons, and of soil manipulation as the application of electrical bias, we suddenly begin to understand RRAM basics.

The reshaping of soil resembles quite well the principles of operation of RRAM, and understanding how these principles are put to practice becomes easier once a clear picture of an RRAM cell is had in mind. The latter may be visualised as a sandwich-like structure, consisting of an electrode-insulator-electrode stack, as depicted in figure 1. Given an appropriate initial electrical bias, a conductive filament arises in the insulator, and the latter's pristine high electrical resistance is changed to a low resistance; this is known as a FORM operation. The tip of the filament can then be ruptured to reinstate high resistance (RESET), and regrown to yield low resistance (SET). High and low resistance are the “0s” and “1s” of RRAM, and achieving them makes the programming of cells possible.

The switching between resistance states has been shown to correlate with the drift of oxygen ions and of vacancies that are left behind by moving oxygen [1]. The response of these entities to electric fields in RRAM, which arise when different biases are applied, is very fast, and allows for writing speeds down to no more than a billionth of a second.

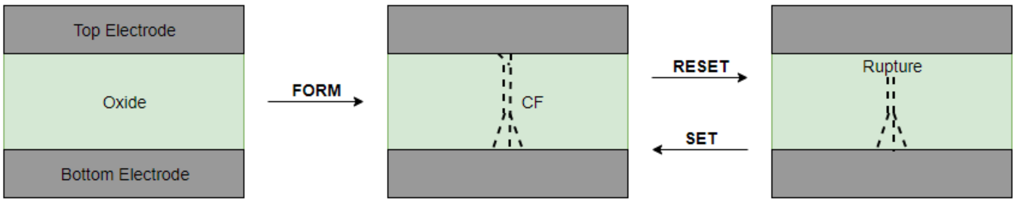

Figure 1: A representation of the different operations that may be performed on RRAM.

Moreover, programmed states are permanent, and do not require power to be retained, and the simplicity of cell design makes scalability a straightforward task for this technology. Further benefits may be achieved with appropriate material selection. In fact, it has been shown that using hafnium oxide as the insulator and indium-tin-oxide as an active electrode results in the possibility to operate RRAM units at biases down to a fraction of a volt [2]. This, together with current limitation, opens the door for the realisation of low power-consumption devices. All in all, a study dedicated to characterising RRAM units featuring promising materials seems like a perfect starting point for deepening our knowledge about systems that may make the necessary difference in the electronics of the world of tomorrow.

References

[1] T. Boubacar, Investigation of HfO2-based resistive RAM cells by electrical characterization and atomistic simulations, Doctoral Thesis at the University of Grenoble, October 2015.

[2] Y. Cong et al, Low-power bipolar resistive switching TiN/HfO2/ITO memory with self-compliance current phenomenon, Applied Physics Express, Volume 7, pp. 034101, February 2014.