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Single TiO_2 Nanowire Devices as Unipolar Memristors

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Extended Abstract

Semiconductor memory devices are ubiquitous in today's portable electronics, but as these devices scale down to higher densities it has become technologically challenging to balance speed with low power consumption. Current volatile random access memory (RAM) devices employed in mobile technology require power to retain information. Non-volatile RAM such as resistive RAM (RRAM) can retain information without consuming power, which makes it ideally suited for battery powered technology.

TiO_2 has been the recent focus of RRAM devices because it has shown non-volatile two state resistive switching. In this work, we fabricated single TiO_2 nanowire devices consisting of TiO_2 nanowires 50-100 nanometres in length spanning two gold electrodes. At a basic level, the nanowire devices display non-volatile two state resistive switching in response to an electrical stimulus. The device can be switched from a high resistance state or 'off' state to a relatively low or 'on' resistance state by applying a bias voltage. However, with finely controlled voltage stimulus, it is possible to define a continuum of resistance states spanning from the 'off' state to the 'on' state. As described in literature by Jeong et al 2008, the resistive switching in TiO_2 thin films is due to the movement of ionic dopants, specifically oxygen vacancies under an applied bias. The use of TiO_2 nanowires in comparison to thin films affords us greater control over the movement of these dopants to and from the metal interface under applied bias, creating continuum resistance states not seen in TiO_2 thin film devices, as well as pronounced current hysteresis in our devices. Varying other parameters such as the frequency of the applied voltage pulse is shown to greatly affect the operation of our nanowire devices. Because ionic dopants are limited in their ability to respond to faster voltage pulses, high-frequency voltage pulses limit the maximum current through the device, and the hysteresis observed in the current trace collapses. These properties as outlined by Chua. in 2011 describe a specific class of RRAM devices termed memory resistors or 'memristors', where the resistance of such a device is defined by the history of voltage or current applied to it. To date, only two state memristance has been reported for TiO_2 thin film devices. We use this new phenomena of continuum memristance to demonstrate memory and learning in our devices through applied voltage stimulus. Finally, we demonstrate that the physical mechanism for memristance in the nanowire device can be described as an n-type Schottky diode where the Schottky barrier height is dynamically modified through shifting dopant fronts under an applied bias voltage. When fully harnessed, the use of TiO_2 nanowires could enhance the memory capacity of a single device as well as increasing the density of devices in a semiconducting memory chip.

References

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