Mater Sci Nanotechnol, Volume 3

Electrical characteristics of single nanowire TiO_2 memristive devices in air and vacuum at room temperature

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The performance of memristive devices are of huge interest today due to their wide use in nanoelectronics with applications in non-volatile memory and storage, and neuromorphic computing. The resistive switching (RS) properties of these devices have shown a range of different behaviours regarding the nature and direction of hysteresis loops. In particular, the presence and origin of the negative differential resistance (NDR) regions found in these hysteresis loops has attracted a lot of interest. In this study, we report the resistive switching properties of a single nanowire of Au-Ti/TiO_2/Ti-Au RRAM devices at room temperature in air and under vacuum. The Clockwise Switching (CWS) and clear NDR regions of the I-V characteristics of the device in vacuum are transformed into bipolar Counter-Clockwise Switching (CCWS) without NDR regions when measurements were made in air. The current level also increased significantly in air comparing with vacuum. We explain this behaviour based on the creation of oxygen vacancies under voltage bias at one interface, and the drift of these charge carriers toward the cathode. These vacancies in the vacuum act as shallow donors and dopants diffuse under bias to create multiple depletion regions along the wire resulting in the NDR behaviour. The presence of oxygen in air results in recombination of the oxygen vacancies, quenching the NDR effect and switching the direction of the hysteresis loop. The dynamics of the depletion layer is described using a phenomenological memristor model based on the Hewlett-Packard (HP) Labs picture in which complex charge conduction phenomena can be captured by fitting ion-drift equations with the experimental data. This study demonstrates that the RS and memristive properties of devices are dependent on the ambient conditions and these results will help facilitate future applications of these devices in highly dense random-access memories and brain-like (neuromorphic) devices.

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