Multistate Memory Devices Based on Free-standing VO_2/TiO_2 Microstructures Driven by Joule Self-Heating

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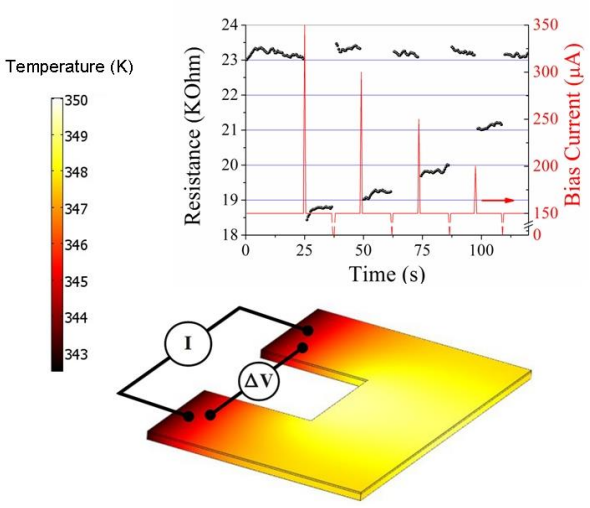
We report a two-terminal multistate memory devices based on crystalline (70 nm VO_2) / (200nm TiO_2 (100)) thin film microcantilevers. VO_2 shows a fast (sub-ps) thermally driven Metal-Insulator Transition (MIT) occurring above room temperature (68°C), where the electrical resistance decreases of more than 4 orders of magnitudes. This MIT is hysteretic and widens when moving from single crystals to thin films. VO_2 films grown on cantilevers show three orders of magnitude resistance change nearby 340 K and hysteretic behavior (width = 6.5 K) during thermal cycles.



Temperature distribution calculated on a VO_2/TiO_2 cantilever under 100 uA bias current. Sample temperature is fixed at 343 K and multi-resistance states written by current pulses of different magnitude, cantilever is powered with 150 uA current bias. Erasing is possible by a short pulse to zero. Adapted from L. Pellegrino et al. Adv. Mater. 24 2929-2934 (2012).

Within the thermal hysteresis region, where phase coexistence of metallic and insulating domains exists, we observe two types of memory effects upon current pulses applied to the microcantilever: **non-volatile** changes of the electrical resistance persist also if the current is switched-off and can be erased only by cooling the device below the hysteresis region. **Volatile** multilevel resistance states are instead possible by biasing the device with a fixed current and written with reproducibility by current pulses of different magnitude. Programmed resistance states can be erased by nullifying the bias with a short zero-current pulse. The memory mechanism is based on localized Joule heating of micrometric free-standing region, which allows the controlled creation of metastable metallic clusters at nanoscale. The higher thermal insulation of free-standing structures with respect to patterned thin film devices is a key point of these devices. Hot spots are created at the cantilever center-end, where thermal dissipation is lower and efficient Joule heating is possible.