Fabrication and characterization of Micrometer-scale ZnO Memristors

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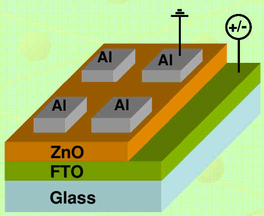
Introduction

Memristors are an interesting class of resistive random access memory (RRAM) based on the electrical switching of metal oxide film resistivity [1]. They are characterized for exhibiting resistive switching between a high-resistance state (HRS) and a low-resistance state (LRS) and have been recently considered as one of the most promising candidates for next-generation nonvolatile memory devices because of their low power consumption, fast switching operation, nondestructive readout, and remarkable scalability [1].

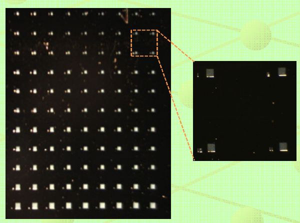
The device structure is simply an oxide layer sandwiched between two metal electrodes. The switching behaviour is dependent both on the oxide material and the choice of metal electrodes. For this reason switching characteristics of many metal oxide films (e.g. TiO_2, NiO, TaO_2, HfO_2) and metal contacts have been studied [1]. ZnO has attracted much attention as an oxide material for memristor application, due to its abundance in nature, which means low cost, and compatibility to CMOS technology [2] in terms of process integration and device scalability down to nanometric sizes.

In this work we report on resistive switching behaviour observed in microscale memristors based on laser ablated ZnO. Results show that devices up to 300 × 300 μm² exhibit a memristive behaviour regardless of device size, and 100 × 100 μm² memristors have the best resistance off/on ratio.

Fabrication



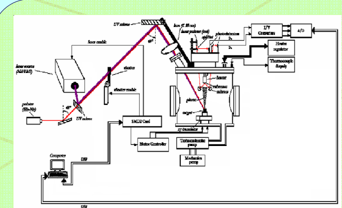
Memristor structure and electrical measurements arrangement



Microscale memristors ranging between 100 x 100 to 300 x 300 μm²

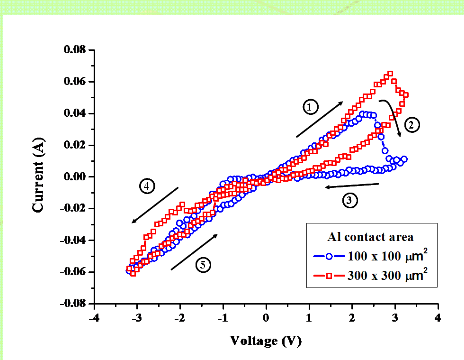
- Deposition of a 40 nm-thick ZnO thin film by PLD on fluorine-tin-oxide (FTO)/glass substrate
  - In order to leave a portion of the substrate as the bottom contact, a metal shadow mask was used during the PLD process
- Aluminium pads (top contact) definition by direct laser-writing microlithography and subsequent lift-off

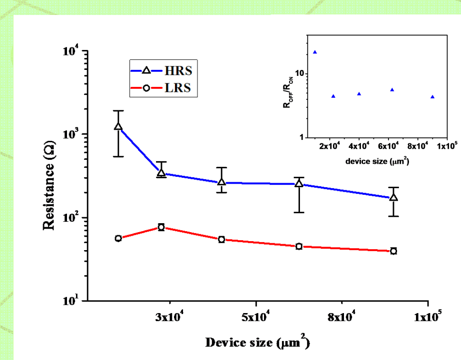
Pulsed Laser Deposition (PLD) is a low cost thin films growth technology, which has been widely utilised for depositing high quality ZnO thin films. It suits perfectly memristors' fabrication needs, because it gives the possibility to finely modify oxides properties by changing growth parameters.



Deposition parameters:
Laser energy: 50 mJ
Temperature: 400 °C
O_2 pressure: 10^{-2} mbar

Characterisation





Conclusions

Smaller devices display a trend of HRS increasing with device size decreasing. This suggests that further work must be addressed toward nanoscale ZnO memristors, which are expected to give a larger R_{OFF}/R_{ON} ratio, much more suitable for memory applications.

References

[1] H. Wong et al.: "Metal-oxide RRAM", Proc. IEEE, 100, 2012, pp. 1951-1970.

[2] Y. Seo et al.: "A CMOS-process compatible ZnO-based charge-trap flash memory", IEEE Electron Device Lett., 34, 2013, pp. 238–240.