Atomic layer deposition of thin oxide films for resistive switching

K. Fröhlich, P. Jančovič, B. Hudec, J. Dérer
Institute of Electrical Engineering, SAS,
Dúbravská cesta 9, 841 04 Bratislava, Slovakia
A. Paskaleva
Institute of Solid State Physics, BAS,
72 Tzarigradsko Chaussee, 1784 Sofia, Bulgaria
T. Bertaud, T. Schroeder
IHP, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany
BTU, Konrad Zuse Strasse 1, 03046 Cottbus, Germany

Resistive switching random access memory (RRAM) is one of the most promising emerging memory devices. The resistive switching cell operation is based on a change in resistance of a metal-insulator-metal (MIM) structure caused by ion migration combined with redox processes in a dielectric layer. Atomic layer deposition (ALD) is often employed for preparation of the dielectric films. TiO_2 and HfO_2 are among the most popular dielectric layers used in resistive switching memory cells [1, 2].

In our contribution we present preparation and properties of metal-insulator-metal structures comprising TiN bottom electrode, TiO_2 or HfO_2 dielectrics, and Pt top electrode. TiO_2 and HfO_2 thin films were prepared by ALD at 300 °C using titanium isopropoxide and tetrakis (ethylmethylamino)hafnium, respectively, as precursors. Thermal, plasma and ozone assisted ALD modes were employed for the growth of the oxide films. TiN bottom (BE) and Pt top (TE) electrodes were prepared by sputtering and vacuum evaporation, respectively, using shadow mask. The area of the tope electrode was 300 x 300 μm^2. Thickness of the TiO_2 films ranged from 20 to 30 nm, while thickness of the HfO_2 films was in the range from 5 to 10 nm. As deposited TiO_2 films were too leaky to perform electroforming. Consequently, Al_2O_3 barrier with a thickness of 2 – 4 nm was deposited on top of the TiO_2 films to suppress leakage current.

Electroforming with the current compliance was necessary to establish resistive switching. After initial electroforming both TiO_2- and HfO_2-based MIM structures exhibited bipolar resistive switching. Several loops (sweeping from 0 to maximum bias and back in both polarities) were necessary to obtain stable switching loops, displayed in the Fig. 1 and 2.

TiO_2-based structures exhibited bipolar resistive switching with a high operation current and on/off current ratio of about 100. Application of the Al_2O_3 barrier resulted in significant decrease in operation current density and increase in the on/off ratio. The structures with 4 nm of Al_2O_3 barrier showed operation current ~ 10^{-3} A, on/off current ratio of about 80 at the reading voltage of 0.2 V. Resistive switching characteristics with similar parameters were observed also for MIM structures with HfO_2 dielectric film.

In our contribution we show that ALD is a promising technique for preparation of resistivity switching structures because it offers possibility to control the oxide layer growth and modify the oxide/electrode interfaces on an atomic level.

References

[1] J.J. Yang, M.D. Pickett, X. Li, D.A.A. Ohlberg, D.R. Stewart, S. Williams, Nat. Nanotechnol. **3** (2008) 429.

[2] H.Y. Lee, Y.S. Chen, T.Y. Wu, F. Chen, C.C. Wang, P.J. Tzeng, M.-J. Tsai, C. Lien, IEEE El. Dev. Lett. **31** (2010) 44.

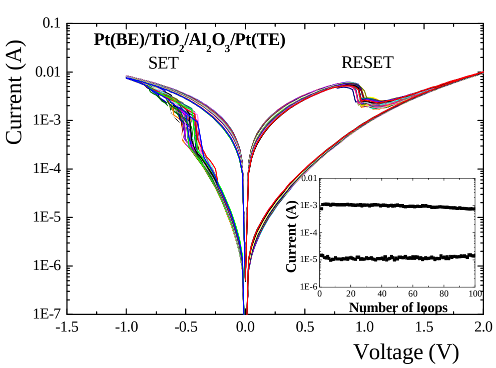

Fig. 1. Resistive switching loops of the 20 nm TiO_2 film with 3 nm Al_2O_3 barrier below the top electrode. The films were prepared using ozone assisted ALD. The inset shows current in a high and low resistivity states, resp. in 100 consecutive loops.

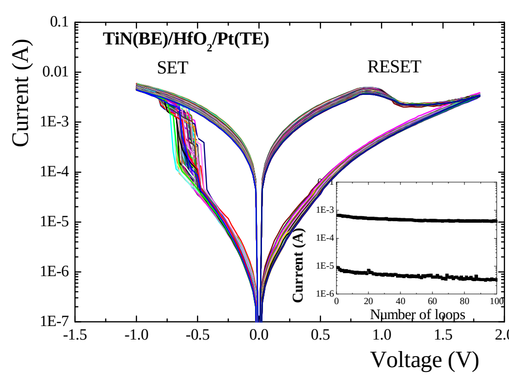

Fig. 2. Resistive switching loops of 5 nm HfO_2 film. The film was prepared using plasma assisted ALD. The inset shows current in a high and low resistivity states, resp. in 100 consecutive loops.