High Entropy Oxide for Resistive Switching Applications

Lukas Heinen[1], Christian Pithan[2], Vikas Rana[1]

Peter Grünberg Institute (PGI)-10[1] & 7[2]

Forschungszentrum Jülich GmbH, 52425 Jülich

Resistive random-access memory (RRAM) phenomena in high entropy oxide (HEO) offer several advantages such as improved endurance, lower variability in I-V characteristics, and lower power consumption. [1, 2] The synergistic interactions among cations create a defective lattice structure that affects oxygen vacancy migration, crucial for resistive switching. Due to CMOS compatibility and tunable device properties as a function of dopants, binary systems such as $NbTaO_x$, and $ZrHfO_x$ offer a promising pathway for energy-efficient, and cost-effective non-volatile memory solutions.

In this study, we demonstrate the resistive switching behavior of up to 50 mol% Nb doped TaO_x thin films, prepared from in-house synthesized ceramic targets using a solid-state reaction method. For this purpose, powder synthesis involved homogenization and comminution via mechanical milling of equimolar mixtures of Nb_2O_5 & Ta_2O_5 before and after calcination. Fabrication of the targets was carried out by Spark-Plasma Sintering. The thin film was deposited via RF-sputtering, and its structural and compositional properties were analyzed using techniques such as X-ray photoelectron spectroscopy (XPS) and X-ray diffraction (XRD). Pt/$NbTaO_x$/Ta/Pt RRAM devices with a 2x2 μm^2 cell size were fabricated through photolithography and dry etching processes. Electrical characterization using a Keithley 4200 SCS parameter analyzer revealed that $NbTaO_x$-based devices exhibit a significantly improved variability in key characteristics such as the low resistive state (LRS) when compared to Ta_2O_5-based devices. The $NbTaO_x$ devices demonstrated a fast SET time of 10 ns and competitive endurance exceeding 10^8 switching cycles. With this promising performance, we further investigate the potential of high-entropy oxides in pursuit of an ideal material for memory applications that can satisfy the requirements of modern memory devices.

[1] M. Ahn, Y. Park, et al., Advanced Electronic Materials, 2021, „Memristors Based on (Zr, Hf, Nb, Ta, Mo, W) High Entropy Oxides“.

[2] R. Waser, M. Aono, Nature Materials, 2007, „Nanoionics-based resistive switching memories“.