Physics-Based Compact Modeling of $BiFeO_3$ Memristive Devices

Y. Liu(1), F. Liu(1), X. Zhao(2,3), N. Du(2,3) and S. Menzel(1)

(1) Peter Grünberg Institut 7, Forschungszentrum Jülich GmbH, Jülich, Germany,

(2) Institute for Solid State Physics, Friedrich Schiller University Jena, Jena, Germany,

(3) Department of Quantum Detection, Leibniz Institute of Photonic Technology, Jena, Germany

$BiFeO_3$(BFO) memristive devices exhibit area-dependent switching behavior and hold great potential for applications in neuromorphic computing and in-memory computing. Nevertheless, the switching mechanism is still under debate. We measured the *I-V* characteristics and switching kinetics of BFO devices and developed a physics-based compact model based on the JART VCM V2 [1], which attributes the switching behavior to the migration of oxygen vacancies. During the measurements we found that after applying a 15 V, 0.1 s pulse, the device irreversibly transitioned from the pristine state to the extended state, accompanied by changes in the switching mode, maximum current level, and ON/OFF ratio. The extended state exhibits improved performance, showing a complementary switching mode and both SET and RESET processes occur gradually. We propose that the pulse pushed most of the oxygen vacancies toward the bottom electrode region, where the Ti^{4+} concentration is high due to Ti^{4+} diffusion during the deposition process. Our model assumes that Schottky contacts are formed between the BFO layer and both electrodes and treats oxygen vacancies as shallow, mobile donors that can modulate the Schottky barrier, thereby altering the resistance state of the device. The migration of oxygen vacancies in the solid is described using the Mott and Gurney theory. Ti^{4+} ions are considered fixed donors that hinder the migration of oxygen vacancies, with the hindrance effect increasing with Ti^{4+} concentration. A mathematical expression is used to describe the Ti^{4+} concentration profile. Our model successfully reproduces the *I-V* behavior and SET switching behavior of BFO devices. These findings provide important insights into resistance switching mechanisms and contribute to the advancement of BFO devices for applications.

[1] C. La Torre et al., IEEE Transactions on Electron Devices, 66, 1268-1275, 2019.