Operation Mechanism and Novel Functions of gapless-type atomic switches based on metal oxide and polymer thin film

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As the downscaling of dynamic random access and flash memories approach the physical limit, new solutions for volatile/nonvolatile storages are being investigated at both the research and industry levels. Among several emerging technologies, resistive switching memory based on cation transport in a thin ionic conductor film is one of the most attractive candidates for the next-generation memory technology. Because of its similarity to the operation mechanism of a 'gap-type atomic switch', in which resistance across a nanometer gap between a mixed conductor electrode and an inert counter electrode is controlled by the formation and dissolution of a metal bridge under bias voltage sweeping [1], cation-migration-based resistive memories are referred to as a 'gapless-type atomic switch' [2].

We have investigated the operation mechanism of Cu, Ag/metal oxide/Pt atomic switch cells using Ta_2O_5 as a model system and demonstrated their unique functions, which cannot be realized by conventional semiconductor switches. Ta_2O_5-based cells exhibit bipolar resistive switching behavior under bias voltage sweeping. They are SET from a high-resistance state (HRS) to a low-resistance state (LRS) at positive bias to an electrochemically active metal electrode (Ag or Cu), and RESET from LRS to HRS at negative bias. The SET process corresponds to the formation of a metal filament by nucleation on the inert counter electrode (Pt), while the RESET process is attributed to the dissolution of the metal filament due to thermochemical reactions [3]. It was found that residual water in the oxide film plays a crucial role in redox reactions of Cu(Ag) and resistive switching behavior [4], in relation to the film morphology [5]. The cell also exhibited conductance quantization and synaptic/memristive behaviors, as shown in Fig. 1, which indicate potential for use in neural computing systems [6].

We also demonstrated that an atomic switch can be realized using a silver-conductive solid polymer electrolyte (SPE) [7]. An Ag/SPE/Pt cell, fabricated with a mixture of poly(ethylene oxide) (PEO) and Ag salt, showed bipolar resistive switching under bias voltage sweeping, similar to oxide-based atomic switches. We also successfully fabricated cells with a junction size of 50 µm on a plastic substrate using an inkjet-printed SPE film [8]. The fabricated cells showed stable switching behavior upon substrate bending (Fig. 2), which indicates their great potential for flexible switch/memory applications. Variations in the operation voltages by temperature and ambient pressure suggested the importance of the crystallinity and water uptake ability of the matrix PEO on the resistive switching behavior. A detailed switching mechanism will also be discussed from observations for a planar cell structure [9].

References

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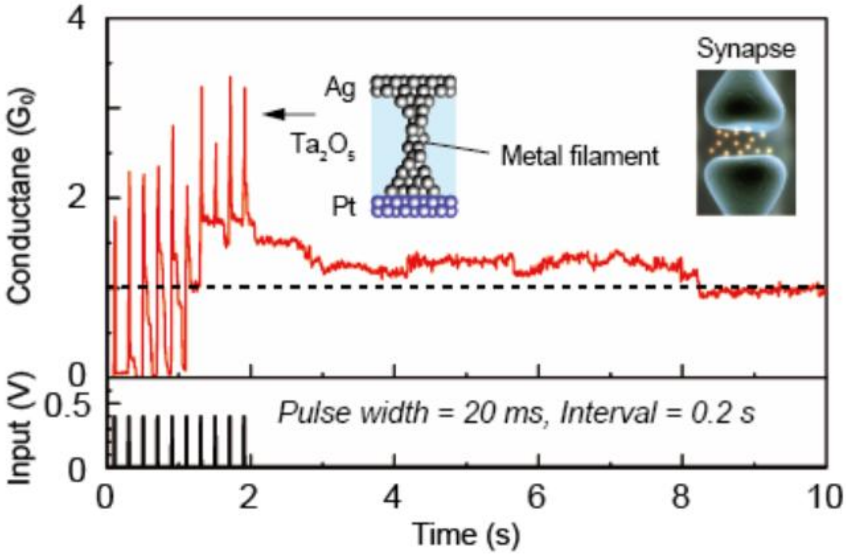

Figure 1. Synaptic behavior of a Ta_2O_5-based atomic switch

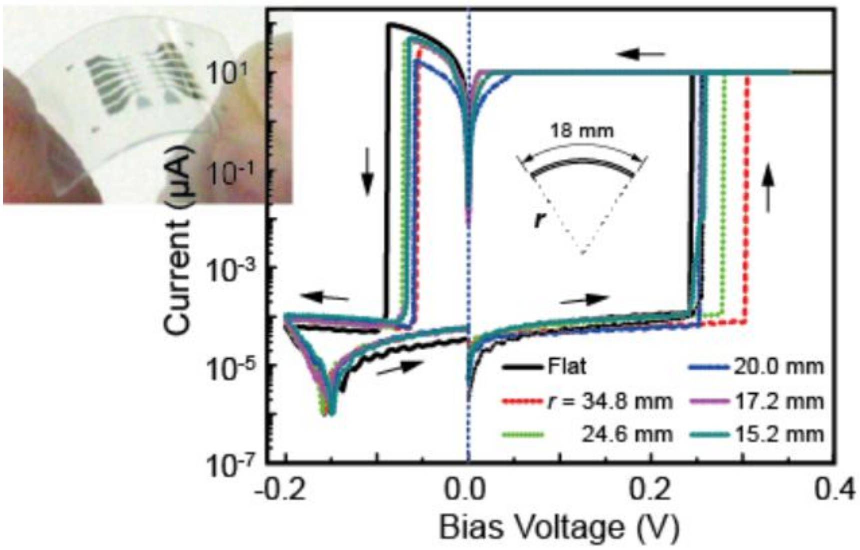

Figure 2. SPE-based cells fabricated on a plastic substrate and their switching behavior under substrate bending