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Electrically-controlled nonlinear switching and multi-level storage characteristics in WO_x film-based memory cells

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ABSTRACT

Resistive switching random access memory (RRAM) is considered as a promising candidate for the next generation memory due to its scalability, high integration density and non-volatile storage characteristics. Here, the multiple electrical characteristics in Pt/WO_x/Pt cells are investigated. Both of the nonlinear switching and multi-level storage can be achieved by setting different compliance current in the same cell. The correlations among the current, time and temperature are analyzed by using contours and 3D surfaces. The switching mechanism is explained in terms of the formation and rupture of conductive filament which is related to oxygen vacancies. The experimental results show that the non-stoichiometric WO_x film-based device offers a feasible way for the applications of oxide-based RRAMs.

1. Introduction

Driven by the continuing need for developing non-charge based non-volatile memories, the resistive switching random access memory (RRAM) has generated significant interests for the next generation high density memory applications [1–6]. The RRAM does not rely on conventional Si-based transistors and can be fabricated in three-dimensional (3D) stack or on different substrates [7–10]. In particular, a simple sandwich structure of RRAM is expected to facilitate its use in scalable crossbar arrays which is an ideal architecture for high density data storage. However, a well-known sneak path problem greatly limits the application of RRAM cells in 3D memory arrays [11–14]. For depressing the sneak current throughout the neighboring cells, various selection elements are proposed such as threshold switching devices, Schottky diodes, metal-insulator transition devices and nonlinear selectors [15–18]. These devices are connected to additional memory elements in series but leading to a more complex structure and fabrication process. Meanwhile, the multi-level storage is also a feasible way to increase the integration density and some approaches have been proposed [19–22]. However, it still needs solutions to overcome some technical obstacles such as complex fabrication processes or multi-layer stacked structures. Here, we report a bipolar resistive switching with nonlinear and multi-level storage characteristics in single Pt/WO_x/Pt cell. This device shows nonlinear characteristics in low resistance state (LRS) and multi-level states by controlling the compliance current (I_{cc}) in set processes. The mapping of current in different time and temperatures are displayed by contours and 3D surfaces to investigate the nonlinear characteristics.

2. Experiment procedure

The WO_x film was deposited on Pt substrate by using a spin coating method. 0.5 g tungsten powder (>99%) was dissolved in 4 mL hydrogen peroxide (30%) to form the precursor, and then stirring for 1 h at room temperature. Subsequently, the precursor solution was spun onto Pt substrate 4 times, then followed by annealing at 400 °C for 30 min. The Pt top electrodes were deposited by ion sputtering with diameter of 100 μm. The sputtering current and time were 5 mA and 4 min, respectively. The WO_x film deposited on Pt substrate was characterized by X-ray Diffraction (XRD) and X-ray Photoelectron Spectroscopy (XPS), respectively. The cross-sectional microstructure was examined by Scanning Electron Microscope (SEM). The electrical characteristics of the device were measured on an Agilent B1500A semiconductor parameter analyzer.

3. Results and discussion

The XRD diffraction pattern of WO_x film deposited on Pt substrate is shown in Fig. 1(a). The WO_x film is (2 0 0) preferred orientation and

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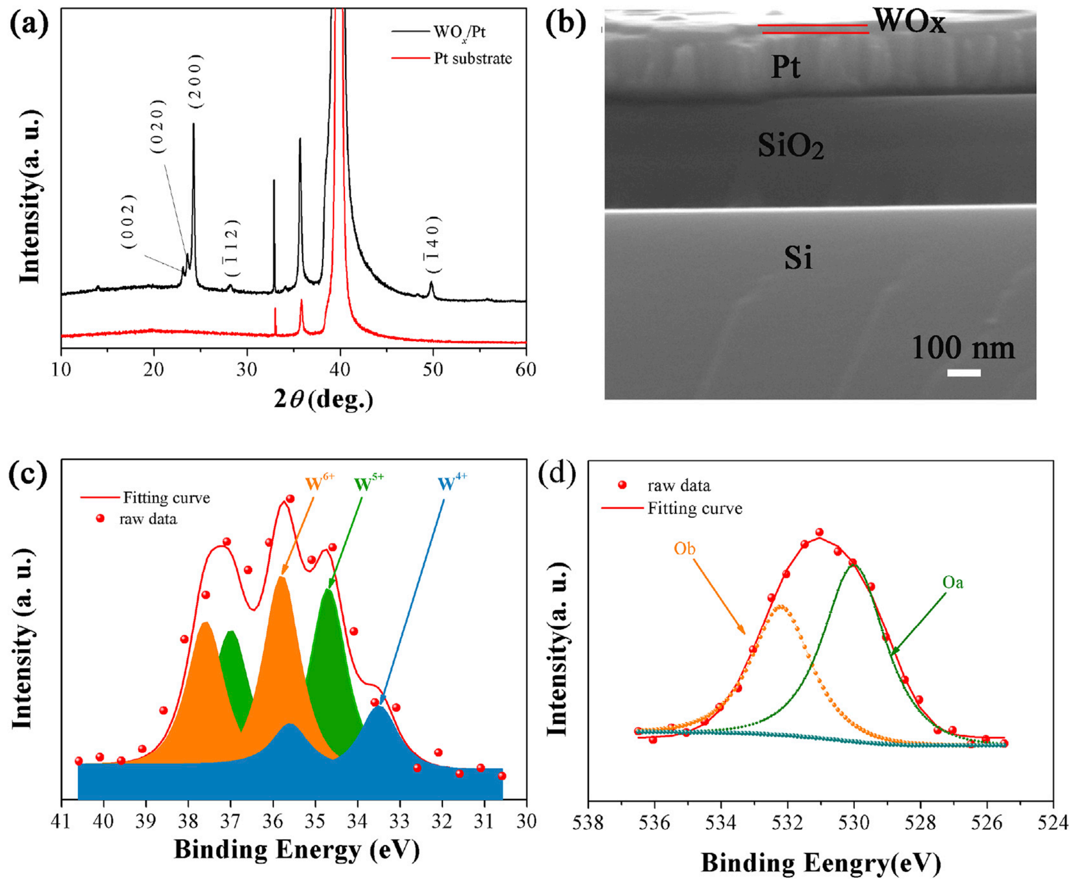

Fig. 1. Characterization of WO_x film. (**a**) XRD diffraction patterns. (**b**) Cross-sectional SEM image of WO_x/Pt interface. (**c**) XPS spectrum of W*4f*. (**d**) XPS spectrum of O*1s*.

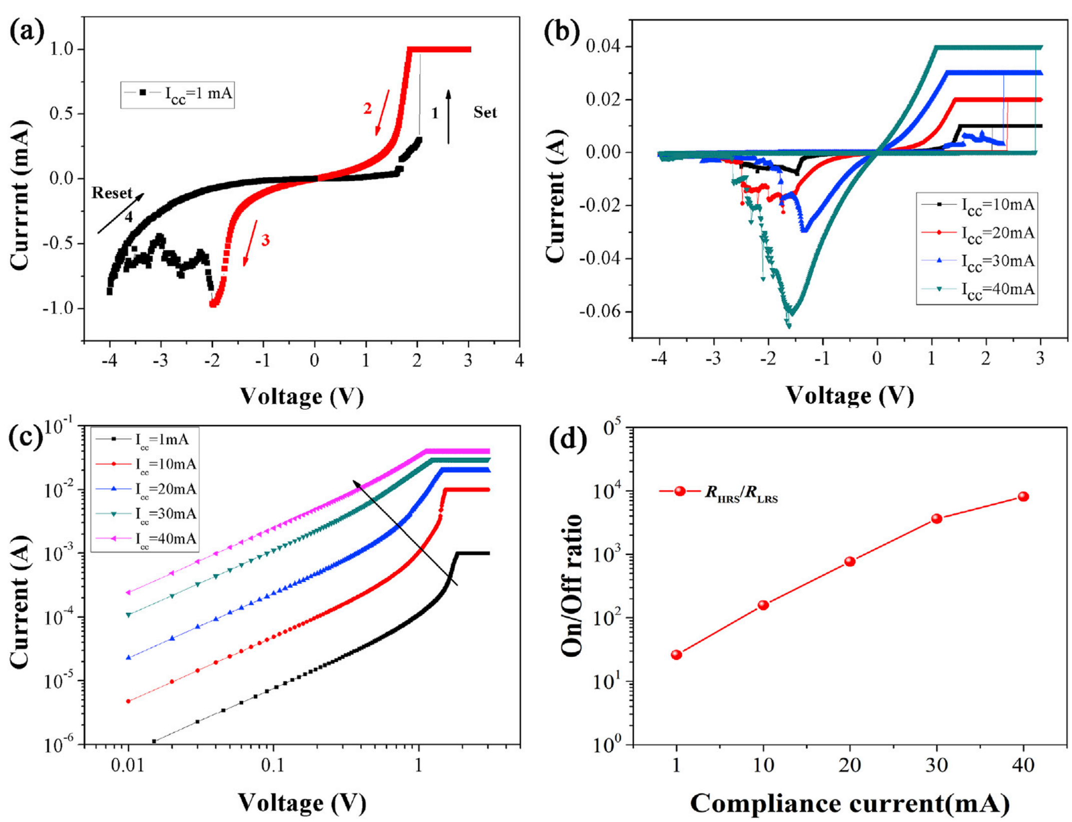

Fig. 2. *I-V* curves and on/off ratios controlled by I_{cc}. (**a**) $I_{cc} = 1$ mA. (**b**) $I_{cc} = 10$, 20, 30, 40 mA. (**c**) LRS in semilogarithmic coordinates. (**d**) On/off ratios of different I_{cc}.