V_3O_5: a promising material for solid-state neurons

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Current controlled negative differential resistance (NDR) in metal-oxide-metal (MOM) devices is of interest as the basis of nanoscale relaxation oscillators for use as solid-state neurons in neuromorphic computing arrays [1]. Vanadium dioxide (VO_2) has received particular attention as an oxide material for neuromorphic computing applications due to its excellent switching characteristics. For example, a coupled VO_2 threshold switching devices were capable of emulating 23 distinct biological neuron spiking characteristics, whereas 10^3 conventional CMOS logic gates can replicate only ten basic neural behaviours [2]. However, despite these attractive features, the IMT temperature of VO_2 (~340 K) is below the typical operating temperature (400 K) of modern computers [3] which arise a concern on its suitability for practical applications.

V_3O_5 is one of the stable phases of the vanadium-oxide system which has an IMT temperature above 400 K ($T_{IMT}{\sim}420K$) that meets the requirements for CMOS compatibility. A little attention has been devoted to the understanding of its IMT or electrical switching properties. We have demonstrated volatile NDR characteristics and fast spiking oscillatory behaviour in V_3O_5-based MOM structures. To understand the origin of switching mechanism in V_3O_5, we performed in-operando mid-wave infrared (MWIR) mapping, scanning thermal microscopy (SThM) and optical reflectivity measurements of device during the switching process. By combining these in-operando temperature measurements and finite element simulations, we have shown that the NDR response is a direct consequence of continuous current constriction and self-filamentation processes that can induce the IMT in the V_3O_5 thin film. Further, we have shown that V_3O_5 offers stable NDR characteristics up to 410 K which is consistent with the IMT temperature of V_3O_5 and can generate different coupling oscillation behaviour which is the basis to emulate neural functionality. These results show that V_3O_5-based devices may be better placed than VO_2 devices to meet the demands of high-density neuromorphic computing applications.

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