Study of vanadium dioxide-based relaxation oscillators for neuromorphic applications

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We present the fabrication of electrical relaxation oscillators based on the integration of both vanadium dioxide (VO_2) nanostructured thin films and monocrystalline VO_2 nano-beams. VO_2 thin films were elaborated using DC magnetron sputtering of a vanadium target in an argon/ oxygen atmosphere while the nano-beams were obtained using a modified vapor liquid solid (VLS) method. VO_2 is a phase change material known to present a near room temperature metal-insulator transition (MIT) at 69°C characterized by a strong electrical resistive change (10^4-10^5 ratio) [1]. The MIT is accompanied by a structural phase transition where the low temperature (semi-conducting) phase has a monoclinic (M1) structure, and the high temperature (metallic) phase exhibits a rutile (R) structure. This phase transition can be triggered electrically, optically or even mechanically. We integrated both type of VO_2 structures in two-electrode devices for electrically activate the MIT. We show that the VO_2 exhibit a non-linear current-voltage characteristic, characterized by a negative differential resistance (NDR) where $\frac{dV}{dI}<0$. In this particular regime, when a constant current with values corresponding to the NDR region is injected in the two terminal device, periodic voltage oscillations can be recorded across the device, which behaves as a relaxation oscillator [2]. Both materials integrating the two types of devices (thin films and nanobeams) have been extensively characterized using X-ray diffraction and four probe electrical testing to determine their structural and physical properties. The electrical performances of the two type of devices integrating nanograin-type thin films and the monocrystalline structures were recorded and compared in order to identify the influence of the structural and morphological properties of the VO_2 materials on the oscillation's parameters (activation current, oscillation frequencies and amplitudes…). We intend to exploit the potential of such oscillating devices behaving as electronic neurons to highlight their potential in neuromorphic applications by realizing coupled oscillatory networks. Such networks are great candidates for the field of bio-inspired electronics as they have already shown effectiveness in image processing while being energy efficient [3].

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