Low temperature annealing for vanadium dioxide in photonic integrated circuits

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Abstract: We show at the annealing temperature of vanadium dioxide (VO_2) fabricated using atomic layer deposition can be suppressed to 300 °C, significantly improving the compatibility of VO_2 with photonic integrated circuits.

The solid-state phase transition of VO_2 occurs at approximately 68 °C, significantly lower than other phase transition materials and phase change materials. This phase transition can be trigger by various external stimuli [1], and it is accompanied with a large change in the material's optical properties. These factors have made VO_2 a very attractive materials for optical and optoelectronic data processing. For example, we have recently numerically demonstrated that a VO_2-based microring resonator can mimic the classical conditioning observed in biology. For these emerging thin film- or nanostructure-based applications, atomic layer deposition is frequently the method of choice. Nevertheless, as-deposited VO_2 thin films are amorphous and require high-temperature annealing, a process that is often incompatible with photonic integrated circuits. In this work, we show that high-quality VO_2 thin films can be obtained with a low annealing temperature of 300 °C. This temperature can be tolerated by most photonic integrated circuits, and represents an important technical step in the development of VO_2-based computing circuits.

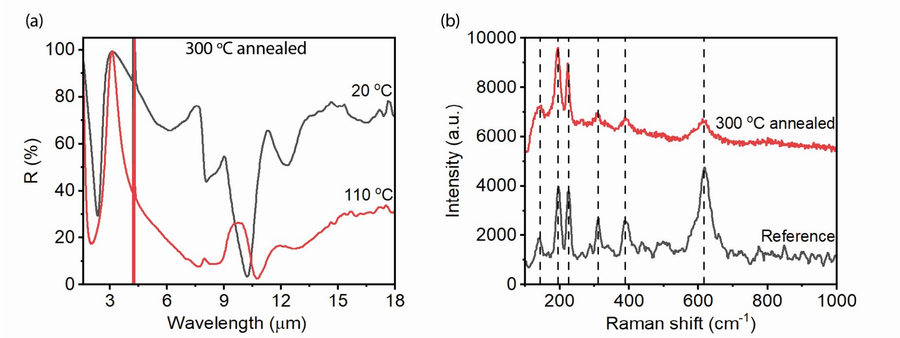

Fig. 1. Properties of a VO_2 thin film. The film was deposited using atomic layer deposition, and then annealed under an oxygen pressure of 2.5 Torr for 3 hours at 300 °C. (a) The reflection of the thin film shows a large contrast between the insulating phase (20 °C) and the metallic phase (110 °C). (b) Its Raman spectrum also shows pronounced VO_2 peaks that align with a reference sample.

References: [1] H. Takeya *et. al.*, "Bolometric photodetection using plasmon-assisted resistivity change in vanadium dioxide," Scientific Reports 8, 12764 (2018). [2] K. Sun *et. al.*, "Room Temperature Phase Transition of W-Doped VO_2 by Atomic Layer Deposition on 200 mm Si Wafers and Flexible Substrates," Advanced Optical Materials 10, 2201326 (2022).