Concepts for VO_2-Based Reconfigurable Distributed Microwave Circuits

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Vanadium dioxide (VO_2) is a phase-change material that exhibits up to a four-order-of-magnitude change in electrical conductivity when it is induced thermally and optically, among other mechanisms. VO_2 has appeared promising for microwave and millimeter-wave reconfigurable circuits when used as switches. Current research has demonstrated low loss in thin-film VO_2 switches during ON state and high isolation during OFF state. In these switches, the VO_2 area is at most a few microns in length and generally thermally or electrically activated. On the other hand, an optically-induced phase change of the oxide that patterns any desired length and width of a distributed passive circuit could enable fully programmable distributed microwave circuits. This is extremely useful for wide-band design applications such as reconfigurable antennas for ultra-wideband RF ICs (DARPA ACT and RF-FPGA program). However, the quantification of RF loss of VO_2 film in transmission lines and waveguides, and the isolation between patterned lines remains unexplored and must be addressed as the first step in determining the plausibility of this concept.

Preliminary measurements of VO_2 loss indicates agreement with the expected high attenuation due to low conductivity (10^5 S/m ON state) thin films. This experimental work includes the fabrication of VO_2 transmission lines (35 nm), subsequent S-parameter measurements from 4-50 GHz, and extraction of the attenuation coefficient. We will present simulations of a concept for reducing loss: adding distributed metallic inclusions in the VO_2 film to decrease loss while still achieving high-resolution programmability of circuits.

One of the challenges with this concept is preserving low signal attenuation of circuits patterned in the ON state while maintaining signal isolation of non-patterned OFF state film. Moreover, because the OFF state VO_2 acts as a lossy dielectric, the challenge is also defining precise current boundaries in the conductive VO_2; there is current leakage at the geometrical boundaries of the distributed structure. This, as well as the lossy and thin nature of these films, greatly impacts the impedance of the distributed structure. Therefore, simulations and parametric studies of various design parameters, such as film thickness and metallic inclusion gaps, will be presented. The goal of these studies is to explore viable use of this phase change material while considering practical limitations imposed by material growth processes and film quality. Performance of passive distributed structures, such as antennas, will also be explored.