Treating the case of incurable hysteresis in VO_2

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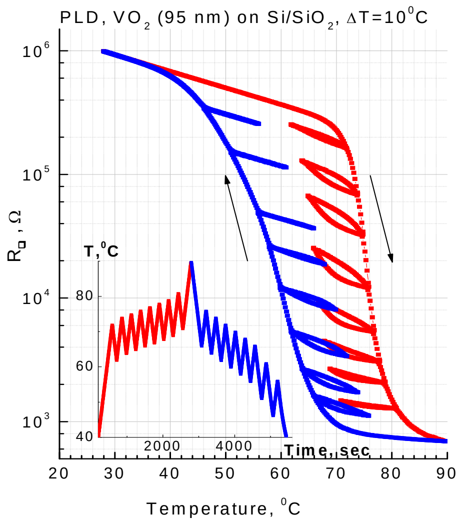
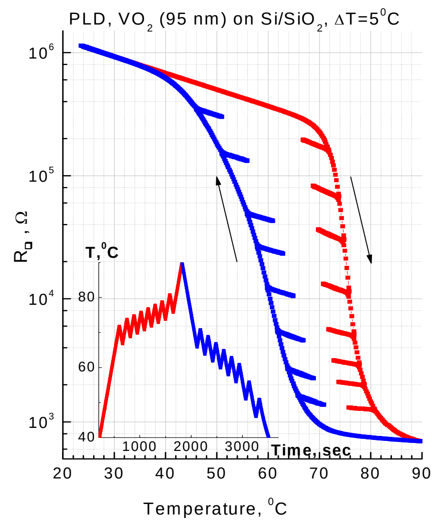
The resistivity ρ(*T*) of VO_2 changes by 3–5 orders of magnitude in a spectacular semiconductor-to-metal phase transition around 68 °C. This transition is always hysteretic; in thin films, the hysteresis width is typically 10–20 °C. For a variety of reasons, of the many proposals to use this transition in applications almost none have materialized. One serious commercial and military application in which the use of VO_2 was initially envisioned is IR visualization (night vision) based on resistive microbolometers. However, technology eventually settled on a VO_2's poor cousin, a non-transitioning mixed oxide VO_X, mainly to avoid hysteresis, which greatly complicates bolometer operation.

We found the way to obtain hysteresis-free operation of VO_2 right in the midst of its hysteretic transition, while at the same time keeping the benefit of adjustable resistance. This new way of operation is based on a new phenomenon of interest in its own right. Here is how it works. In the hysteresis region, a *backward* round-trip temperature excursion taken from any point on the major loop will produce a minor loop, as can be seen in the figure on the left.





We have found that for sufficiently small excursions these minor loops degenerate into single-valued, non-hysteretic branches (NHBs) linear in log(ρ) *vs. T* and having essentially the same or even somewhat higher temperature coefficient of resistance TCR = d[ln(ρ)]/d*T* as the semiconducting (S) phase at room temperature, as can be seen in the figure on the right. We explain this behavior based on the microscopic picture of percolating phases. Similar short non-hysteretic branches are found in the otherwise hysteretic optical reflectivity $R_\lambda(T)$. There is an interesting and revealing correlation between the slopes of the optical reflectivity $dR_\lambda(T)/dT$ and TCRs. In NHBs, the partial shorting out of the S-phase by the metallic phase provides for total low resistivity. Thus, VO_2 becomes a semiconductor "sponge" with nanoscale metal enclosures, while maintaining the semiconducting resistivity in the percolating S-phase

This provides an entirely new way of operating a microbolometer, allowing for *tunable* resistance which can be chosen from a range spanning 2–3 orders of magnitude, while removing hysteresis and all associated problems. This trick can be used in other transitioning materials as well, in the resistive or optical domain. In a way, we learned how to live with incurable hysteresis, and even to benefit from it.