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Percolation effects in networks of vanadium dioxide nanocrystals[1]

JOHN ROZEN, RENÉ LOPEZ, RICHARD HAGLUND, LEONARD FELDMAN, Department of Physics and Astronomy & Institute of Nanoscale Science and Engineering, Vanderbilt University, Nashville, Tennessee 37235 — Bulk vanadium dioxide undergoes a phase transition from a semiconductor to a metal near 68 ^{o}C upon heating. A unique aspect of VO_2 nanocrystals is that their small size leads to meta-stable states and to the widening of the hysteresis loop traced out by the semiconductor-to-metal phase transition. We report simultaneous measurements of the transmittance and of the resistance made on thin VO_2 nanocrystalline films. An offset between the effective electrical and optical switching temperatures is observed. Indeed, there is an intermediate state where the films are optically metallic but electrically semiconducting (opening the possibility of designing tri-state devices). This is explained in terms of current percolation through a network of nanometer-scale grains of different sizes undergoing the transition at distinct temperatures. An effective-medium approximation can model this behavior and proves to be an indirect method to calculate the surface coverage of the films. Also, the understanding of the collective properties of the nanocrystals leads to the reconstruction of the electrical hysteresis of the phase transition.

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