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Mesoscopic metal-insulator transitions at twin domain walls in improper ferroelastic VO_2[1]

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Appearance of unusual phenomena at interfaces of different materials due to symmetry breaking and atomic, electronic, or spin reconstructions is well established area of intensive research. Domain walls in ferroic materials also can show unusual behavior due to symmetry discontinuities. VO_2 is a strongly-correlated-electron material, which exhibits a metal-insulator phase transition with a structural, lattice symmetry-lowering transformation making this material an improper ferroelastic. We observe mesoscopic metal-insulator transitions at the ferroelastic domain walls in the lower-symmetry phase of VO_2 that occur at temperatures as much as 10-12 °C below the bulk transition, resulting in the formation of metallic channels in the semiconducting material. The experiments are made using AFM-based scanning near-field microwave microscopy, which allows simultaneous accurate imaging of topography and the low-frequency dielectric function with a special resolution as high as 50 nm. The latter is possible due to a relatively high frequency used (in a few GHz range), when the sample-probe capacitive coupling becomes sufficiently strong and the electric current path is complete by displacement currents between the sample, probe tip, and the probe shield electrode. Density functional calculations indicate that ferroelastic domain walls of this type possess metallic character at low temperatures, which can be ascribed to elevated structural symmetry at the domain walls. The observed behavior, linked as well to the strain inhomogeneity inherent to ferroelastic materials, is generally relevant to symmetry-lowering phase transitions in other material systems.

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