Domain Melting and Percolative transport in 1T-TaS_2

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Charge density waves (CDWs) arise from Fermi surface nesting and electron–phonon coupling, producing coupled modulations of charge and lattice [1]. A prototypical system, 1T-TaS_2, exhibits multiple CDW transitions, culminating in a low-temperature commensurate $\sqrt{13} \times \sqrt{13}$ Star-of-David phase. In this regime, interlayer stacking of CDW clusters controls the ground state: aligned stacking favors a Mott insulator, while slight misalignment induces metallicity [2]. We study two devices with contrasting low-temperature behavior—one insulating and another showing a resistance drop near ~100 K. A weak resistivity dip and Gaussian-like second harmonic peak between 50–100 K indicate a bistable regime due to coexistence of Mott and metallic domains. Current–voltage measurements show pronounced NDR, indicating Joule heating–driven domain evolution, further enhanced by voltage pulses [3]. We model the system using a phenomenological free energy, $F(\varphi, I) = \varphi^2(1 - \varphi)^2 + aI\varphi - bI^2\varphi^2$, capturing bistability between insulating ($\varphi = 0$) and metallic ($\varphi = 1$) states and explaining NDR. Incorporating time-dependent Ginzburg–Landau dynamics with Kardar Parisi Zhang (KPZ) equation for inhomogeneous growth yields, $\varphi \sim \exp(-x/d)$, where x/d is domain to channel ratio, describing filamentary channel formation. Conductivity follows $\sigma \propto (I - I_{th})^\beta$ with $\beta \approx 1.3$, consistent with 2D isotropic percolation. The fractal dimension evolves from $D_f \approx 0.3$ to ≈ 0.9, indicating a crossover from domain- to channel-dominated transport within a unified Landau–KPZ framework.

References

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[2] Ma, L., Ye, C., Yu, Y., Lu, X. F., Niu, X., Kim, S., ... & Zhang, Y. (2016). *Nature communications*, *7*(1), 10956.
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Figures

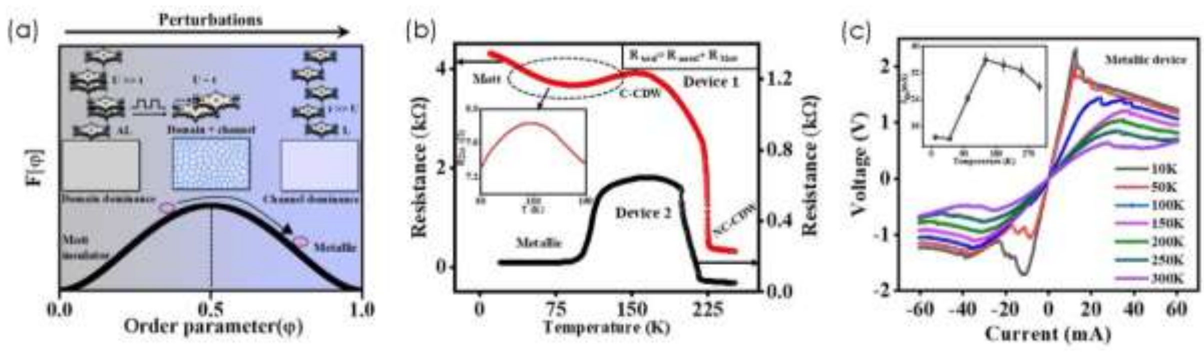

Figure (a) Stacking-driven transition from Mott insulating to metallic state with corresponding free energy landscape. **(b)** Temperature-dependent resistivity of two devices showing distinct low-temperature states (Mott and metallic below 100 K). **(c)** I–V characteristics of the metallic device exhibiting pronounced negative differential resistance (NDR).