Electron transport in pressed VO_2 samples: Mott hopping vs percolation behavior

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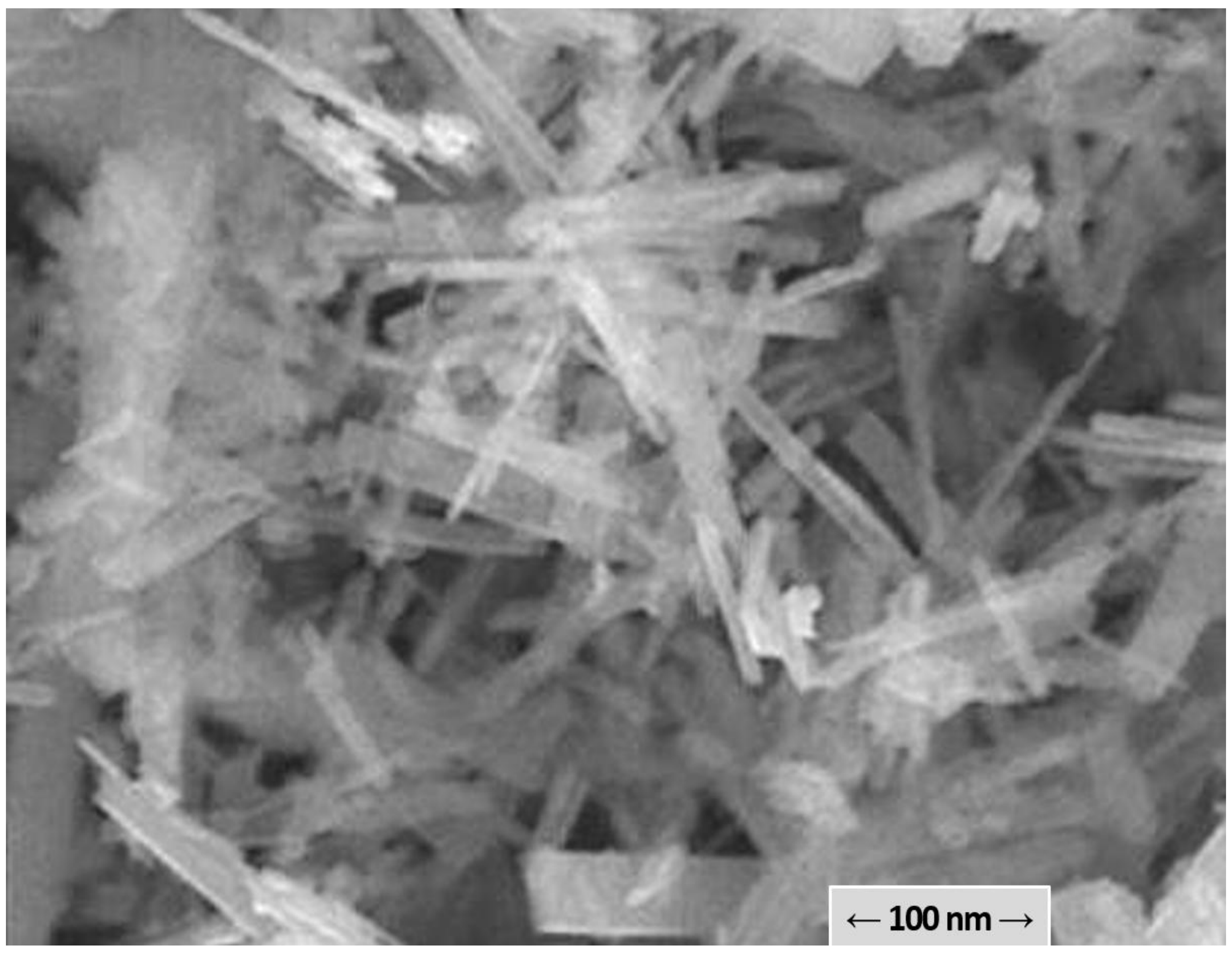
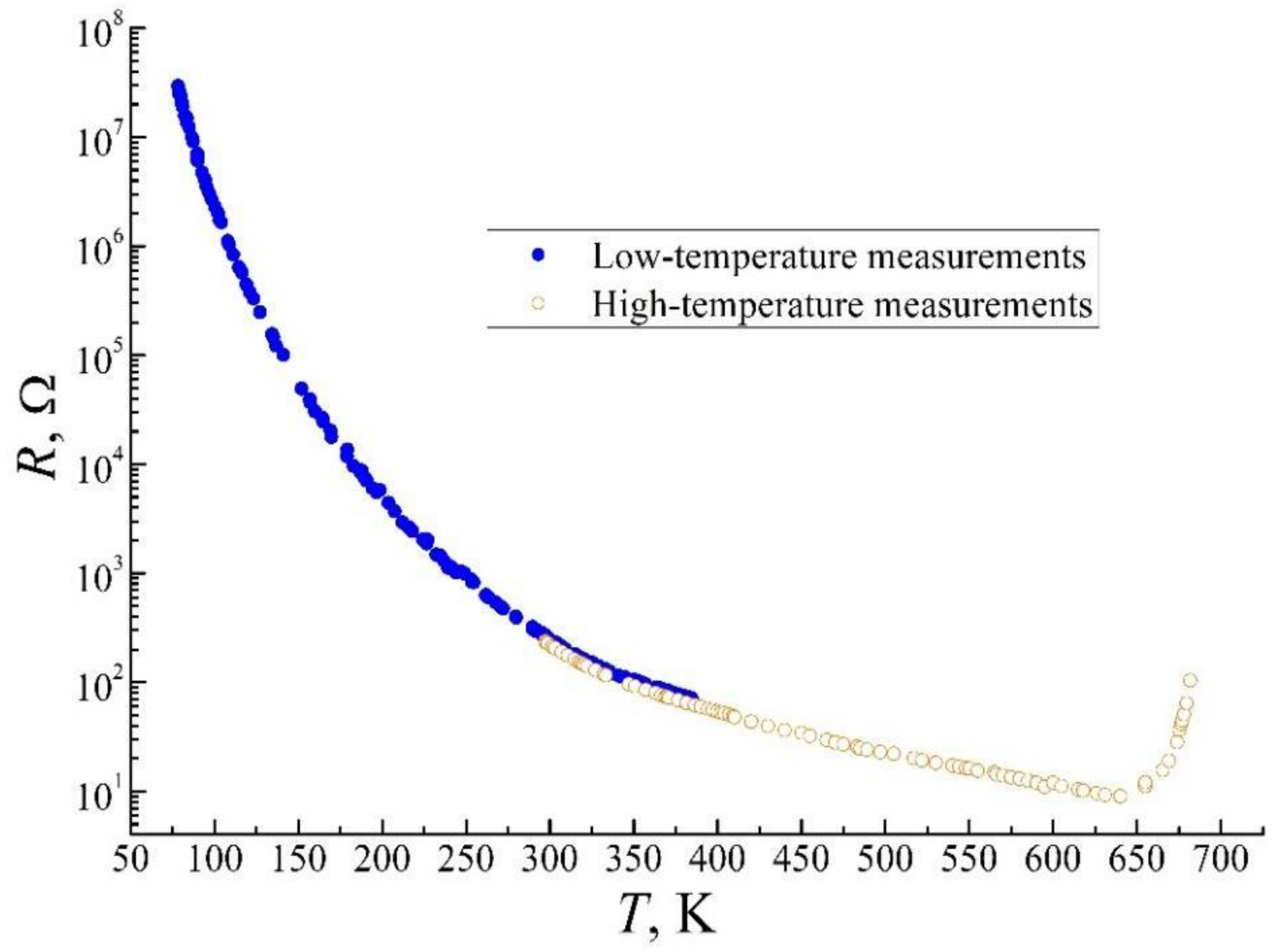
In this study, we investigate the temperature-dependent conductivity of compressed VO_2 nanopowders to distinguish between Mott variable-range hopping (VRH) and percolation-driven transport mechanisms.

The initial samples contained 99% of two monoclinic modifications of vanadium dioxid, which is typical for hydrothermally obtained VO_2 nanopowders. The coexistence of these phases suggests potential structural inhomogeneities that could contribute to the broadening of the metal-insulator transition.

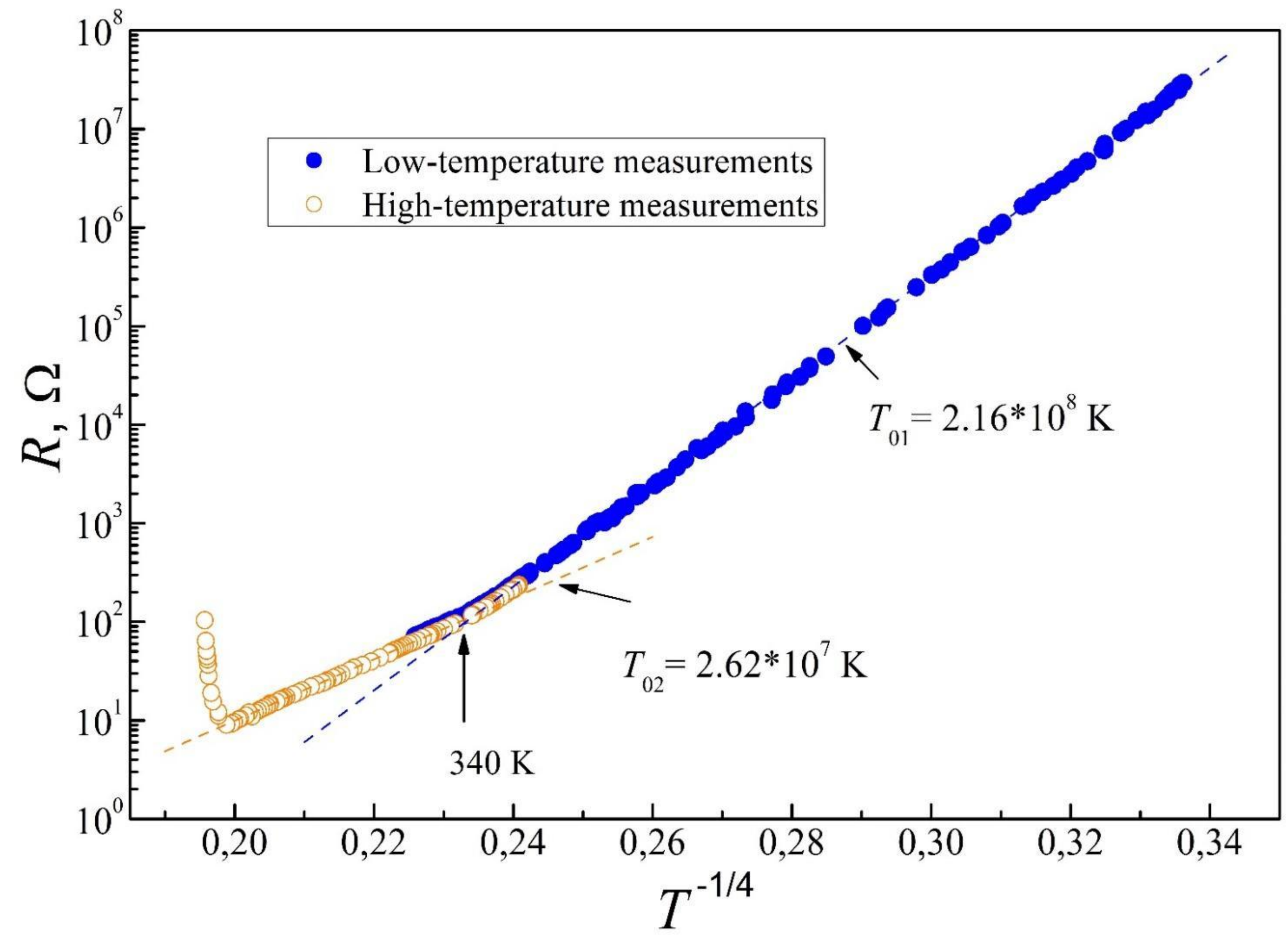
The nanoparticles synthesized hydrothermally were a kind of rod-shaped, with a thickness/diameter of around 70 to 100 nm and lengths up to 1 µm.



SEM image for synthesized VO_2 nanoparticles.



Temperature-dependent resistance of pressed VO_2 powder sample (T = 78 – 682 K), measured at I = 50 µA.



Resistance of VO_2 pressed powder sample plotted as lnR versus $T^{-1/4}$.

Two linear regions were distinguished on the $ln(R) = f\,(T^{-1/4})$ plot, presumably corresponding to the manifestation of variable-range hopping (VRH) conductivity mechanism in 3D case. However, further analysis revealed that this behavior could be better explained by a percolative transport mechanism with activation-assisted tunneling. While this mimics the formal structure of VRH, it originates from other physical origins — including grain anisotropy, surface oxidation (e.g., V_2O_5 layers), and the anisotropic geometry of the percolative network.

These two regimes correspond to distinct transport scenarios:

- **Before the MIT (T < 340 K):** Transport occurs through semiconducting VO_2 grains (~0.6–0.7 eV bandgap), where localized states and intergranular insulating barriers, caused by structural disorder, impede electron transport.
- **Above the MIT (T > 340 K):** Despite increased density of states $N(E_F)$ in the metallic phase, residual intergranular barriers and disorder suppress full metallic behavior. The resistance shows a percolative-like temperature dependence: $\rho \propto \exp[(T_0/T)^{-1/4}]$, where T_0 reflects intergrain tunneling and structural inhomogeneity.