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Photoconduction and Low-Temperature Ohmic Conduction of Peierls Conductor o-TaS_3 under Uniaxial Strain

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It is well known [1] that in quasi-one-dimensional conductor orthorhombic TaS_3 (*o*-TaS_3) below the Peierls transition temperature, $T_P \approx 220$ K, all conduction electrons are condensed into a charge-density-wave (CDW) state and at low electric field, *E*, do not contribute to the conductance, *G(T)*, provided by quasi-particles thermally exited over the Peierls gap and obeying an activation law with the activation energy $E_\Delta \approx 800$ K (Ohmic conductance). *G(T)* becomes strongly non-linear at $E > E_T$ (E_T – the threshold field for CDW depinning) due to CDW sliding, which is accompanied by generation of narrow-band-noise (NBN), whose frequency is proportional to CDW velocity. Below $T \leq T_P/2$ the Ohmic conductance in the chain direction begins to deviate from the initial activation law, a new activation energy, E_L, being approximately half [2], while the perpendicular conductance preserves the initial value $E_\Delta\perp \approx 800$ K in all temperature range. A transition to the new activation law is often accompanied by an appearance of a plateau with a weakly dependent conductance connecting the different activation parts of *G(T)*-curve. The nature of the low-temperature Ohmic conduction is attributed to collective excitations of the CDW, presumably solitons [2, 3].

At high *T* the CDW wave vector, *q*, is slightly incommensurate with the lattice one and tends to commensurability when *T* decreases to T ≈ 30 K [4]. A strain, ε, applied in the chain direction, is a powerful tool of influence on *q*, leading to unusual changes in transport properties of *o*-TaS_3 [5-11], such as: different strain-dependences for the Ohmic conductance (with a maximum at a critical strain ε_c) and for the nonlinear one (with a minimum at ε_c); strain-induced decrease of T_P and an increase of E_Δ; disappearing of NBN and an emergence of ultra-coherent CDW near ε_c. The results imply an increase of incommensurability value with a growth of the strain [11], i.e. a growth of solitons concentration. Till now all the strain-induced phenomena in *o*-TaS_3 were studied at high temperature range between $T = 66$ K and T_P. Here we present the results of the experimental study of the uniaxial strain influence on the low-temperature Ohmic conduction at 10 K < *T* < 77 K together with a first observation of the strain effect on the photoconduction, which appears at the same temperature region [3].

For the study we have prepared a structure (see insert in Fig. 1) on the base of high-quality *o*-TaS_3 crystal ($E_T \sim 0.5$ V/cm, cross section $S \sim 3$ μm^2) consisting of three segments: part A – without strain, central buffer part C, part B – with a strain $\varepsilon = \Delta L_B/L_B \approx 1\%$ (where ΔL_B is a change in a part B length L_B), a contact width was ~ 0.2 mm. All conductance measurements were done along the chain direction in two-probe configuration in the voltage-controlled regime. IR LED, providing light intensity $W = (10^{-4} – 30)$ mW/cm^2 at the sample position, was used; the photon energy $\hbar\omega = 1.3$ eV, optic Peierls gap value $2\Delta_{opt} = 0.25$ eV at $T = 40$ K [12]. The usual AC modulation method (modulation frequency $f = 4.5$ Hz, meander) was used for the photoconduction measurements.

Fig. 1 shows temperature dependences of the Ohmic conductance for the segments A, $G_A(T)$, (upper blue curve) and B, $G_B(T)$, (red curve) together with corresponding sets of temperature dependences of photoconductance, $\delta G_A(T)$ and $\delta G_B(T)$, at different *W* (all values

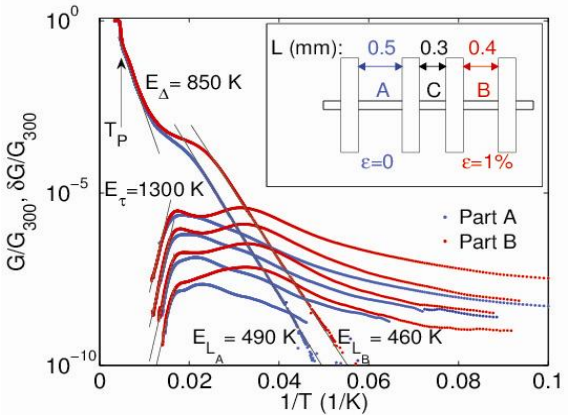

Fig. 1. Temperature dependences of Ohmic conductance $G(T)$ for the segments with and without strain (upper curves) together with corresponding sets of temperature dependences of photoconductance $\delta G(T)$ at following light intensities W, top down: 10, 1, 0.1, 0.01 mW/cm^2. The insert shows the drawing of the studied structure.

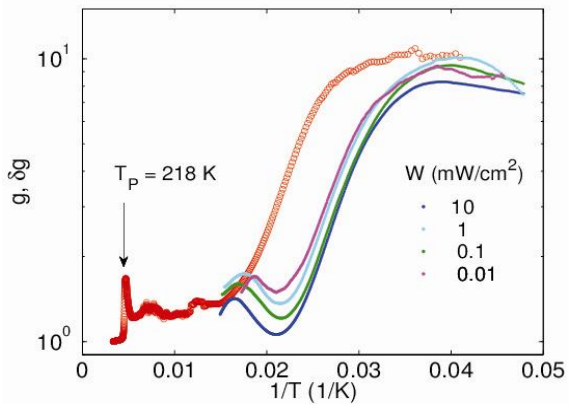

Fig. 2. Temperature dependence of the strain-induced relative change of the Ohmic conductance $g=G_B/G_A(T)$ (red circles) and a set of the similar dependences of the photoconductance change $\delta g=\delta G_B/\delta G_A(T)$ (dots) at different W.

G_A, G_B, δG_A, δG_B are normalized to corresponding room-temperature conductances, G_{A_300} and G_{B_300}). At high T the stain-induce changes of the dependences are not so dramatic: one can see a smoothing of the Peierls transition, a T_P decrease ~ 6 K and a small (≈ 30 %) $G(T)$ growth, while E_Δ does not noticeably change for this sample. The activation energy of the photoconductance, E_τ, reflecting temperature dependence of the non-equilibrium current carrier recombination time [3], also does not show a noticeable change under the strain. The low-temperature changes are much more substantial: an additional large contribution to both the conductance and photoconductance (an increase of the main peak and an appearance of a new one) is observed. The value of E_L slightly (≈ 7 %) increases with the strain.

Fig. 2 shows temperature dependences of the strain-induced relative changes of both the conductance $g=G_B/G_A$ and photoconductance $\delta g=\delta G_B/\delta G_A$ (for each W). The sharp peak of g at T_P corresponds to suppression of T_P by the strain. Whereas g and δg experience a step-like growth at slightly different temperatures, the final low-temperature values of g and δg (for all W levels, which differ by 3 orders) being practically the same.

The observed features are consistent with a simple model implying strain-induced increase of concentration of solitons which contribute into both conduction and photoconduction. Further investigations are required to verify this assumption.

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