Photo-Irradiation Effect on Dynamics of Charge-Density-Wave Condensate in Quasi-One-Dimensional Conductors TaS_3

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Abstract

We find a new photo-irradiation effect on the current-voltage characteristics of quasi-one-dimensional conductors TaS_3. When the TaS_3 single crystal is irradiated with a weak 488 nm emission from Ar^+ laser, the electrical current is enhanced around the threshold voltage V_t below the Peierls transition temperature T_P. The current enhancement is attributed to the increase of CDW contribution due to the screened pinning potentials by photo-excited quasi-particles in plastic creep phase of CDW motion.

Key words: Charge-Density-Wave; Dynamics; Photo-Irradiation Effect; TaS_3

1. Introduction

Conduction electrons in quasi-one-dimensional conductors condense into Charge-Density-Wave (CDW) state below a Peierls transition temperature T_P [1]. The CDW condensate is pinned by some ionized impurity potentials in the absence of external electric field. When an external field above the pinning potential is applied, the depinned CDW contributes to electrical conductions, so that the current-voltage (I-V) characteristics exhibit a large deviation from Ohm's law; the dynamic evolution of CDW motion is classified into (i) a pinned solid, (ii) a plastic creep, and (iii) a moving (sliding) solid [2] as the applied field increase. It is recognized that the CDW dynamics is strongly influenced by thermal excited quasi-particles [1,3].

Recently, Ogawa *et al.* have reported that at low temperatures a photo-irradiation of molybdenum blue bronze $K_{0.3}MoO_3$ affects the dynamic phase transition of CDW motion from slide to creep [4,5]. This effect was observed under the low density of thermal-excited quasi-particles condition.

In this paper, we present a new photo-irradiation effect on CDW dynamics for a quasi-one-dimensional conductor TaS_3 under many photo-excited quasi-particles condition in the near vicinity of T_P.

2. Experimental

Orthorhombic TaS_3 single crystals used were synthesized by chemical vapor transport technique. The samples had elongate needle shape along the b-axis. Typical sample size was about $0.1\ \mu m \times 10\ \mu m \times 5$ mm.

Current-voltage (I-V) characteristics were measured by using dc two- or four-probe method. The temperature dependences of electrical resistivity revealed that the Peierls transition temperature T_P of the samples was about 220 K. Laser light irradiated was Ar^+ 488 nm or He-Ne 640 nm emission, the power in front of cryostat window was 20 mW/cm^2. The weak intensity of irradiation enables us to ignore the rise of sample temperature by the photo-irradiation.

3. Results and Discussion

Figure 1 (a) shows the typical I-V characteristics of positive bias voltage side, at 230, 210, and 190 K; the

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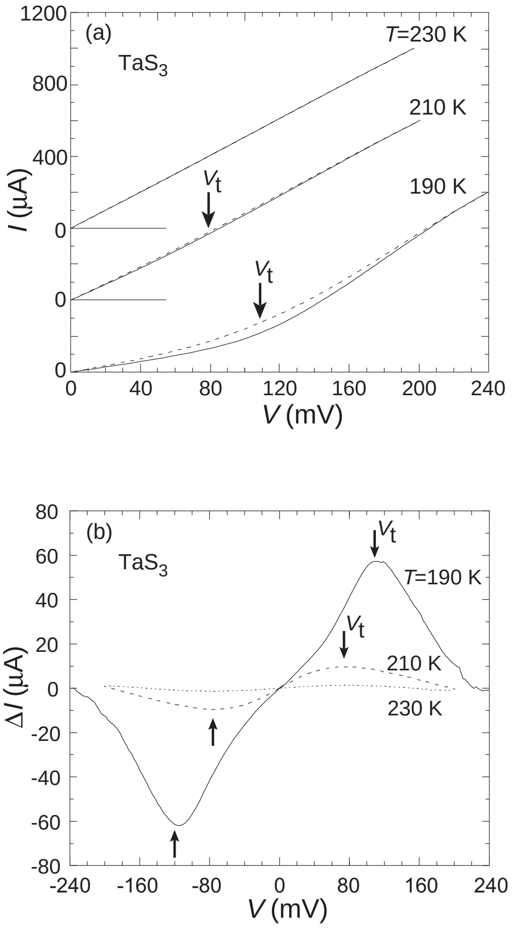

Fig. 1. (a) Typical current-voltage characteristics in positive bias side at 230, 210, and 190 K; solid and dashed lines indicate dark and photo-irradiation cases, respectively; arrows denote threshold voltage $V_{\rm t}$. (b) Current changes by photo-irradiation ΔI are plotted against applied voltage at 230, 210, and 190 K; arrows denote threshold voltage $V_{\rm t}$.

solid and dashed lines stand for the dark and photo-irradiation ones, respectively. At 230 K which is higher than the $T_{\rm P}$, the I-V curves for both dark and irradiation cases are linear; both lines are superimposed. This result indicates that no photo-irradiation effects are observed above $T_{\rm P}$.

Below the $T_{\rm P}$, the I-V curves in the absence of irradiation bend at a threshold voltage $V_{\rm t}$, indicating that the CDW condensate contributes to the electrical conduction. It should be noted that the photo-irradiation affects remarkably the current around the $V_{\rm t}$ for the case of 190 K, while less current enhancement is observed for the case of 210 K.

The current changes by the photo-irradiation $\Delta I(= I_{\rm irrad.} - I_{\rm dark})$ are plotted against the applied voltage at these temperatures in Fig. 1 (b). The ΔI's which are symmetric for the origin exhibit a maximum around the $V_{\rm t}$ below the transition temperature $T_{\rm P} \sim 220$ K. The intensity of the maximum increases with decreasing temperature. In the higher voltage side, the current changes ΔI tend to zero. These results probably correspond with the dynamical phase diagram in the motion of CDW condensate [2].

Our finding is interpreted as following tentatively. The enhancement of the ΔI is attributed to the increase of CDW contribution in the plastic creep phase, because the photo-excited quasi-particles produce the screening and make the pinning potentials slightly shallow. In the higher voltage region (sliding solid phase), the reduction in the pinning potential by the screening can be neglected for the moving CDW condensate, so that the current change ΔI becomes zero as shown in Fig. 1 (b).

The present result suggests that the strength of pinning potentials can be controlled by photo-irradiation through the screening of pinning potentials by the excited quasi-particles.

4. Conclusion

We have investigated the effect of photo-irradiation on the dynamics of CDW condensate in quasi-one-dimensional conductors TaS_3. Below the Peierls transition temperature, the electric current around the threshold field is enhanced by a photo-irradiation. The current enhancement in plastic creep phase of CDW motion is attributed to the increase of CDW contribution due to the screened pinning potentials by photo-excited quasi-particles.

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