STM Observation of CDW depinning at the surface of $K_{0.3}MoO_3$

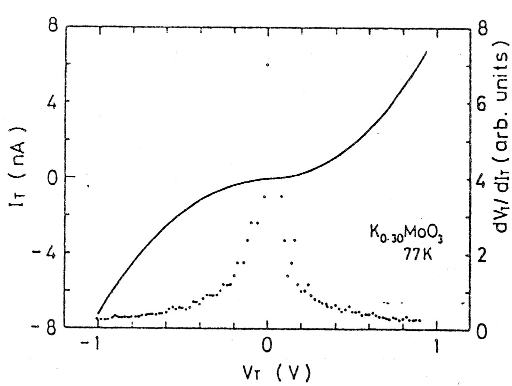
Kazushige Nomura, Kôichi Ichimura and Takashi Sambongi
Department of Physics, Hokkaido University, Sapporo 060, JAPAN

Abstract.-The STM tunneling current was investigated in the non-linear CDW conduction regime of $K_{0.3}MoO_3$. The peak structure was found in the tunneling current spectra, showing the sliding motion of CDW at the sample surface.

The STM (Scanning Tunneling Microscope) is a powerful method for the observation of condensed electronic states such as the charge density wave (CDW) state[1]. It is suggested that both static and dynamic properties of CDW could be investigated with the STM. We performed the STM measurement combined with the transport measurement in $K_{0.3}MoO_3$ and obtained the evidence for the sliding motion of CDW[2]. Here we will report the result of STM observation and discuss the CDW depinning at the surface.

The STM measurement was done on the cleaved $(\bar{2},0,1)$ surface of a single crystal of $K_{0.3}MoO_3$. We can measure the tunneling current under usual transport current in our STM apparatus.

In Fig. 1, we show a typical tunneling current-voltage (I_T-V_T) curve obtained with fixing the tunneling tip position. The curve shows a remarkable non-linearity, exhibiting the Peierls gap structure, below the transition temperature (180 K) unlike a straight line at the room temperature. We can estimate the gap 2Δ as the width of dV_T/dI_T. The obtained CDW gap 2Δ is about 130 meV at 77 K and roughly consistent with those in other methods. As shown



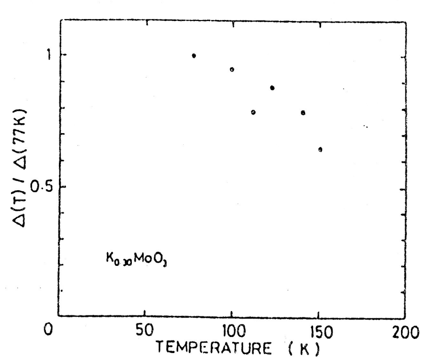


Fig. 1 Tunneling current I_T vs. tunneling voltage V_T (solid line) and dV_T/dI_T vs. V_T (solid circle).

Fig. 2 Temperature dependence of the normalized Peierls gap $\Delta(T)/\Delta(77K)$.

(received October 27, 1989)

in Fig. 2, the gap decreases toward the transition temperature with increasing temperature. This temperature dependence well characterizes the CDW condensed phase and assures that we really see the CDW state in our tunneling experiment.

We analyzed the tunneling current under usual transport current bias. The tunneling voltage was about 50 mV and the tip position was again fixed. As shown in Fig. 3, a new peak (indicated by arrows in the figure) appears in the tunneling current spectra for the transport current exceeding the threshold value (I_C=0.95 mA) and the peak frequency increases with increasing transport current. In Fig. 4, we show the peak frequency against the transport voltage. The value of peak frequency is roughly the same order as the narrow band noise

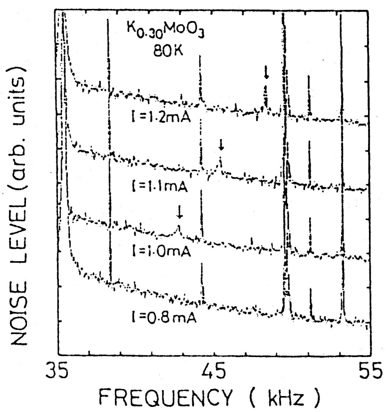
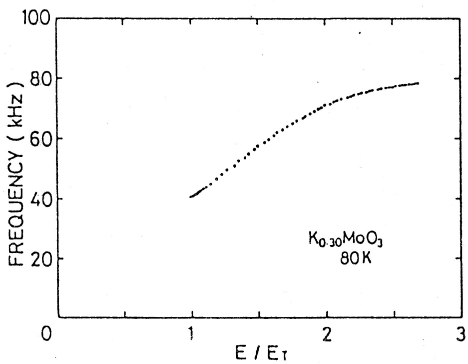


Fig. 3 Spectra of tunneling current under transport current. For current exceeding the threshold value (I_C=0.95 mA), a new peak (indicated by arrows) appears in the current spectra.



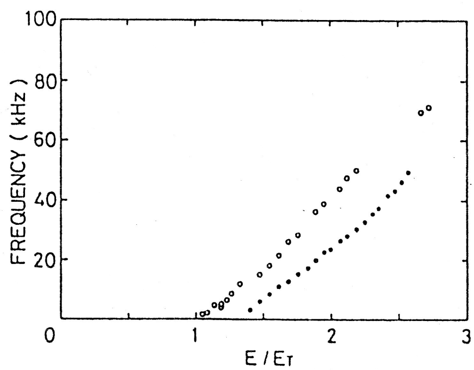


Fig. 4 Peak frequency in the tunneling current spectra vs. transport voltage.

Fig. 5 Narrow band noise frequency vs. transport voltage. Solid and open circles represent two different fundamentals.

frequency observed in the same sample, which is shown in Fig. 5. Therefore, the origin of peak in the tunneling current spectra is naturally attributed to the tunneling current modulation by the sliding motion of CDW at the surface.: The sliding motion of CDW at the surface was confirmed in the present experiment.

In such a mechanism the modulation frequency is proportional to the sliding velocity of CDW. The peak frequency in the tunneling spectra and that of the narrow band noise correspond to the CDW velocity at the sample surface and that in the bulk, respectively. The former shows that the CDW starts to slide abruptly just above the threshold with a finite velocity and the velocity of CDW increases rather linearly with the applied voltage at the surface. On the other hand, the velocity of CDW increases smoothly from 0 at the threshold field in the interior of the sample, as expected from the usual pinning mechanism[3]. These results indicate that the CDW is easily depinned at the surface and slide with much higher velocity than that in the bulk. The linear response of CDW velocity at the surface to the applied electric field, observed near above the threshold, suggests that the CDW behaves as if it suffers only negligibly small pinning potential, once it has been depinned. We have few theories for the pinning mechanism of CDW at the surface. Some screening effect by normal electrons may be important at the surface. The pinning by the three-dimensionality may play a major role in the surface pinning of CDW. More detailed experiment is in progress.

References

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