PROTON CHANNELING ANOMALIES BELOW 40 K IN $K_{0.3}MoO_3$

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Proton channeling is a very sensitive technique which allows to detect small atomic displacements (~ 0.1 Å) with respect to equilibrium positions. The channeled particles are dechanneled by thermal vibrations, impurities, lattice imperfections. This technique is a useful local method of investigation of the CDW state (1).

We have previously reported a 1 MeV proton channeling study of the Peierls transition in $K_{0.3}MoO_3$(2). The minimum backscattering yield X_{min} (defined as the ratio N_{ch}/N_r where N_{ch} and N_r are the number of protons backscattered in respectively channeled and random directions) shows a very weak anomaly in the vicinity of the Peierls transition temperature (180 K) upon cooling from a virgin state and a large hysteresis upon heating, as illustrated in Figure 1. It was ascertained that the insulating red bronze $K_{0.33}MoO_3$ shows no anomaly in the whole explored temperature range 4K-300 K.

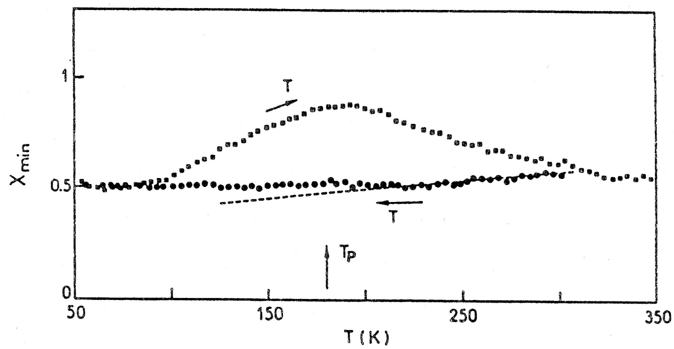

Fig. 1 Minimum backscattering yield X_{min} as a function of temperature ; (the dotted line is a guide to the eye), beam ⊥ to the cleavage plane (b, [102] ; beam diameter ~ 1mm, analyzed depth ~ 1µm.

As an increase of X_{min} always indicates an increase of the structural disorder, the observed large hysteresis strongly suggests that rearrangements of CDW defects are involved upon thermal cycling and that the Kohn anomaly plays only a minor role in the temperature dependence of X_{min}. We now report a study of proton channeling in the low temperature insulating CDW state. The aim of the

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experiments was to study the change from a deformable to a rigid behavior of the CDW dynamics in the vicinity of 40 K. Preliminary results are given in Ref. 3.

When the proton beam is perpendicular to the cleavage plane (b, [102]), X_{min} shows an anomalous increase below ~40 K upon cooling as shown in Figure 2-a. In addition, X_{min} shows a large hysteresis upon heating indicating that the structural disorder responsible for this increase is retained upon heating.

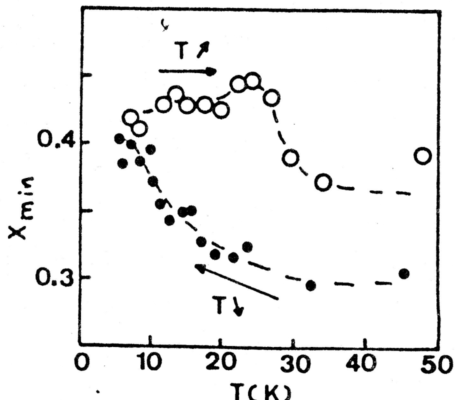

Fig. 2-a. X_{mim} as a function of temperature. Beam ⊥ to the cleavage plane.

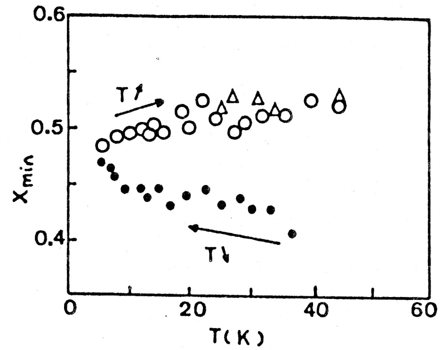

Fig. 2-b. Same as Fig 2-a, sample slightly misoriented. (●) cooling ; (0) ; heating ; (Δ) subsequent cooling.

When the sample is slightly misoriented, the magnitude of the anomaly becomes much weaker as shown in Fig. 2-b. This figure also shows that X_{min} (T) is reversible in the temperature range 25-50 K. When the sample is heated from 20 K to 30 K then cooled again to 20 K the hysteresis is very large as shown in Figure 3. The experimental point A (T = 20 K) is shifted towards B. A subsequent thermal cycling (curves 3 and 4 in Figure 3) shows anomalies similar to that shown Fig. 2-a. However, the magnitude of this effect becomes smaller.

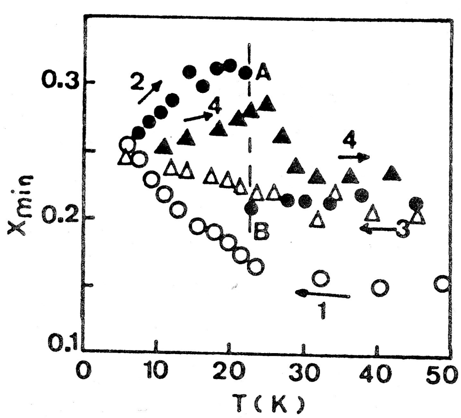

Fig. 3 X_{min} as a function of temperature:(o) cooling from a virgin state ; (2) (•) heating. From T = 20 K (A) a heating was performed up to 30 K, then a cooling down to 20 K (B) ; (3) subsequent cooling (Δ) and heating (4) cycle (▲).

These results imply that, even at low temperatures, the internal degrees of freedom of the CDW still play a role. The observed effects are too large to be accounted for solely by lattice defects. We propose that metastable CDW structural defects are responsible for the disorder which appear at low temperatures in the insulating state. This disorder has not been detected by x-ray experiments so far. In order to account for this behavior we suggest that domain walls parallel to the b-axis occur below ~ 40 K. These longitudinal walls of arbitrary thickness [4] carry no charge ; this is compatible with an insulating low temperature state. Above ~ 40 K, the walls could be discommensurations perpendicular to the b-axis. Another plausible mechanism could be a rearrangment of CDW phase dislocations coupled to impurities. A puzzling feature is the strong hysteresis in X_{min} for $4 K < T < 50 K$ while there is no hysteresis in the EPR spectra in this temperature range [5]. Further work would now involve a study to the anisotropy of X_{min} at low temperatures and structural studies.

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