ESRF

Experiment title:
High resolution X-ray scattering from pinned and sliding CDWs in quasi-one-dimensional MX3-compounds

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Beamline:
ID1O / BL9

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Local contact(s):
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Report:

The sliding motion of charge-density-waves (CDW) under an applied electric field is subject to fixed boundary conditions at the electrodes, where the CDW current must be converted to quasi-particle current by phase slippage processes. The CDW is thus compressed near one contact and stretched near the other, resulting in a macroscopic spatial variation of the CDW periodicity [1, 2].

The basic purpose of the experiment was to measure this periodicity variation in the sliding state using high *momentum* resolution X-ray diffraction. To achieve also high *spatial* resolution the X-ray spot width was reduced to 100 μm. We have carried out measurements on NbSe$_3$ at 90 *K* on the upper CDW (T_c = 145 *K*) with modulation wave vector (O, q, O), q=0.24. The ribbon-shaped single crystal sample of cross-section 40x5 μm^2 and of length 10 *mm* was mounted on a 60 μm thick sapphire substrate. We used a four-contact configuration (see fig.1):

- two narrow (50 μm), non-perturbative ("weak") gold contacts (contact resistance: 200-300 Q.), labeled 2 and 3 in fig. 1
- two broad, perturbative ("strong") silver contacts (contact resistance: a few Ohm), at the ends of the sample (labeled *1* and *4*)

(Non-)Perturbative contacts mean that the equipotential planes are (are not) disturbed by the presence of the contact. During the measurements we met with the following difficulties:

- the positions of the electrodes with respect to the X-ray spot could not be determined with sufficient accuracy.
- during the course of the experiment contact 3 broke (infinite contact resistance).
- the X-ray measurements under electric field revealed two defective zones (labeled 1' and 4' in fig. 1), acting as strong pinning centers. As discussed by Zettl et al. [3], these centers are equivalent to perturbative electrodes as far as electron conversion processes (phase slips) are concerned.

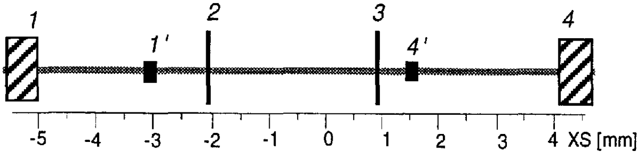
Fig. 2a) shows the positional shift $\Delta q(xs)$ of the (O, 1+q, O) satellite peak for a current $I=\pm 3 \cdot I_T$ applied between electrodes *1* and 4, where $I_T = 6.8$ *mA is* the threshold current (measured in situ). We find that the space derivative of the CDW deformation changes sign at a distance $\Delta xs \approx 1$ *mm* away from the strong pinning centers *1'* and 4'. This result confirms our earlier measurements [4] on a $NbSe_3$ sample, using two perturbative electrodes 3.5 *mm* apart. However, since the distance between *1'* and 4' is comparable to the contact distance in ref. [4], we cannot decide whether this value of Δxs is intrinsic to the phase slip process or scales with the distance between contacts.

Fig. 2b) shows $\Delta q(xs)$ for the same current *I* applied between the "weak" contact 2 and the "strong" contact 4. At the "weak" contact we observe a sharp maximum of Δq with a very abrupt return to zero outside the contact. A detailed observation of $\Delta q(xs)$ in the vicinity of the contact was hampered by the finite spatial extent of the X-ray beam (100 μm) and the inaccuracy in the determination of the electrode location.

Part of the beamtime was devoted to the test to observe speckle patterns from CDW domains using a coherent X-ray beam [5]. Since the beamline can provide longitudinal and vertical coherence lengths up to a few *μm*, one can hope to observe directly the interference pattern from coherent CDW phase domains. In fact, structures in the diffracted beam were observed, but they seem rather to reflect the local sample quality than interference pattern from CDW domains.

The basic problem here is to balance intensity versus monochromatisation requirements. The scattering from the CDW domains, not very intense, requires a high incident intensity, as provided e.g. by the Si(111) monochromator used in the present measurements. However, such a setup does not provide a sufficient beam coherence length. The beam coherence could be improved by using e.g. a Si(220) monochromator at the expense of incident photon intensity.

Fig.1: Positions of the electrodes on the sample (see also text)



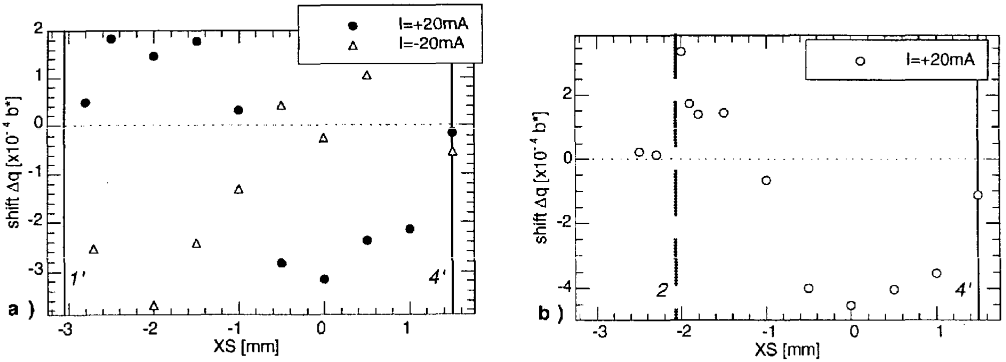


Fig.2: Shift Δq of the high temperature CDW satellite at (O, 1+q,0), q=0.242, at T=90K for applied currents of $I=\pm 3 \cdot I_T$ (threshold current $I_T=6.8mA$) using different contacts (see text). The full lines refer to the positions of the strong pinning centers *1'* and *4'*. The dashed line refers to the position of the "weak" contact *2*.

References:
[1] P.Monceau (edit.). *Electronic properties of inorganic quasi-one-dimensional compounds.* Reidel, Dordrecht, 1985.
[2] L. P. Gor'kov, G.Grüner (edit.). *Charge Density Waves in Solids.* Modem Problems in Condensed Matter Sciences, Vol.25. Elsevier, 1989
[3] R. P. Hall, M.F.Hundley and A.Zettl. phys.Rev. B 38 (1988) 13002
[4] P. Monceau, H. Requardt, F.Ya Nad', R. Currat, C. Vettier and J.E.Lorenzo, ESRF Annual Report 1994/1995, p.R149
[5] M. Sutton, S. G. L. Mochrie, T. Greytak et al. Nature 352 (1991) 608.