ESRF	**Experiment title:** **Phase slippage at the interface between CDW blocks moving at different velocities**	**Experiment number:** HS2030
Beamline: ID10A	**Date of experiment:** from: 28/04/03 to: 8/05/03	**Date of report:** 27/02/04 *Received at ESRF:*
Shifts: 36	**Local contact(s)**: G. GRÜBEL	

Names and affiliations of applicants (* indicates experimentalists):

R. Danneau*	ILL/CRTBT Grenoble
P. Monceau	CRTBT - CNRS Grenoble
R. Currat	ILL Grenoble
A. Ayari*	Physics Dpt, Univ. Maryland USA
H. Requardt*	ESRF Grenoble
J.E. Lorenzo*	Cristallographie -CNRS Grenoble
L. Ortega*	Cristallographie - CNRS Grenoble

Report:

A charge density wave (CDW) is a modulation of the conduction electron density associated with a periodic lattice distortion of same periodicity. Below the Peierls transition temperature, the CDW system exhibits a superstructure characterized by satellite diffraction peaks. Above a threshold applied electric field, E_T, the CDW, whose phase is normally pinned by randomly distributed impurities, becomes unpinned and begins to *slide* with respect to the underlying lattice, giving rise to *collective* electron transport:

$$J_{\mathrm{CDW}} = nev$$

with J_{CDW}, the CDW current density, v, the CDW drift velocity and n, the conduction electron density [1]. The velocity of the sliding condensate is limited by the rate of conversion between normal and condensed carriers near the current electrodes. This conversion is mediated by *phase-slip* processes consisting in the nucleation and lateral motion of phase-dislocation loops, each loop allowing the CDW phase to advance by 2π. The phase-slip phenomenon produces a small change in the CDW spatial periodicity in the near-electrode region [2,3], which is seen as a shift in the CDW satellite position in rec. space. Similar CDW phase-distortions have also been observed near macroscopic growth defects, such as grain boundaries, or near defects induced by radiation damage [4].

One remarkable characteristic of CDW dynamics is the *temporal* coherence of the sliding motion, which manifests itself in periodic voltage oscillations at fixed input current, the so-called Narrow Band Noise (NBN), whose Fourier spectrum exhibits sharp frequency peaks. This temporal coherence can be broken by injection of an additional small current, i, between two closely spaced (~100 μm) electrodes, which causes a local increase of the CDW velocity. Experimentally, it was shown [5] that for i larger than a critical value i_{th}, the NBN fundamental frequency splits, indicating that the CDW coherence is broken into 3 independent blocks with different drift velocities.

The aim of the present proposal was the detailed study of the local CDW deformations induced by the small additional current, as a unique example of a *controllable* phase-slip center at the boundary between sliding domains with different drift velocities.

Up until now, we have used electrical gold contacts, 0.2 µm-thick, deposited on a 100 µm-thick sapphire substrate. This technique is simple, with the disadvantage that the step on the substrate surface produced by the contact tends to strain the sample in the near-contact regions. For this experiment we have developed a new contact-deposition method, borrowed from Si-microelectronics, which allows to obtain buried gold contacts, a few µm-wide, on a silicon wafer. Fig. 1 shows such a substrate, equipped with 3 pairs of buried gold electrodes: 2 wide electrodes (1 and 2) for injection/extraction of the main current, *I*, and 2 pairs of small electrodes, 5 µm-wide and 95 µm apart, labeled (3,4) and (5,6), for the local injection/extraction of a small additional current, *i*.

Fig.2 shows the observed CDW-satellite shift, $q(x_S)$, in the vicinity of electrode pair (3,4), corresponding to, resp., x_S = -0.675 and –0,570 mm, for i = +/- 5.6 i_{th} (i_{th} = 0.9 mA) and $I = 0$, at T = 100 K. The two electrodes behave very similarly:

- the CDW deformation peaks precisely at the electrode position
- the CDW deformation extends far (~ 300 µm) outside the inter-electrode region, an effect already reported in ref. [3], but seen much more clearly here.
- there is asymmetry between current injection and current extraction, the CDW deformation being more pronounced at the electron-extraction electrode.
- there is a ~ 1. 10^{-4} $Å^{-1}$ offset between the satellite position far from the electrodes and the satellite position for i=0, measured after the complete depolarization of the sample, as discussed in ref. [2].

Except for the latter effect, which was not evidenced before, the present results confirm and complement previous observations, with a higher degree of accuracy, due to the reduced size and high quality of the contacts. Unfortunately, we were not able to perform the planned 2-current experiment since our first sample, which was used to measure $q(x_S)$ between electrodes 1 and 2 as well as other preliminary measurements, was destroyed after several days of beam-time, due to a failure in the electronic hardware connected to the sample. The time required to install, cool, orient and characterize a second sample prepared in advance, was such that the data collected on the second sample are also only fractional.

References:

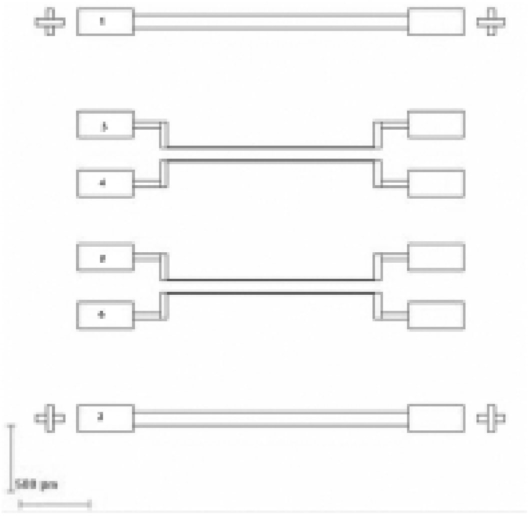

Fig. 1: Electrode geometry for the two-current experiment. The crosses are used to position the substrate with respect to the X-ray beam.

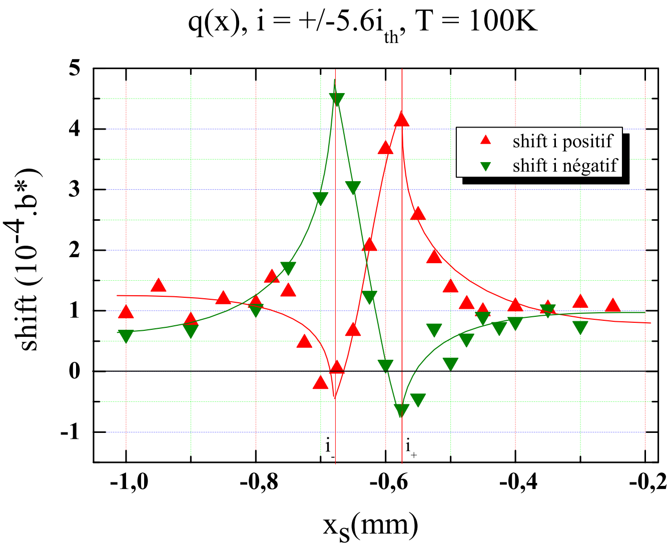

Fig. 2: Satellite shift near the closely-spaced (95 µm) electrodes for i = +/- 5.6 i_{th} ($I = 0$; T = 100 K). The origin of the vertical scale refers to the satellite position at $i = 0$, in the depolarized state. The lateral beam width was 20 µm.

[1] G. Grüner, Rev. Mod. Phys. **60** (1988) 1129.
[2] H. Requardt et al., Phys. Rev. Lett. **80** (1998) 5631.
[3] S. Brazovskii et al., Phys. Rev. B **61** (2000) 10640.
[4] D. Rideau et al., Europhys. Lett. **56** (2001) 289.
[5] M. C. Saint-Lager, Ph. D. thesis, Université Joseph-Fourier, Grenoble (1988).