SMALL ANGLE NEUTRON SCATTERING FROM THE FLUX LINES LATTICE: NEW DEVELOPMENTS

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In the mixed state of type II superconductors, the magnetic field B penetrates as flux lines (vortices). The critical current is directly related to the vortex pinning by defects and the knowledge of the vortex structure is of primary importance. Among existing experimental techniques, small angle neutron scattering (SANS) remains one the best ways to investigate the bulk of the vortex lattice, by applying magnetic fields of 0.02 to 20 T which correspond to inter-vortex distances of 1 to 10 µm. In classical SANS measurements, the vortex is aligned with the applied field and diffraction intensity only exists in the plane perpendicular to the magnetic field. Recent developments of this technique are related to the existence of diffracted intensity out of this plane. This is the case if the vortices meander to adjust their position to extended bulk defects such as columnar defects or twin boundaries. This is also the case of surface pinning where the vortices are curved to accommodate the presence of transport current J (curl B = μ_0 J).

In the presence of twin boundaries, the critical current is strongly modified by the interaction with these extended defects, with a peak of critical current when B is aligned onto the defects. In order to understand this feature, we have studied the influence of twin boundaries (TB) on the vortex lattice structure in a high T_c cuprate **YBaCuO.** We have studied samples possessing different TB densities and performed diffraction measurements on two diffraction planes. We find that the effect of TB's is double: the flux lines are not straight in the direction of the field but are meandering along to choose the TB direction. Depending on the ratio of the flux line density to the twin boundary density, a deformation of the Flux Lines Lattice (FLL) unit cell is also observed. This is likely due the fact that the screening currents are no longer cylindrical, in agreement with an image-like effect [1]. In twinned YBaCuO, the FLL apparent symmetry is square whereas Abrikosov lattice observed in untwinned crystals is usually hexagonal (Fig 1).

Concerning the nature of the vortex pinning, we have investigated the **role of surface pinning**. Most of the time, FLL properties are analyzed with the help of electronic transport measurements. The pinning of the FLL explains the existence of a critical current below which the current flow is non-resistive. For overcritical current, the FLL flows in the bulk of the sample in a resistive manner. There is a long-standing debate concerning the real nature of pinning (bulk versus surface) since pertinent probes are really rare. Nevertheless, these two models differ by the fact that below the critical current, bulk pinning predicts bulk penetration of the applied current, whereas surface pinning predicts surface current only. As a consequence of Maxwell equations, bulk current leads to a bending of the flux lines, which broadens the Bragg peaks in a particular direction (Fig. 2). Using this property, we have

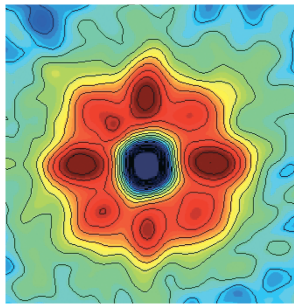

Figure 1. Diffraction pattern from the FLL in a twinned YBaCuO sample(T=4K, B//c-axis=0.1T). The apparent square symmetry is due to the twin boundaries.

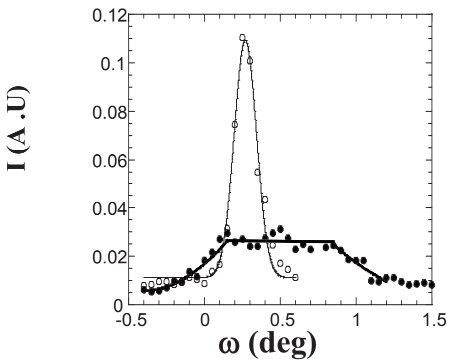

Figure 2. Bragg peak of the FLL in PbIn for straight lines (thin peak, I_{bulk}=0) and lines curved by the current induced self field component (broad peak, I_{bulk}=18A) (T=2K, B=0.1T).

shown that the pinning by the surface strongly dominates in a conventional low T_c superconductor (**PbIn**)[2]. Furthermore, it is proved that inhomogeneous surface state at large scale leads to an inhomogeneous current distribution.

A very peculiar case of flux lines pinning appears in the "peak effect" observed in **$NbSe_2$**, i.e. a sudden increase of the critical current I_c close to the superconducting-normal transition. It is an open question: does this correspond to a bulk disordering transition in the FLL? As shown in the fig. 3, we were able by field cooling (FC) or zero field cooling the sample (ZFC) to get this high I_c state as well as the low I_c state in a $NbSe_2$ crystal. In both cases, there is a nice FLL. The main difference lays in the rocking curves, which suggest that both states are due to surface pinning, and that the double peak reflects a tilting of the FLL by the pinning currents surrounding the sample in the FC process. The anomalous transport properties observed after FC are in this picture linked to the annealing of these metastable surface currents by the transport current and to the disappearance of this double peak structure [3].

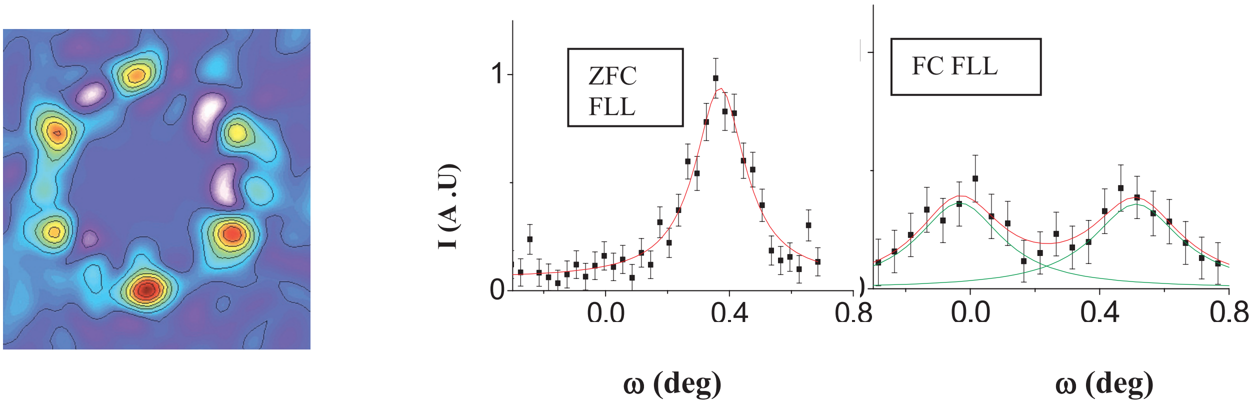

Figure 3. Left: Diffraction pattern from the FLL in $NbSe_2$ (T=2K, B=0.4T). Right: Rocking curve around the framed peak after zero field cooling (ZFC) and after field cooling (FC). Note the double peak after the FC.

References

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