Flux flow noise in high Tc superconductors thin films

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We have studied the fraction pinned of vortex in a type II superconductors. The sample used is the $YBa_2Cu_3O_{7-\delta}$ thin films. This fraction pinned is determined from the comparison of the experimental results and the theoretical results previously definite. In continuation one will study the variations of this fraction according to the temperature of the applied magnetic field and the electric current crossing the sample.

I.INTRODUCTION

We shall describe the noise voltage, generated by the viscous flow of flux and derive expressions for the power spectrum of the noise.

We consider a superconducting slab of width w and length l between the potential probes in a perpendicular magnetic field. Transport current flows in a direction perpendicular to the field and along the length of the sample.

Discrete flux entities of magnitude Φ, which is an a priori unknown multiple of the flux quantum φ_0, are generated at the edge of the superconductor at random times. They subsequently flow, independently of each other, across the superconductor and it takes a time τ for them to cross the specimen The flux entities, which in type-Il superconductors are bundles of vortex lines (flux bundles), are assumed to follow the same velocity time function, so that identical voltage pulses are generated. The flux is moving in a direction perpendicular to current and field, which means that guided motion and the Hall effect are neglected. The total flux in the specimen is constant.

As follows from $\vec{E} = \frac{-1}{c}(\vec{v} \wedge \vec{B})$, the flow of one flux bundle gives rise to a potential difference between the probes, for 0<t<τ. $V(t) = \frac{\Phi . v(t)}{c.\omega}$,

where v(t) is the velocity, which may be time-dependent. The area under the voltage pulse is determined by the amount of flux that is transported and is equal to Φ/c. If N is the average flux-bundle-generation rate, the average voltage across the sample can be written,

$$V = < V > = N.\int_0^\tau V(t).dt = N\frac{\Phi}{c}.$$

The mean-squared noise voltage in a frequency band between f and f+df is

$$<\delta V_f^2> = S(f).df.$$

If the generation and annihilation of the bundles is instantaneous and the velocity is constant, the resulting voltage pulse is a rectangular one **[1]**:

$$V(t) = \phi / c.\tau \quad \text{for} \quad 0 \le t \le \tau,$$

V(t)=0 otherwise

and $$S(f) = \frac{2\phi . V}{c}[\frac{\sin(\pi . f.\tau)}{\pi . f.\tau}]^2.$$

If the experimental spectra agree with the theory, the measurements will permit the determination the values of the transit time τ. As shown in fig. 1 this is dependent on the shape of the elementary voltage pulse. It was shown that at low current densities only a fraction (1-p) of the number of vortex lines is moving. Equation $\vec{E} = \frac{-1}{c}(\vec{v} \wedge \vec{B})$ is then modified and reads $\vec{E} = \frac{1-p}{c}(\vec{v} \wedge \vec{B})$. It follows then for the potential difference:

$$V = \frac{l\omega B(1-p)}{c\tau}.$$

Determination of τ from the noise measurements will therefore yield the value of the moving flux fraction (1-p).

1. EXPERIMENTAL

$YBa_2Cu_3O_{7-\delta}$ films with a thickness of 400 nm, and a width of 7.53 µm are deposited by the laser ablation method on the surface (100) of $SrTiO_3$ substrate. The resistance vanished, in zero magnetic field, at $T_c=90$ K. Electrodes of measurement are in gold and deposited on the surface of the sample in situ by evaporation. The distance between electrodes of power measurement is 135 µm. Contact resistances were less than 1Ω. A direct current, perpendicular to the magnetic field, is applied on edges of the sample. The sample central region voltage signal goes through a low-

noise transformer of report n=100, then in a preamplifier of gain equal to 100 and finally in a RC filter. The signal is visualized on a programmable oscilloscope then recorded and analyzed by computer.

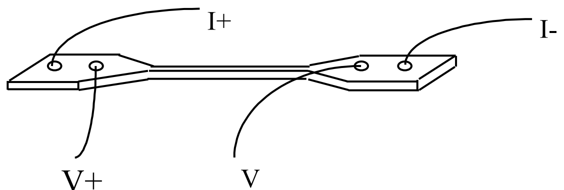

Fig. 1 : Schematic representation of our sample $YBa_2Cu_3O_{7-\delta}$

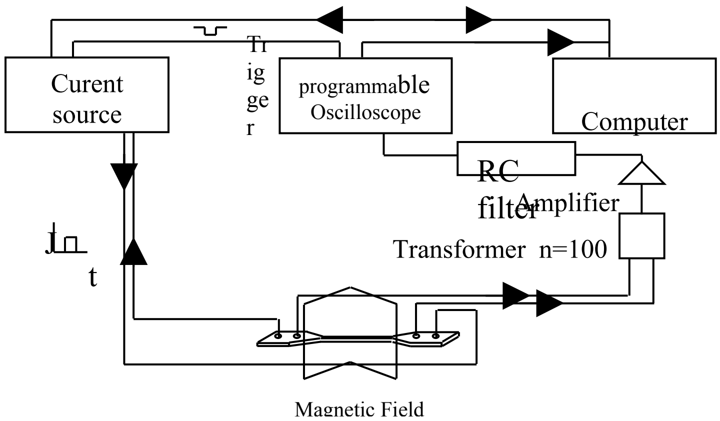

Fig.2 : Schematic of measurement principe

2. RESULTATS AND DISCUSSIONS

Noise spectra were measured for various combinations of current, magnetic field, and temperature. Figure 1 shows two examples of flux flow noise spectra. The spectra agree with the model as given above for a single voltage pulse of duration τ.The determination of the flux line fraction p that is pinned was done by comparing the theoretical spectrum for a rectangular pulse.

Figures 2 and 3 show p as a function of temperature at different values of magnetic field and transport current. The value of p decreases with temperature. Increasing the current always results in a lower value of p. This temperature and current dependence can be understood in terms of the effective driving force on the flux lines $(J-J_c).\Phi_0$. As J_c goes down with increasing temperature an increase of both current density and temperature causes a lower value of pinned flux lines fraction

Figures 4 show p as action of the density of current at two directions of magnetic field H=10 T // to **c** and // to **ab** for the temperature T=77K.The fraction pinned in vortices p is more important in the case where the field H it s parallel to **c**.

In the oxides of YBCO type the CuO2 layers and their neighborhood are strongly superconductive, and the spaces between these layers are unlike weak superconductivity.

The lines of flux are steadier when they are placed in the layers of weak superconductivity and parallel in the plane CuO_2, their energy of inclusion in the superconductor is minimum. The layers of weak superconductivity act like sites natural of pinning of the vortices. The energy of pinning is bigger when the magnetic field is applied to the plane ab in the same way that in the perpendicular case (H // to the c axis) [2-3]. The maximal trapping is given if the lines of flux are aligned precisely in the same way to the plan of the movie, interact thus with the layers of weak superconductivity and are pinned by the totality of their length. The corresponding noise is therefore very weak

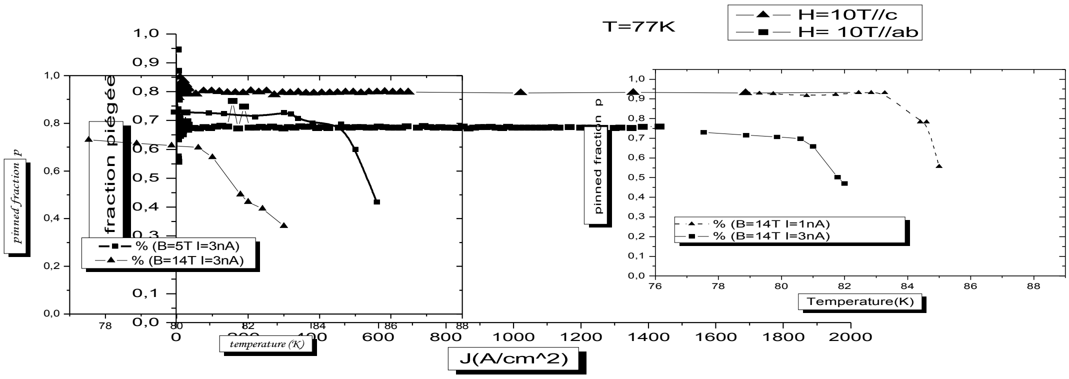

Fig.2. Pinned flux fraction versus temperature for different values of the magnetic fields.

Fig.3. Pinned flux fraction versus temperature for different values of the current

Fig.4. Pinned flux fraction versus current density for two directions of the magnetic field (H=10T // to **c** and // to **ab**) in the temperature T=77K

When the vortices are free to move the associated noise is more intense. In the contrary case the vortices are localized more and more between the plane ab, the strength of trapping exercised by these plans acts more and more on segments of the length of the vortices logs and their movement becomes thus less free. The pinning in the plane ab is more efficient than the one created by the shortcomings

3. CONCLUSION

The occurrence of flux-flow noise shows that the flux cannot be moving as a rigid vortex lattice, since the generation is random and also because of the velocity distribution for the flux bundles **[5]**. The flux presumably moves by vortex-grain-boundary glide and by vortex-dislocation motion. Within the grains the vortex lattice may be conserved. The results suggest that at high fields and currents there is a liquid-like vortex structure.

We conclude that the agreement between the experimental and theoretical flux-flow-noise spectra provides strong evidence for the flux-flow model, for type-Il superconductors. This agreement also shows that the generation of flux bundles is more or less random and that the rigid vortex lattice is not retained during flux flow. The measurements have also made possible the determination of transit time and bundle size and given information on the effect of pinning on flux flow.

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