Control of the Vortex Flow in Microchannel Arrays Produced in YBCO Films by Heavy Ion Lithography

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INTRODUCTION

Both fundamental issues for vortex matter (in low-dimensional systems) and device application aim attracted attention to controlled vortex motion mechanisms in the presence of micrometric bi-dimensional structures in superconducting thin films. Techniques include electron beam lithography, that is used to generate arrays of micrometric and nanometric size holes [1] and Heavy Ion Lithography (HIL) [2], respectively.

Arrays of micrometric size rows of strips patterned by HIL (0.114 GeV Au-ions at a fluence of 3.4·10^{11} cm^{-2} at Tandem-XTU facility) in YBCO films, each of them surrounded by same size virgin zones, are created in such a way to force vortex paths through tilted tracks. These layouts are useful to investigate vortex guidance viability as well as to study the availability of power splitting lines based on the control of vortex vector velocity. The aim of this report is to outline how the vortices penetrating the array are exhibiting, at low temperatures, the expected “collective behaviour” that belongs to a “continuum limit”, while at high temperatures, (for full vortex penetration) the vortex velocity gains a role as a vector into determining the tuneable, geometry dependent vortex motion. Thus the availability of power splitting devices started to be investigated by means of d.c. longitudinal and transversal (Hall signal) detection, as shown in the following paragraphs.

MAGNETO OPTICAL IMAGING MEASUREMENTS

From the sequence of Magneto-Optical Imaging (MOI) frames [3] at increasing applied field and from the profile across the microchannels reported in figure 1 it is readily recognized that vortex penetration occurs in accordance with the characteristic patterns of critical state for confined geometries (vortex critical-state arrangement of the whole sample).

ELECTRICAL TRANSPORT MEASUREMENTS

The measurements of the longitudinal, \( V_L \), and Hall voltage, \( V_{H} \), across the irradiated pattern are shown in figure 2.

![Figure 1](image-url)
First we note that due to the extended temperature range where dissipation occurs in the irradiated microchannels with respect to the as-grown YBCO, a shoulder in the longitudinal resistance is observed [4].

Fig. 2. Voltage vs. temperature of the longitudinal and Hall voltage signals across the irradiated pattern.

Correspondingly, a non-zero Hall signal is detected in this regime (this temperature range is dependent on the applied bias current). Since the onset critical temperature of the irradiated YBCO, at the used HEHI fluence, falls inside the dissipative region of the as-grown one, the Hall resistance presents only one, asymmetric, peak. The ratio between the longitudinal and Hall voltages, \( V_L/V_H \), corresponds to the ratio of the vortex velocity components, perpendicular and parallel to the current direction, respectively [5]. In order to verify the controlled vortex flow into the microchannels, this ratio has to be compared to the tangent of the angle between the direction of the microchannels and the applied current. In our case, the \( V_L/V_H \) ratio is very close to the expected value (1.96 = \( \tan(63^\circ) \)) in a relatively large temperature range, from about 84.5 K to 87.5 K (figure 3). This constitutes the striking evidence that the microchannels act as easy-flux flow channels and vortices are forced to move along their direction by the applied current flowing into the strip.

**CONCLUSIONS**

The simultaneous measurement of the longitudinal and Hall voltages results to the quantitative estimation of the vortex velocity direction that is found to be in excellent agreement with the direction of motion imposed by the irradiated microchannel array geometry. Thus an inclined array of microchannels patterned by HEHI lithography in YBCO strips is driven to produce a controlled vortex flow, in a well-defined temperature range. Into the irradiation patterned geometry the confined flow direction of vortices in turns generates a significant electric field perpendicular to the applied electrical current. Therefore these measurements suggest that the functional arrangement of flux-flow microchannels could open the way to novel designs for the application of high temperature superconducting films as power splitter and other reciprocal three-ports elements in the microwave field.

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