Vortex motion channeling effects in Nb with mesoscopic arrays of Ni lines

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Abstract

Ordered arrays of submicrometric Ni lines have been fabricated in sputtered Nb films. Magnetotransport $R(H)$ and (I, V) curves were measured close to the critical temperature using a cross-shape bridge that allow us to apply current in two directions: parallel or perpendicular to the lines. The experimental results show anisotropic vortex motion with clear channeling effects. In $R(H)$ data, magnetic features appear due to the matching between the periodic array of pinning potentials and the driving vortex lattice. However, they are absent in the (I,V) curves.

Key words: Superconductivity; vortices; nanostructures

1. Introduction and experiment

Transport measurements in superconducting thin films grown on top of a periodic array of submicrometric particles are a good tool to learn more about the vortex dynamics [1].

In this paper, we report effects observed in the dissipation of Nb films when the applied current is along the two main directions of an underlying array of magnetic lines.

The samples consist of a superconducting Nb thin film, that has been grown by sputtering technique, on top of an array of submicrometric magnetic structures deposited on Si substrates. The array has been fabricated by electron beam lithography, following the procedure described in [2]. The lines of 40 nm thickness were covered with a 100 nm superconducting Nb layer. Conventional photolitography and ion beam etching were used to define a cross-shape bridge. This allow us to apply current either perpendicular or parallel to the lines. Transport measurements were performed using a hellium cryostat with a superconducting magnet which provides a magnetic field perpendicular to the substrate plane.

2. Results

In Fig. 1, the superconducting transition curve is plotted for current along the Ni lines. The samples show a sharp transition with a critical temperature T_c= 8.7 K.

The magnetotransport behavior in the superconducting state for both current configurations is shown in Fig. 2. The graphs show the magnetic field dependence of the resistance at different currents: (A) current parallel to Ni lines and (B) current perpendicular to them. First of all, worth a while to note that the normal state resistance shows an enhancement when the current is applied perpendicular to the lines. In Fig. 2(A), since current is along Ni lines, vortex motion is perpendicular to them. Although no signature of reduced dissipation is observed, we can distinguish smooth changes of slopes that are absent in Fig. 2(B). The higher values of the resistance observed in Fig.

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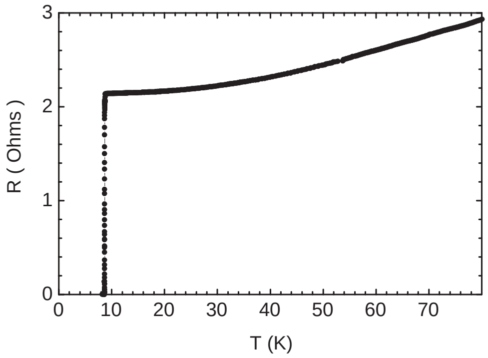

Fig. 1. Temperature dependence of the resistance for the Nb film with an array of Ni lines: 200 nm width and separate 500 nm (center to center).

2(B), in spite of the three order of magnitude higher values of current used in Fig. 2(A), indicates a channeling effect for vortex motion parallel to Ni lines. This effect is similar to the one observed in rectangular arrays of dots [3]

Finally, (I, V) curves at constant fields, with current applied along Ni lines, were measured at $0.94T_c$ to see the influence of the channelled potential landscape in the critical current (see Fig. 3). The fields were chosen so that we can explore the regions in which the slope changes were observed (see Fig. 3 inset), but no significant effects in the critical current were obtained.

In summary, Nb films with mesoscopic arrays of Ni lines show anisotropic superconducting behavior with channeling effects. The vortex motion in the direction perpendicular to the channel pinning potential exhibits clear matching effects which are not observed in the critical current behavior.

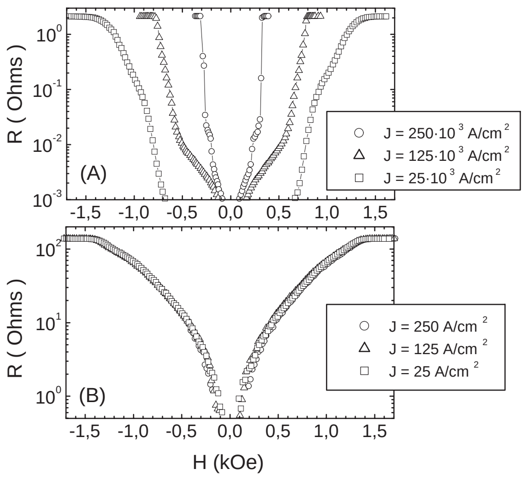

Fig. 2. Resistance vs magnetic field for a Nb film with a Ni line array (200 nm width and separate 500 nm) at $0.96T_c$. (A) Currents applied parallel to the Ni lines. (B) Currents applied perpendicular to the Ni lines.

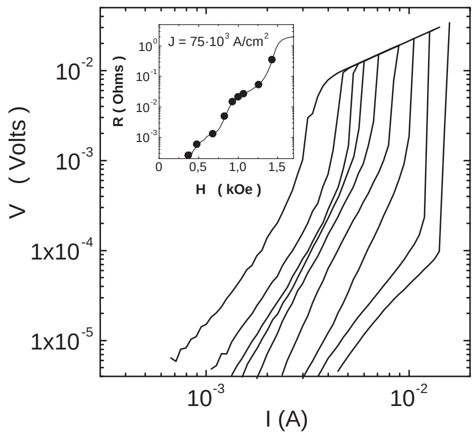

Fig. 3. (I, V) curves at different magnetic fields for the Nb film with the Ni line array (200 nm width and separate 500 nm) at $0.94T_c$. The field value of every curve is, from left to right: 1.43 kOe, 1.26 kOe, 1.07 kOe, 1.00 kOe, 0.93 kOe, 0.83 kOe, 0.68 kOe, 0.48 kOe, 0.37 kOe. Inset shows the field position of every curve along the R vs H curve using 75 kA/cm^2.

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