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Building of tridimensional Josephson junction arrays with controlled anisotropy

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Abstract

This work depicts optimized preparation routes employed to produce and characterize tridimensional disordered Josephson junction arrays. The arrays were fabricated from granular superconductors, using Nb powder. All relevant signatures of a Josephson junction array are exhibited by the samples, including the typical Fraunhofer dependence of the critical current with the applied magnetic field, a magnetic remanence presented in a certain temperature interval, and the paramagnetic Meissner effect. Our results show that the anisotropy of the samples can be controlled by the pressure applied in the preparation process.

Keywords: Josephson arrays; Magnetic response; Anisotropy

1. Introduction

Basic and applied research on Josephson junction arrays (JJAs) is a motivating area of investigation, not only for the many interesting physical properties of junctions and arrays, but also for a number of instigating correlations and similarities with other physical systems. Two-dimensional Josephson junction arrays (2D-JJAs) have been extensively studied, through experiments on real samples and numerical simulations. On the other hand, investigations involving tridimensional Josephson junction arrays (3D-JJAs) are less frequent.

Controlling the amount of disorder of the sample, i.e., its granularity, turns out to be a convenient way to study connections and similarities between granular samples and JJAs. To pursue this study, we have fabricated 3D-DJJAs from granular material. In this work we discuss some results related to preparation of 3D-JJAs with controlled anisotropy.

2. Experimental procedures

The 3D-JJAs employed in the experiments reported here are granular samples of Nb, a low temperature superconductor (LTS), fabricated from classified powder. Nb powder is separated according to grain size, using a set of special sieves, and then submitted to controlled pressures to form a pellet. All samples are submitted to uniaxial pressures, for the first conformation. In some cases the subsequent process involves application of isostatic pressures, as discussed below.

The quality of the samples was monitored using X-ray diffraction (XRD) and scanning electron microscopy (SEM) imaging. Magnetic measurements were carried out using a commercial Quantum Design SQUID magnetometer which includes an AC option. AC-susceptibility ($\chi_{AC} = \chi' + i\chi''$) was measured using an excitation field (h) of 3.8 Oe, at a frequency (f) of 100 Hz.

3. Results and discussion

The magnetic behavior of the specimen can be taken as the primary indication that it is a genuine 3D-DJJA.

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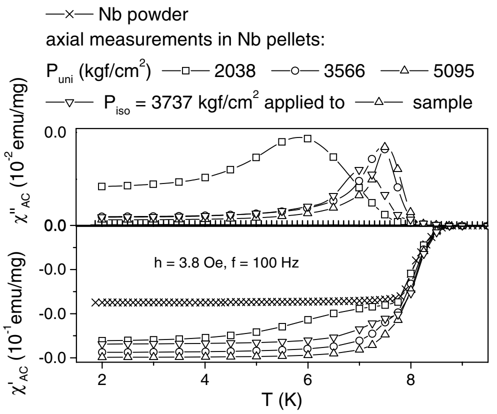

Fig. 1. AC-susceptibility of a Nb 3D-DJJA submitted to different pressures, measured in the axial geometry (see text).

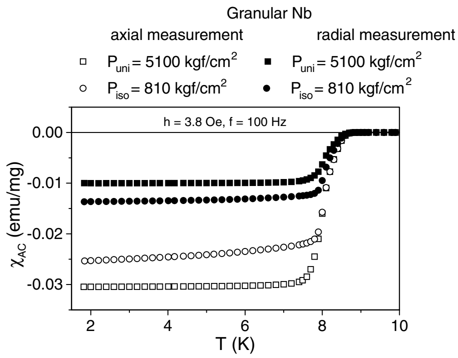

Fig. 2. AC-susceptibility of two Nb 3D-DJJAs, before and after application of an isostatic pressure, measured in both axial and radial geometries (see text).

Fig. 1 shows χ_{AC} versus temperature (T) of Nb samples, measured in a configuration for which the excitation field h is parallel to the uniaxial pressure axis. The sequence of curves reveals how the intergranular response develops as the uniaxial pressure is increased: in the case of the powder specimen, the screening currents are restricted to grain surface, so that its magnetic response is smaller than that for the compressed samples. For a uniaxial pressure of 2038 kgf/cm^2 the intergranular behavior manifests itself as a 2-step transition in χ' and a corresponding peak in χ''. As the pressure is enlarged, the temperature of the peak increases, as a result of the strengthening of the weak-links. Subsequent applications of an isostatic pressure softens the step exhibited by χ' and, at the same time, enhances the effective Meissner volume of the sample.

To verify that this behavior accompanies the anticipated softening of the anisotropy, we have also measured χ_{AC} in the radial configuration, in which h is perpendicular to the uniaxial pressure axis. Fig. 2 compares radial and axial measurements of χ' before and after a further application of an anisotropy-softening isostatic pressure of 810 kgf/cm^2. It is quite clear that the curves, which were the opposite extremes (most negative and less negative) before application of the isostatic pressure, tend to approximate each other, as expected.

It is worth mentioning that the samples studied are genuine 3D-DJJAs, as they reveal the characteristic signatures [1,2], namely, the Fraunhofer pattern for the field dependence of the critical current, the paramagnetic Meissner effect and the magnetic remanence distinctive of these arrays [2]. Thus one can conclude that the inherent anisotropy of granular 3D-DJJAs, which is characteristic of the process employed so far, can be controlled and eventually eliminated by application of uniaxial and isostatic pressures in appropriate sequences.

4. Final remarks

In short, we have successfully prepared 3D-DJJA samples using grains of low temperatures superconductors. Magnetic measurements reveal that the samples present all relevant signatures of JJAs. The arrays are anisotropic, as revealed by their different magnetic responses for axial and radial measurements. This anisotropy, inherent to the fabrication process, can be controlled by application of uniaxial and isostatic pressures in appropriate sequences during the preparation process.

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