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Unusually strong coherent response from grain-boundary Josephson network in polycrystalline $Pr_xY_{1-x}Ba_2Cu_3O_{7-\delta}$

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Abstract – By applying a highly sensitive homemade AC susceptibility technique to $Pr_xY_{1-x}Ba_2Cu_3O_{7-\delta}$ polycrystals (with x=0.0, 0.1 and 0.3), we observed a Fraunhofer type periodic dependence of the real part of the AC susceptibility at low magnetic fields. Using a single-plaquette approximation, we were able to successfully fit all the data assuming a strong coherent response from Jos ephson vortices penetrating intergranular regions of grain-boundary Josephson.

It is well-known [1] that important for large-scale applications properties of any realistic device based on Josephson effects require a very coherent response from many Josephson contacts comprising such a device. Usually [2], due to inevitable distribution of critical currents and sizes of the individual junctions, a grain-boundary induced Josephson network in polycrystalline materials manifests itself in a rather incoherent way, making it virtually impossible for applications. That is why, ordered (and more costly) artificially prepared Josephson junction arrays (JJAs) are used instead to achieve the expected performance [3].

In this Communication, we report on a clear evidence for unusually strong coherent response of grain-boundary Josephson network in our polycrystalline $Pr_xY_{1-x}Ba_2Cu_3O_{7-\delta}$ (PYBCO) samples which manifest itself through a Fraunhofer type magnetic field dependence of the measured AC susceptibility.

A grain-boundary structure of YBCO sample, responsible for the observed unusually strong low-field AC response is clearly seen on the SEM scan (Fig.1). The onset temperatures $T_C(x)$ for all studied samples (independently confirmed via the resistivity, magnetization and AC susceptibility). The complex response $\chi_{ac}=\chi'+i\chi''$ was measured as a function of the AC field $h_{ac}(t)=h\cos(\omega t)$ taken at fixed temperature. The field dependence of the normalized real part of AC susceptibility $\Delta\chi'(h)=\chi'(h)-\chi'(0)$ for different temperatures and Pr content is shown in Fig.2. A pronounced Fraunhofer type form of the observed curves suggests a rather strong coherent response from many Josephson junctions comprising the grain-boundary network and hence the high quality of our samples. This experimental fact allows us to employ the so-called single-plaquette approximation [4] to describe the observed phenomenon. The best fits for the low-field region using $\chi_J'(h)=\frac{1}{2\pi}\int_0^{2\pi} d(\omega t)\left[\frac{\delta M_J(t)}{\delta h_{ac}(t)}\right]=\chi_0 J_0(f)$ (see fig. 2), where $M_J(t)=I_J(t)S/V$ (V is the properly defined volume), $\chi_0=2\pi I_{CJ}S^2/\Phi_0 V$, $J_0(f)$ is the Bessel function, $f=h/h_J$ ($h_J=\Phi_0/2\pi S$) is characteristic Josephson field.

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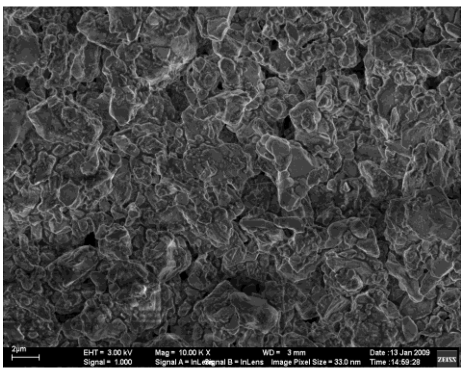

Figure 1: SEM scan photography of polycrystalline $YBa_2Cu_3O_7$.

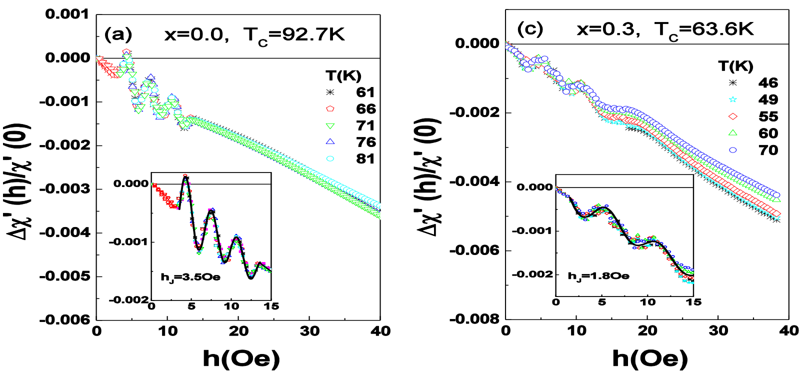

Figure 2: The magnetic field dependence of the normalized real part of AC susceptibility at different temperatures for samples with different Pr content: (a) x=0.0, (b) x=0.3. Inset: the best fits (solid line) of the low-field region according to Eq. (see above), using the Josephson field h_J as the only fitting parameter.

Reference

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