Flux Dynamics Effects in Superconducting Compacted Platinum Powders

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We have performed measurements of the complex magnetic ac susceptibility of superconducting compacted platinum powders at temperatures 0.1 \( \leq T \leq 10 \) mK with different ac excitation frequencies in the interval 5 Hz \( \lesssim \omega/2\pi \lesssim 10 \) kHz and with different excitation field amplitudes at 0.006 \( \lesssim b_{AC} \lesssim 2 \mu T \). The dependence of the ac susceptibility on the excitation field amplitude permits to determine the intergranular critical current density \( j_c \) whereas the frequency dependence reflects the flux dynamics. By comparing the experimental results with theoretical predictions we identify flux flow, flux pinning and flux creep effects in the regimes of intra- and intergranular superconductivity. The possible impact of these effects on the superconducting parameters like \( j_c \) of the samples is discussed.

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1. INTRODUCTION

Superconductivity of compacted platinum powders has been observed in measurements of electrical resistivity, magnetic ac susceptibility and static magnetization (Meissner effect), whereas in bulk platinum no superconductivity has been found down to \( \mu K \) temperatures. Detailed studies of the dependence of the ac susceptibility on the excitation field amplitude revealed a separation of inter- and intragranular superconductivity in the platinum compacts: At \( T \approx 1.9 \) mK all superconducting samples show a sharp onset of superconductivity which can be interpreted as the intragranular transition into the superconducting state. In the regime of intergranular superconductivity which appears at lower temperatures, the ac susceptibility strongly
depends on the excitation field amplitude thus reflecting the intergranular critical current density $j_c$. Surprisingly, the intergranular superconductivity was found to be significantly weaker for samples with higher packing fractions $f$ (0.50 ≤ $f$ ≤ 0.80). (The packing fraction $f$ is defined as the ratio of the volume of the massive material to the total volume of the cylindrical sample (including voids)). For example, $j_c(B = 0, T = 0) \approx 0.07$ A/cm$^2$ for $f = 0.67$ and $j_c(B = 0, T = 0) \approx 0.8$ A/cm$^2$ for $f = 0.50$.

In this work we vary the excitation field amplitude and in particular the frequency of our ac susceptibility measurements in order to identify flux dynamics effects as one possible direct consequence of the granularity of the platinum compacts on their superconducting properties. A topical review about ac susceptibility measurements and flux dynamics was given by Gömöry. Basically, one may distinguish between a linear and a nonlinear (excitation field amplitude dependent) ac susceptibility. Combining various kinds of linear flux dynamics effects like Meissner screening, (thermally activated) flux flow, and Campbell’s reversible screening, Brandt calculated the complex magnetic field penetration depth as a function of temperature and ac frequency. Nonlinear flux dynamics concerns hysteretic penetration of magnetic flux lines into a superconductor which arises from flux pinning effects together with large vortex displacements due to the alternating excitation field; this situation is usually described in terms of critical state models. In this context, variation of the excitation frequency of an ac susceptibility experiment enables to probe the time scales of flux dynamics expressed, e.g., in the flux creep velocity.

2. SAMPLE CHARACTERISATION AND EXPERIMENTAL METHODS

The platinum samples are prepared by mechanical compression of commercially available, high purity platinum powder which has been produced by chemical manufacturing. All results presented in this work have been obtained from samples made of “Platinum Powder Grade I” supplied by Alfa Johnson Matthey GmbH, Zeppelinstr. 7, D-76185 Karlsruhe, Germany. We have determined the grain size distribution of this powder by means of scanning electron microscopy (SEM) which revealed an average grain size of ≈ 1.3 μm and a distribution width (FWHM) of almost 2 μm. Sample “AlfaPt#1” has a packing fraction $f$ of 0.67 whereas sample “AlfaPt#2” has a comparable packing fraction ($f \approx 0.65$) but has been annealed for about 30 minutes at 100°C in high vacuum (p ≈ 10$^{-6}$ mbar). We would like to emphasize at this point that the effect of thermal treatment on the