Abstract

Type II superconducting materials are technologically interesting since they are characterized by the existence of a superconducting phase even after the penetration of the magnetic field inside them. In fact, while type I superconductors are characterized by a net transition from the perfect diamagnetic state (Meissner state) to the normal state, the magnetic field penetrates type II superconductors above a lower magnetic critical field in form of tubes of quantized magnetic flux, which are surrounded by vortices of superconducting currents, placed in a regular hexagonal lattice (mixed state or Abrikosov state). In this mixed state the superconductor can sustain the magnetic field and carry a current larger than in a type I superconductor. The superconducting phase persists below an upper magnetic critical field and a critical current density both depending on the temperature. In particular, the interaction of the superconducting vortices with the shielding currents and the external transport currents can generate dynamical phenomena which produce dissipation, and then increase the temperature and suppress the critical current density of the superconductor. On the other hand, these motion processes are hindered by the presence of defects which act as pinning centers of the vortices inside the lattice making the material able to sustain a current density below the critical value.

Two families of particularly interesting type II superconducting materials are the high temperature superconductors (HTS) and iron-based superconductors, characterized by unconventional superconductivity mechanisms which sensibly depend on the doping and the crystal structure and give high values of the superconducting critical temperature.
In particular, in both the families of HTS and iron-based superconductors, thermally activated mechanisms of magnetic flux relaxation are very important due to the high involved temperatures. The study of these mechanisms by means of the analysis of the AC magnetic susceptibility measurements as function of the temperature has been treated in this thesis. In fact, the analysis of the nonlinear AC susceptibility curves has been used to obtain superconducting properties and information about the dynamics of the vortices governing the AC magnetic response of type II superconducting materials. The presence of thermally activated phenomena of the magnetic flux relaxation in the mixed state of these materials, allows one to extract several superconducting parameters from the analysis of the curves of the AC susceptibility first harmonic as function of the external parameters. On the other hand, the analysis of the third harmonic curves of the AC magnetic response allows one to obtain detailed information about the dynamical processes governing the response of the material to the external magnetic field.

Since both the iron-based and the high critical temperature superconductors are typically characterized by an internal granular structure, their magnetic response is in

general due to the magnetic interaction between the inter- and intragranular superconducting currents, which are associated to two different contributions in the magnetic moment acquired by means of the AC susceptibility technique. Then, the main goal of this work has been the development of a physical model for describing the magnetic response of a granular system measured by the AC susceptibility technique, based on the existence of effective nonlinear magnetic fields induced by the magnetic response of the material through the demagnetizing factors due to the geometry of both the whole sample and the individual grains and acting on their surfaces, respectively. In fact, the developed physical model allows one to decompose the total magnetic response in the inter- and intragranular contributions, and in terms of an effective demagnetizing factor of the grains which depend on the geometry and superconducting properties of the grains. In particular, the magnetic susceptibilities of the inter- and intragranular volume fractions of the sample and the mechanisms of vortex dynamics inside them can be determined from the magnetic response of the material.

On the other hand, an analytical method has been formulated for the separation of the different harmonic contributions of the inter- and intragranular magnetic responses by taking into account the distortion, due to the intermodulation of the in-phase and out-of-phase (with respect to the external field) harmonics components of the effective magnetic fields, which generates harmonic contributions in the magnetic response in addition to those ones due to the nonlinearity of the material.

An approach based on both the developed physical model and analytical method has been used to analyze the magnetic response of a granular sample of the $FeSe_{0.5}Te_{0.5}$ iron-based compound. This has allowed us to extract several superconducting parameters and detailed information about the regimes of magnetic relaxation in the inter- and intragranular fractions of the material by analyzing the AC susceptibility curves numerically determined starting from the experimental curves of the whole sample magnetization measured by the AC susceptibility technique. The comparison with the results which have been directly obtained from the whole sample magnetization curves when the inter- and intragranular contributions are partially distinguishable has confirmed the importance of the magnetic interaction between the inter- and intragranular magnetic responses due to demagnetizing effects in the structure of a granular system, and also achieved a tool for the separation of the linear and nonlinear contributions in the two material fractions.