Current Flow in Polycrystalline Iron-Based Superconductors Assessed by Scanning Hall Probe Microscopy

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Abstract — The steadily increasing critical currents in iron-based wires and tapes are promising for applications; however, major improvements are still necessary for these materials to become competitive. The current flow in polycrystalline iron-based superconductors was investigated by means of Scanning Hall Probe Microscopy (SHPM) to explore possibilities for advancing these materials.

We studied the field dependence of the critical current density in Co- and K-doped Ba-122 polycrystals with different grain sizes. The magnetization profiles of the samples, from which the macroscopic critical current density as well as the currents flowing within the grains can be inferred, were directly visualized by SHPM. Measurements at various applied fields enabled us to track the complex evolution of the magnetization profiles, which exhibit a pronounced dependence on the magnetization history. This history effect was confirmed by magnetization measurements in a SQUID magnetometer as well as direct transport measurements.

We present a model explaining this evolution and hence the history effect in the critical current density. The model is based on the assumption that adjacent grains are coupled by Josephson currents. Within the framework of this model the macroscopic critical current density results from the interplay of intra-granular currents with these Josephson currents. Fitting the free parameters of this model to data obtained from SHPM measurements and from SQUID magnetometry results in very good agreement with these data. Realistic values of the free parameters (average thickness of the Josephson junctions and magnetic penetration depth) were obtained. An important prediction of this model, which is also supported by our experimental data, is that the macroscopic critical current density increases with decreasing grain size. This result may pave the way towards a significant improvement of the performance of granular high-temperature superconductors.

Keywords (Index Terms) — Critical current density, iron based superconductors, scanning Hall probe microscopy, granularity, Josephson junction.