

Evidence of ferromagnetic nanoclusters in superconducting $\text{RuSr}_2\text{Gd}_{1.5}\text{Ce}_{0.5}\text{Cu}_2\text{O}_{10-\delta}$

S. García¹ and L. Ghivelder²

¹Laboratorio de Superconductividad, Facultad de Física – IMRE, Universidad de La Habana, San Lázaro y L, Ciudad de La Habana 10400, Cuba.

²Laboratório de Baixas Temperaturas, Instituto de Física, Universidade Federal do Rio de Janeiro, C.P. 68528, Rio de Janeiro, RJ 21941-972, Brasil.

The presence of long-range ferromagnetic (FM) order and superconductivity in the ruthenate-cuprate $\text{RuSr}_2\text{Gd}_{1.5}\text{Ce}_{0.5}\text{Cu}_2\text{O}_{10-\delta}$ has been intensively studied, and different models proposed to explain how this striking coexistence of two usually exclusive phenomena can occur. Recently, it was suggested that normal-state FM clusters segregate from an antiferromagnetic superconducting (SC) matrix. Looking for confirmation of this proposal upon a quantitative basis, we measured the field cooled (FC) magnetization M_{FC} from 300 K down to the long-range FM transition temperature $T_{\text{M}} \cong 100$ K for different magnetic fields up to $H = 3$ T. To consider the effects of possible spin fluctuations, a log-log plot of the observed $\chi_{\text{DC}} = M_{\text{FC}}/H$ against $t = T/T_{\text{M}} - 1$ was performed. However, the expected universal behavior on t , after a proper H scaling, was not observed. Instead, a strong non-linearity, i.e., an H dependence of χ_{DC} , was detected, even for temperatures as large as $T/T_{\text{M}} = 1.4$. We show that these results can be explained if magnetic clusters of $\sim 50 \mu_{\text{B}}$ in size, corresponding to a diameter of about 20 \AA , are present. Fits of the non-linear isothermal M vs. H curves collected above T_{M} , using a modified Langevin function, confirm this interpretation. Further support comes from the large intragrain critical current density in the SC state ($J_{\text{C}} \sim 10^6 \text{ A/cm}^2$), since FM clusters with an average size similar to the coherence length ξ can effectively act as pinning centers of the vortex lines.