Nuclear Magnetic Resonance Study of the Effect of Proton Irradiation on Rh Doped BaFe2As2 Superconductors

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INTRODUCTION

Understanding how different types of defects influence both the superconducting and normal state properties of the iron based superconductors is essential both to test their stability for future technological applications as well as to shed new light on their gap symmetry and pairing mechanism.

In this Report we present the results of ⁷⁵As NMR measurements on BaFe₁₋ₓRhₓ₂As₂ (x = 0.068, 0.107) samples irradiated at CN accelerator with 5.5 MeV protons.

EXPERIMENTAL METHODS AND RESULTS

⁷⁵As Nuclear Magnetic Resonance (NMR) measurements (T₁, T₂ and line-width) were performed on BaFe₁₋ₓRhₓ₂As₂ single crystals (x = 0.068, 0.107) at ¹µ₀H₀ = 7 T magnetic field parallel to the c axis before and after proton irradiations at the fluences Φ = 3.2 × 10¹⁶ p/cm² and 6.4 × 10¹⁶ p/cm². Tc was determined by means of superconducting quantum interference device (SQUID) zero-field-cooled magnetization measurements in a 10 Oe magnetic field. It was found that in the optimally doped (x = 0.068) sample Tc decreases from 23 K (Φ = 0) to 21 K (Φ = 6.4×10¹⁶ p/cm²) while with x = 0.107 the critical temperature ranges from 12.5 K for Φ = 0 to 11.5 K for Φ = 6.4×10¹⁶ p/cm². The weak influence of proton irradiation on Tc is in good agreement with the results already reported for Co [1] doped and K [2] doped BaFe₂As₂.

The NMR spin-lattice relaxation rate, 1/T₁, was estimated by fitting the recovery of the transverse nuclear magnetization after a saturation recovery sequence while the spin-spin relaxation rate (1/T₂) was obtained by fitting with a stretched exponential the magnetization decay measured after an Hahn echo sequence.

It was found that, both for x = 0.068 and x = 0.107, above Tc 1/T₁ displays a linear Korringa temperature dependence, which is characteristic of metallic systems. The slope appears to be independent from irradiation suggesting that, as expected, the proton defects have no influence on the density of states at the Fermi level.

Previous ⁷⁵As NMR experiments [3,4] on non-irradiated BaFe₁₋ₓRhₓ₂As₂ revealed a marked increase of 1/T₂ upon cooling already above Tc, suggesting the onset of unconventional very low-frequency activated dynamics [3,4] which is thought to be associated with activated motions of domain walls separating regions where (π/a, 0) and (0, π/a) nematic correlations develop. Spin-spin relaxation rate measurements performed after irradiation revealed that while Tc changes weakly by increasing fluence, T*, the characteristic temperature at which 1/T₂ begins to increase, is markedly suppressed, suggesting that the proton-induced defects are pinning the domain walls motions.

The low temperature NMR line width of the optimally doped compound increases significantly while increasing fluence (see Fig. 1). The temperature dependence of the NMR line could be nicely fit by a Curie Weiss law, \[ \Delta \nu = \Delta \nu_0 + C/(T + \Theta) \] \quad (1)

where the value of the contribute \(\Delta \nu_0\), due to dipolar nucleus-nucleus interaction, is always assumed equal to 21.5 kHz. The sign change of the Weiss constant Θ indicates the onset of ferromagnetic correlations in proximity of the proton induced defects.