Gd^{3+} AND Eu^{2+} LOCAL ENVIRONMENT IN $Ca_{1-x}R_xB_6$ (R=Gd,Eu): AN ESR STUDY

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Introduction

CaB_6 is a controversial insulator, which upon light doping can display weak ferromagnetism up to rather high temperatures. EuB_6 is a semimetal, which at low T becomes a ferromagnetic metal, exhibiting two transitions at T_{c1} = 15.3 K and T_{c2} = 12.7 K. GdB_6, on the other hand, is a metal. The alloys of CaB_6 with RB_6 shed light on the controversial system CaB_6.

Method

Electron Spin Resonance (ESR) probes the local environment of the Gd^{3+} and Eu^{2+} $4f^7$-ions with S=7/2. The line-shape, i.e. Lorentzian or Dysonian, indicates if the environment is insulating or metallic, respectively. The temperature and field dependence, as well as the anisotropy (angular dependence) of the line-width and the g-shift provide information on the relaxation and interaction mechanism. X and Q-band frequencies are used.

Results

For x < 0.001 the spectra show resolved fine structures due to the cubic crystal electric field and, in the case of Eu, the hyperfine structure due to the nuclear hyperfine field is also observed. The resonances have Lorentzian line-shape, indicating an insulating environment for the Gd^{3+} and Eu^{2+} ions. As x increases, the ESR lines broaden due to local distortions caused by the Ca/Gd, Eu ions substitution. For Gd (x ~ 0.001) and Eu (x ~ 0.02), the spectra present superposition of Lorentzian and Dysonian resonances, suggesting a coexistence of insulating and metallic environments for the Gd^{3+} and Eu^{2+} ions.[1,2] (Note that each Gd^{3+} dopes the system with one electron). The Gd^{3+} and Eu^{2+} fine structures are still observable up to x ~ 0.003 for Gd and x ~ 0.15 for Eu. For larger values of x the fine and hyperfine structures are no longer observed, the line-width increases, and the line-shape becomes purely Dysonian anticipating the metallic and semimetallic character of GdB_6 and EuB_6, respectively. These results clearly show that in the low concentration regime the $Ca_{1-x}R_xB_6$ (R = Gd,Eu) systems are intrinsically inhomogeneous.

The g-value in $Ca_{1-x}Eu_xB_6$ was found to be anisotropic and magnetic field dependent. The amplitude of the anisotropy increases at low temperatures. The observed angular and temperature dependence of the g-value suggests tetragonal symmetry caused by a distortion along a direction perpendicular to the largest crystal face, the [001] direction. The g-values decrease at higher fields, which is interpreted in terms of an exchange interaction between the localized Eu^{2+}-spin with conduction electrons.[3]

Conclusions

No evidence of weak ferromagnetism was found in the ESR spectra of either metallic or insulating regions. A tetragonal distortion in Eu samples arises due to the presence of the surface in platelet-like samples.

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References

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