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ESR OF Gd^{3+} IONS IN $Gd_{0.9}(Ce_zLa_{1-z})_{0.1}Cu_6$ COMPOUNDS

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The effect of a replacing La by Ce in $Gd_{0.9}La_{0.1}Cu_6$ was investigated by ESR method. It was found that cerium ions cause an increase in the conduction electron relaxation to the lattice and change the conduction electron band structure.

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1. Introduction

In the last few years $RECu_6$ compounds (RE — rare earth ions) have been investigated by many authors [1–5, 8–10]. In our preceding paper [6] the results of the ESR measurements performed on $Gd_yCe_{1-y}Cu_6$ and $Gd_yLa_{1-y}Cu_6$ compounds were reported. We have found that cerium ions open the strongly bottlenecked $GdCu_6$ system [7] more efficiently than lanthanum ions. In the present work we study how the Ce concentration influences the system when the quantity of Gd^{3+} ions is fixed. The ESR measurements were performed on $Gd_{0.9}(Ce_zLa_{1-z})_{0.1}Cu_6$ system. From the observation of the parameters characteristic of ESR, i.e. $\mathrm{d}DH/\mathrm{d}T$ (the temperature slope of the linewidth) and Δg shift ($\Delta g = g_{\mathrm{exp}} - g_{\mathrm{insul}}$, $g_{\mathrm{insul}} = 1.993$ for Gd^{3+}) we could get some information about the bottleneck parameter and the relaxation relations in the investigated system.

2. Experimental details

$Gd_{0.9}(Ce_zLa_{1-z})_{0.1}Cu_6$ polycrystalline sample were prepared by arc melting of the starting materials La, Ce, Gd (3N), Cu (5N) in inert argon atmosphere. All samples were examined by X-ray diffraction using Fe K_α radiation and in all of them the orthorhombic structure was stated. ESR measurements were performed within the X band in the temperature range 4.2–300 K. The absorption parts of the resonance lines were separated numerically from the total asymmetrical ESR signal.

3. Results and discussion

In Fig. 1 the temperature dependence of linewidth for $z = 0$, 0.2, 0.4 and 1 are shown. Results exist for $z = 0.6$ and 0.8, but are not shown for the sake of clarity. Below 50 K an increase in the linewidthwith decreasing temperature is observed, which is characteristic of magnetic interaction or ordering. Above 50 K the linewidth increases linearly with temperature (the paramagnetic region) and the dDH/dT values increase from 2.2 ± 0.2 Oe/deg for $Gd_{0.9}La_{0.1}Cu_6$ to 4.6 ± 0.2 Oe/deg for $Gd_{0.9}Ce_{0.1}Cu_6$. From Fig. 3 it can be seen how the temperature slope of the linewidth increases with the Ce concentration. We can use the formula for a bottlenecked system [7]:

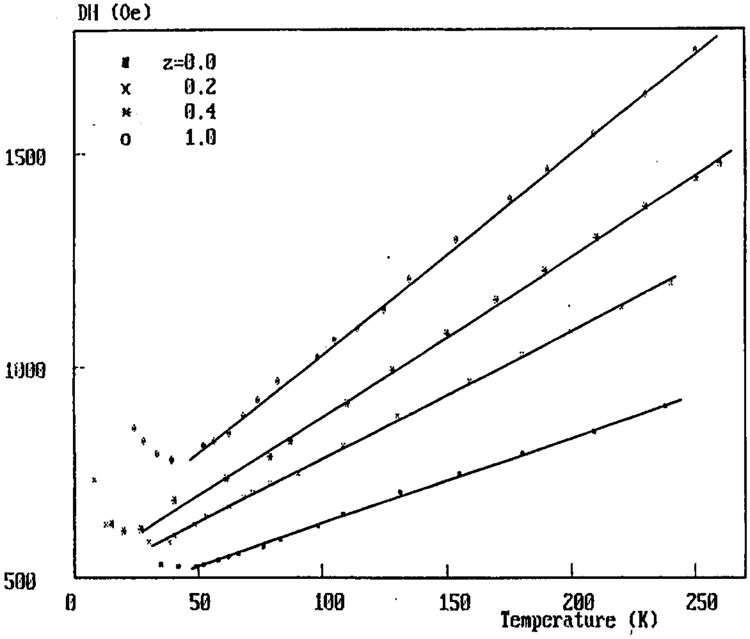

Fig. 1. Temperature dependence of a resonance linewidth for some $Gd_{0.9}(Ce_zLa_{1-z})Cu_6$ compounds.

$$\mathrm{d}DH/\mathrm{d}T = (\mathrm{d}DH/\mathrm{d}T)_K X/(X+1),$$

where $X = \delta_{el}/\delta_{eS}$ is the bottleneck parameter, δ_{el} — the conduction electrons (CE)-lattice relaxation rate, $\delta_{eS} = (8\pi/3h)S(S+1)N(E_F)\, J^2_{Se}y$ — the CE-Gd spins relaxation rate, $N(E_F)$ — the electron density of states on the Gd site, J_{Se} — the exchange constant between localized spins and CE, y — the concentration of magnetic ions and $(\mathrm{d}DH/\mathrm{d}T)_K$ — the Korringa slope. The dDH/dT changes could be caused by an increase in the δ_{el} rate or (and) a diminution of the δ_{eS} relaxation rate. If we assume that the presence of Ce in the compounds does not influence the RKKY interaction between Gd ions (i.e. $N(E_F)$ and J_{Se}) as is

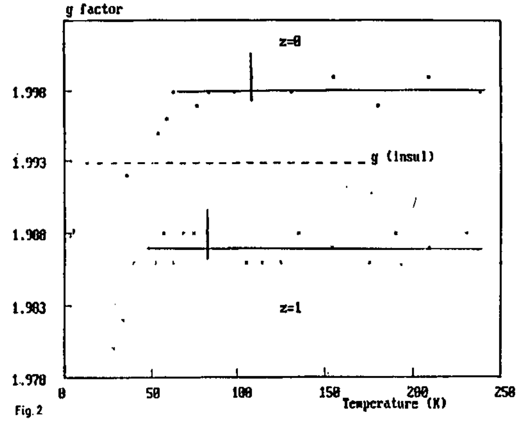

Fig. 2

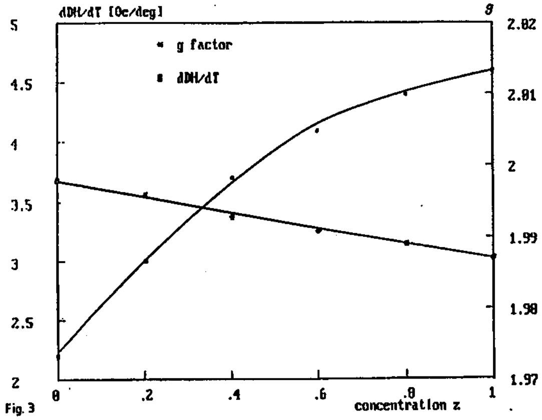

Fig. 3

Fig. 2. The g factors versus temperature for $Gd_{0.9}La_{0.1}Cu_6$ and $Gd_{0.9}Ce_{0.1}Cu_6$ compounds.

Fig 3. The temperature slope of ESR linewidth and g factor as a function of Ce concentration in $Gd_{0.9}(Ce_zLa_{1-z})Cu_6$.

suggested in [11], then the δ_{eS} is constant, because the concentration of magnetic ions Gd^3 does not change ($y = 0.9$). We can obtain that the CE–lattice relaxation rate increases about twice, when La is completely replaced by Ce.

The second ESR parameter, g-factor, is measured very accurately in this experiment (with errors ±0.002) (Figs. 2, 3) and decreases linearly with increase in Ce content in the system. Δg shift is positive for $Gd_{0.9}La_{0.1}Cu_6$ (+0.005) and negative for $Gd_{0.9}Ce_{0.1}Cu_6$ (−0.006).

For "dense" bottlenecked systems we have [12]:

$$\Delta g = (g_e - g_S)k^2(\chi_e/\chi_S)(1 + \chi_S\lambda/k),$$

where χ_e and χ_S are the conduction electron and local moment susceptibilities, g_e and g_S are the respective g factors, $k = g_S/g_e$ and $\lambda = 2J_{Se}/g_S g_e \mu_B^2$. The change of the Δg shift sign from positive to negative can be caused only by changing g_e value. It is evident that the conduction electron band changes when we replace La by Ce and in this way the presence of Ce ions influences the RKKY interaction between Gd ions.

4. Conclusion

From ESR measurements of $Gd_{0.9}(Ce_zLa_{1-z})_{0.1}Cu_6$ we can see that dDH/dT values increase with increasing Ce concentration in the system and Δg shift changes from positive for $z = 0$ to negative for $z = 1$. From these experimental facts we conclude that the presence of cerium in the investigated system not only increases the conduction electron–lattice relaxation rate, but also changes the conduction electron band structure and in that way influences the Gd–Gd RKKY interaction.

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