SPIN STRUCTURE OF K2Cu_{x}M(1-x)F_{4} (M = Co AND Mn) IN THEIR FERROMAGNETIC PHASE; FMR MEASUREMENTS
I. Yamada, T. Anbe, Y. Yamaguchi, M. Itoh

To cite this version:
I. Yamada, T. Anbe, Y. Yamaguchi, M. Itoh. SPIN STRUCTURE OF K2Cu_{x}M(1-x)F_{4} (M = Co AND Mn) IN THEIR FERROMAGNETIC PHASE; FMR MEASUREMENTS. Journal de Physique Colloques, 1988, 49 (C8), pp.C8-1489-C8-1490. <10.1051/jphyscol:19888685>. <jpa-00228918>

HAL Id: jpa-00228918
https://hal.archives-ouvertes.fr/jpa-00228918
Submitted on 1 Jan 1988

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers. L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
SPIN STRUCTURE OF $K_2Cu_xM_{(1-x)}F_4$ ($M = Co$ AND $Mn$) IN THEIR FERROMAGNETIC PHASE; FMR MEASUREMENTS

I. Yamada, T. Anbe, Y. Yamaguchi and M. Itoh

Department of Physics, Faculty of Science, Chiba University, Yayoi-cho, Chiba-260, Japan

Abstract. – We report ferromagnetic resonance of the two-dimensional randomly mixed systems, $K_2Cu_xCo_{(1-x)}F_4$ and $K_2Cu_xMn_{(1-x)}F_4$ with very low concentration of Co and Mn. In the ferromagnetically ordered state, the resonance field shows strong angular variation in the $c$-plane having four-fold symmetry.

When isomorphous ferromagnetic and antiferromagnetic compounds are mixed randomly, there usually arises three phases, namely, ferromagnetic phase, spin-glass phase and antiferromagnetic phase. $K_2Cu_xMn_{(1-x)}F_4$ (abbreviated as Cu-Mn from now) is an example of such mixed systems; the end members $K_2CuF_4$ and $K_2MnF_4$ are a two-dimensional Heisenberg ferromagnet and an antiferromagnet, respectively. From the EPR-measurements, the appearance of three phases mentioned above has been suggested [1]. Recently, this suggestion has been confirmed by the susceptibility measurements [2]; for $x > 0.8$, the system shows ferromagnetic phase at low temperatures. There is another system $K_2Cu_xCO_{(1-x)}F_4$ (Cu-Co), namely the mixed system of $K_2CuF_4$ and a two-dimensional Ising antiferromagnet $K_2CoF_4$. We have recently confirmed by the static magnetic measurements that this mixed system also shows three phases which will be reported elsewhere. In the Cu-Co, the ferromagnetic phase appears for $x > 0.95$. Owing to $S = 1/2$ on a square lattice, $K_2CuF_4$ ($T_c = 6.25$ K) [3] has almost negligible in-plane anisotropy. When a very small number of $Cu^{2+}$ are displaced randomly by $Co^{2+}$ ($Mn^{2+}$), how will be a spin arrangement in the $c$-plane? Since $F^-$-octahedra in $K_2CuF_4$ distort owing to the cooperative Jahn-Teller effect, each $Co^{2+}$ ($Mn^{2+}$) should be surrounded by the distorted $F^-$-octahedron as far as the concentration of $Co^{2+}$ ($Mn^{2+}$) is very small. In such a case, there should arise a difference between the effect of $Co^{2+}$ and $Mn^{2+}$ on a net spin arrangement in the $c$-plane because the spin of $Co^{2+}$ is strongly connected with the $F^-$-ligand field whereas the spin of $Mn^{2+}$ has almost no connection with the ligand field because of its $L = 0$ state. In order to investigate the ground state of spins and the spin-relaxation in the mixed systems introduced above with very small concentration of $Co^{2+}$ ($Mn^{2+}$), we have made experiments of ferromagnetic resonance (FMR).

Each sample used was polished into a sphere of diameter about 1 mm or less. Unevenness of the surface was approximately $20 \sim 30$ μm. With these sphere samples and very weak microwave power, the magnetostatic mode (Walker mode) did not appear. FMR experiments were done by a conventional X-band spectrometer with a cylindrical cavity of TE011 mode. Owing to a good shaped sphere of each sample, single FMR line having a Lorentzian lineshape was observed. The experiment was done over the temperature range $1.3$ K $\sim 25$ K including the paramagnetic region. The angular dependence of the resonance field $H_{res}$ in the $c$-plane for the Cu-Co with $x = 0.995$ measured at 1.3 K is shown in figure 1; $H_{res}$ has a four-fold anisotropic behavior in the $c$-plane; the minimum appears for the external field $H// [110]$ and the maximum for $H// [100]$. This behavior is enhanced by the increase of $Co^{2+}$. The dependence of $H_{res}$ on the temperature is shown in figure 2 for both cases of $H// [110]$ and $H// [100]$.
[100] together with that for \( H_\parallel / [001] \); with increasing the temperature, the anisotropic behavior of \( H_{\text{res}} \) in the \( c \)-plane becomes weaker and disappears approximately above 10 K. The difference of \( H_{\text{res}} \) parallel and perpendicular to the \( c \)-axis at high temperatures in figure 2 arises from the different values of \( g_\alpha \) and \( g_\beta \). As the angular dependence of \( H_{\text{res}} \) in the \( c \)-plane shows, the net spin is easy to align to the [110] direction. As far as the concentration of \( \text{Co}^{2+} \) is very small, they are isolated with each other, namely each \( \text{CoF}_6 \) is surrounded by \( \text{CuF}_6 \). Since the surrounding \( \text{CuF}_6 \) are distorted due to the Jahn-Teller effect, then \( \text{CoF}_6 \) are also distorted. In a low symmetric ligand field, a spin of \( \text{Co}^{2+} \) should be aligned with one of the principal axes of the ligand field because of the strong effect of the ligand field on a \( \text{Co}^{2+} \)-spin. Now, let's suppose that a spin of \( \text{Co}^{2+} \) has a direction parallel to the longest axis of the distorted \( \text{F}^- \)-octahedron. Since the distorted \( \text{F}^- \)-octahedron are arranged with their long axes orthogonal to each other, then the spin of \( \text{Co}^{2+} \) has two choices for its direction, parallel to [100] or parallel to [010]. Under the condition of ferromagnetic coupling of \( \text{Cu}-\text{Cu} \) and antiferromagnetic coupling of \( \text{Cu}-\text{Co} \), \( \text{Cu}^{2+} \)-spins around a \( \text{Co}^{2+} \)-spin [100] are forced to align to the [100] direction whereas \( \text{Cu} \)-spins around a \( \text{Co}^{2+} \)-spin [010] are forced to align to [010]. Then, majority of \( \text{Cu} \)-spins very far from \( \text{Co}^{2+} \) are obliged to have the direction parallel to [110] as shown in figure 3.

Similar angular anisotropy of \( H_{\text{res}} \) and \( \Delta H_{\text{pp}} \) are observed in the Cu-Mn system (see Fig. 1). However, the anisotropic behaviors are not so excellent as compared with that of the Cu-Co system because of a weak connection of \( \text{Mn}^{2+} \)-spin with the \( \text{F}^- \)-ligand field. That is, only the 4th or more higher order perturbation terms can given the ligand field effect on \( \text{Mn}^{2+} \)-spins. Thus, a spin arrangement similar to that of the Cu-Co system can be expected, though each \( \text{Mn}^{2+} \)-spin should have some inclination from the principal axis of the ligand field owing to the weak connection of \( \text{Mn}^{2+} \)-spin with the ligand field.

A more detailed report including the temperature dependence of the linewidth will be reported elsewhere.