

MAGNETIC PROPERTIES OF CALCIUM DOPED YIG¹⁾

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The magnetization and cubic anisotropy measurements performed on thin YIG:Ca films and the bulk crystal suggest that the Fe^{4+} ion does not play the dominant role in the charge compensation and is not responsible for the anomalous dependence $M_s(T)$.

1. INTRODUCTION

Formerly, the cubic anisotropy of $\text{Y}_{3-x}\text{Ca}_x\text{Fe}_5\text{O}_{12}$ with x between 0 and 0.27 was measured on bulk crystals, where the static constant K_1 was found to be zero in contrast to a nonzero dynamic contribution [1]. Recently a considerable attention has been given to epitaxial YIG:Ca films for which a decrease of magnetization M_s for $T \rightarrow 0$ K has been observed [2]. These anomalies were explained assuming that the Fe^{4+} (d) ions, localized at low temperatures are ferromagnetically coupled to the Fe^{3+} (a) ions [3]. An alternative explanation of these effects based on the assumption that at $T \rightarrow 0$ K the holes become localized forming the paramagnetic O^- ions has been suggested [4]. As a continuation of the latter work, we present in this paper some experimental results and discuss them comparing them with the Fe^{4+} (d) model.

II. EXPERIMENTAL PROCEDURE AND RESULTS

$\text{Y}_{3-x}\text{Ca}_x\text{Fe}_5\text{O}_{12}$ epitaxial films and bulk crystal were prepared by the LPE and flux method, respectively, (Pb and Pt content < 0.03). The effective magnetization M_{eff} and cubic anisotropy constant K_1 were measured at 25 GHz using the FMR method and the saturation magnetization M_s by means of a magnetometer; in both cases between 7 and 300 K. The results for M_{eff} and M_s are shown

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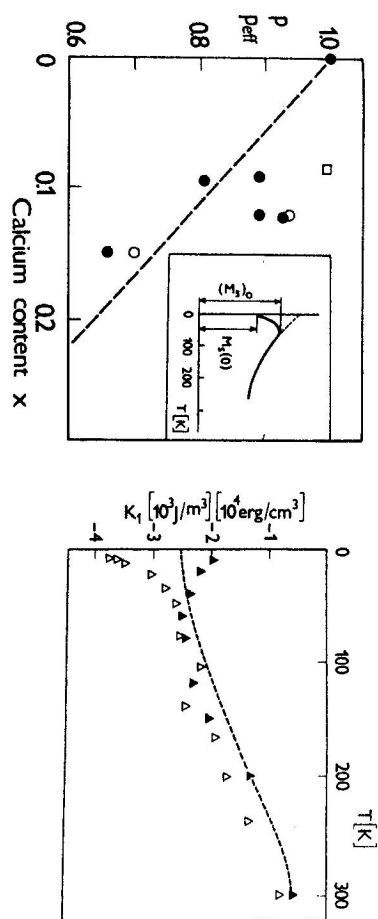


Fig. 1 Dependence of the ratio $p(\text{O})$ and $p_{\text{eff}}(\bullet)$ on the Ca content; (\square) the value of p evaluated for the bulk crystal. The dashed line corresponds to the function $p = 1 - (9/5)x$.

Fig. 2 Temperature dependence of K_1 for the film with $x = 0.15$ (\blacktriangle), and the film with $x = 0.09$ (\triangle); the dashed curve represents the dependence $K_1(T)$ for YIG.

III. DISCUSSION

The decrease of p and p_{eff} with increasing x has been explained by the occurrence of either the Fe^{4+} (d) ions [3] or of the O^- ions [4]. In both cases the dependence $p(x)$ should be given approximately by the line $p = 1 - (9/5)x$ so that it is not possible to decide between these two models. This can be rather done by inspecting the cubic constant K_1 . The contribution $\Delta K_1 = K_1 - K_1(\text{YIG})$ extrapolated to $T = 0$ K is positive or negative but its magnitude $\Delta K_1(0)$ is less than about $1.5 \times 10^3 \text{ J/m}^3$, similar results are in [5]. (Let us note that the constant K_1 involves a dynamic contribution, which may be according to [1] e.g. $5 \times 10^2 \text{ J/m}^3$) This result will be now compared with theoretical estimates of the contribution $\Delta K_1(0)$ due to the Fe^{4+} ion (Tab. 1). We may conclude from it that the concentration of the Fe^{4+} ions, if any, is much less than the Ca content x (approximately one fifth). It seems therefore that the Fe^{4+} ion does not play the dominant role in the charge compensation and also cannot be responsible for the magnetization anomalies. In order to support these conclusions, it would be useful to refine the theoretical calculation of ΔK_1 for the Fe^{4+} ion.

Table 1

Estimated single-ion contributions of the Fe^{4+} ion to K_1 in YIG at 0 K [6]; the data for the Fe^{4+} (d) ion with the lowest orbital singlet \rightarrow have been calculated according to the works [7], [8], taking $8\beta H_{cr} = 150 \text{ cm}^{-1}$ and $\lambda = 125 \text{ cm}^{-1}$ (after the covalent reduction by the factor 0.8).

site	ground term	lowest level	$\Delta K_1(0)$ [cm ⁻¹ /ion]	$\Delta K_1(0)$ due to Fe_{6i}^{4+} [10 ³ J/m ³]
d	5T_2	orbital doublet	-85	-711
d	5T_2	orbital singlet	-0.5	-4.2
a	3T_1	orbital singlet	3	25

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МАГНИТНЫЕ СВОЙСТВА ЖИГ С ДОБАВКОЙ КАЛЦИЯ

Измерения намагниченности и кубической анизотропии на тонких пленках и массивном кристалле ЖИГ. Са показывают на то что ион Fe^{4+} не доминирует при компенсации заряда и не является источником аномальной зависимости $M_s(T)$.