FARADAY ROTATION OF YIG: Mn GARNET LPE FILMS[1])

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The spectral dependence of the Faraday coefficient in YIG: Mn garnet LPE films was measured in the visible region. The main effect of manganese manifests itself in a diamagnetic type of transition at 2.54 eV, which was found to be due to the crystal field transitions of Mn^{3+} in octahedral sites.

ФАРАДЕЕВСКОЕ ВРАЩЕНИЕ ГРАНАТОВЫХ ПЛЕНОК YIG:Mn

В работе приведены результаты измерений коэффициента фарадеевского вращения в гранатовых пленках YIG:Mn в видимой области спектра, которые были выращены при помощи эпитаксии из жидкой фазы. Влияние марганца сказывается главным образом на диамагнитном переходе при энергии 2,54 эВ, который обусловлен присутствием ионов Mn^{3+} в октаэдрических положениях решетки.

I. INTRODUCTION

Substitution of manganese ions into yttrium iron garnet (YIG) — based films for magnetic bubble applications has a favourable effect on the magnetic anisotropy and the mobility of magnetic domains [1]. These effects were ascribed to the elastic strains caused by the presence of Mn^{3+} Jahn-Teller ions in octahedral positions [2]. As the magnetooptical properties proved to be sensitive in detecting certain ions in the definite crystallographic environment [3], it seemed desirable to verify the supposed distribution of Mn ions by investigating the Faraday rotation spectra of YIG:Mn garnet films.

II. EXPERIMENTAL PART

In the present paper the spectral dependence of the Faraday rotation (FR) in the visible part of spectra was measured on a series of garnet films $Y_3Fe_{5-x}Mn_xO_{12}$ with

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$x = 0$, 0.15, 0.32 and 0.52, respectively. The samples were grown from PbO/B_2O_3 based melts by an usual liquid phase epitaxial (LPE) method on (111) or (001) oriented GGG substrates. More details about the preparation and the magnetic and crystallographic properties of films were published elsewhere [2].

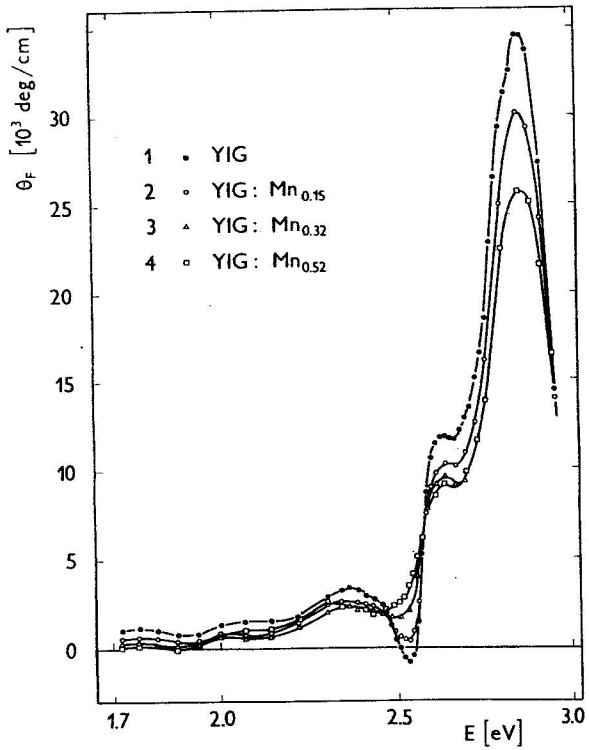

Fig. 1. Spectral dependences of the specific Faraday coefficients in YIG: Mn garnet films.

Spectral dependences of the Faraday rotation in garnet films were measured by a rotation modulation method as described earlier [3]. In Fig. 1 the dependence of the specific Faraday coefficient Θ_F on the photon energy is shown. It is seen that the significant effect of the manganese substitution consists in diminishing a sharp paramagnetic type of transition occurring at 2.57 eV and in the decrease of the large positive peak at 2.85 eV.

To visualize a contribution of Mn ions to FR spectra of YIG we plotted in Fig. 2 the difference of the specific Faraday coefficients of YIG:Mn and YIG samples, respectively, normalized to the Mn ion in the formula unit. A salient feature of

Fig. 2 is the presence of the diamagnetic type of transition at 2.54 eV, the magnitude of which is linearly dependent on the Mn content. The other parts of the $\Delta\Theta_F$ spectra display a nonlinear behaviour showing the largest influence of Mn-substitution at the lowest Mn-concentrations. A detailed analysis of the $\Delta\Theta_F$

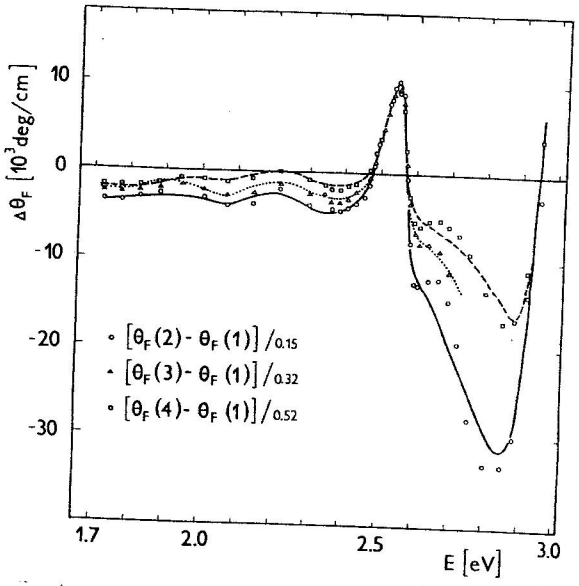

Fig. 2. Spectral dependences of the normalized difference Faraday coefficients of the samples as denoted in Fig. 1.

spectra by means of the UNIFIT 2 fitting procedure as made for the YIG:Bi system [4] reveals that the observed spectra can fairly well be represented by one diamagnetic transition placed at 2.54 eV and five paramagnetic transitions found at 1.87, 2.13, 2.26, 2.57 and 2.95 eV, respectively. The calculated curves based on these transitions are represented in Fig. 2 by full lines. A comparison with the earlier analysis of the YIG spectra [4] shows that the first four paramagnetic transitions occur already in YIG and the substitution of manganese merely alters (nonlinearly) their magnitude. The fifth paramagnetic transition (at 2.95 eV) represents a summation effect of several transitions occuring at neighbouring energies and we shall not consider it here.

On the other hand, the diamagnetic transition at 2.54 eV has no analogue in the YIG spectra and its magnitude is linearly dependent on the Mn content. Therefore, it can be concluded that this transition is inherent to Mn ions only.

III. DISCUSSION

Let us look for the possible $3d$-crystal field transitions of Mn^{2+} and Mn^{3+} ions in octahedral and tetrahedral sites, respectively. Unfortunately, there are no magnetooptical spectra of Mn ions in magnetic garnets that would enable a comparison with our results. One would expect the absorption and the magnetooptical spectra of Mn^{2+} ions to be analogous to the spectra of isoelectronic Fe^{3+} ions, i.e., starting at low photon energies with the $^6A_1 \rightarrow {}^4T_1$ and $^6A_1 \rightarrow {}^4T_2$ weak paramagnetic types of transitions [4]. From the optical absorption of octahedrally coordinated Mn^{2+} complexes it is found [5] that the corresponding energies are at about 2.3 and 2.8 eV, respectively. For tetrahedrally coordinated Mn^{2+} these transitions are expected to shift to higher energies. The latter conclusion is confirmed by the absorption and MCD measurements on tetrahalogeno-manganese complexes [6], where the first transition ($^6A_1 \rightarrow {}^4T_1$) was found at 2.75 eV and the second ($^6A_1 \rightarrow {}^4T_2$) at 3.4 eV, respectively.

On the other hand, the octahedrally coordinated Mn^{3+} ion in corundum was found [7] to display two strong absorption bands with different polarizations centred at 2.32 and 2.55 eV and assignet respectively to the $^5E \rightarrow {}^5A_1$ and $^5E(^5D) \rightarrow {}^5E(^5T_2)$ transitions. As the denerate ground state (^5E) of the Mn^{3+} ion is in octahedral sites stabilized by the Jahn-Teller effect and is not further split by the trigonal or spin-orbit interaction, the two transitions are expected to cause a diamagnetic shape of transition centred at about 2.5 eV. This conclusion is in full agreement with our analysis of the observed FR spectra of YIG:Mn films.

REFERENCES

[1] Breed, D. J., Voermans, A. B., Nederpel, P. Q. J., van Bakel, B. A. M.: J. Appl. Phys. *54* (1983), 1519.
[2] Novák, P., Maryško, M., Krupička, S., Kub, J., Šimšová, J., Čermák, J., Nevřiva, M.: Phys. Stat. Sol. (a) *80* (1983), K 213.
[3] Šimša, Z.: Czech. J. Phys. B *34* (1984), 78.
[4] Šimša, Z., Le Gall, H., Šimšová, J., Koláček, J., Le Paillier-Malécot, A.: IEEE Transaction on Magnetics, MAG-*20* (1984), 1001.
[5] Ballhausen, C. J.: *Introduction to Ligand Field Theory.* Mc Graw-Hill, New York 1962.
[6] Katô, H.: J. Chem. Phys. *58* (1973), 1964.
[7] Mc Clure, D. S.: J. Chem. Phys. *36* (1962), 2757.

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