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The Role of Technological Factors (Parameters of LPE) in Defect Generation and Formation of Properties of Magnetic Bubble Materials

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Abstract. It is shown that in a value range of molar parameter $R_S = 0.31 - 0.50$ the magnetic garnet films $(YSmLuCa)_s(FeGe)sO_{12}$ have overstoichiometric amount of $Ca^{2+}$ ions. Their concentration grows with the increase $R_S$.

It is established that charge neutralization of excess $Ca^{2+}$ ions is executed predominantly by $V^+_{O^2}$ and $V^-_{O^2}$ vacancies.

The contribution of oxygen vacancies in coercive force and magnetic anisotropy of films is determined.

1. INTRODUCTION

Magnetic garnet films with $(Ca, Ge)$ substitution have high values of Curie point and domain wall mobility. Due to these properties such film are a perspective material for manufacture of logic and storing devices on magnetic bubbles. The operational parameters, as well as presence of defects of above-stated materials are in many respects defined by the technological factors of growth. The purpose of given work was study of influence of molar parameter $R_S$ on properties and defectivity of magnetic garnet films with $(YSmLuCa)_s(FeGe)sO_{12}$ composition.

2. OBJECTS OF RESEARCHES AND EXPERIMENTAL TECHNIQUES

Films were fabricated by a method of liquid-phase epitaxy from a solution in flux PbO-B$_2$O$_3$ on the substrates Gd$_3$Ga$_5$O$_{12}$ with (111) crystallographic orientation. The molar parameters (molar ratios of components in the melt [1]) $R_1$-$R_4$ and $R_5$ were had similar values for all specimens. Parameter $R_5$ therewith varied and was equal: 0.31; 0.35; 0.48 and 0.50. The film growth rate ranges from 0.75 to 0.80 µm/min.

The coercive force $H_c$ and field of effective magnetic anisotropy $H_k$ were determined by standard techniques [1]. The difference between experimentally measured ($H_c$) and designed ($H_e$) values was defined as:

$$\Delta H_c = H_c - H_e,$$

where $H_c = H_0 + H_D - M_s$, $H_0$ and $H_D$ are the growth- and stress-induced (caused by discrepancy of lattice parameters between film and substrate) components of uniaxial anisotropy, $M_s$ is saturation magnetization.

For study of film defectivity the following methods were used: X-ray microscopic microanalysis, X-ray photoelectron spectroscopy (XRPES), X-ray diffraction, X-ray topography, thermostimulated conduction current in short circuit regime (TSCCSC) and polarization-optic technique. Microanalysis of samples has allowed to find out that the $R_S$ value insignificantly influences the concentration of rare earth ions, $Fe^{3+}$ ions and impurity ions of $Pb^{2+}$ and $Pt^{4+}$, appearing during growth. At the same time, in all films without exception the presence of overstoichiometric $Ca^{2+}$ ions was found out. As $R_S$ increases from 0.31 to 0.50, the overstoichiometric $Ca^{2+}$ concentration increases from 0.03 to 0.11 in formula unit.

3. RESULTS

Measurements of magnetic parameters of samples have found out that the increase of parameter $R_S$ (representing of overstoichiometric $Ca^{2+}$ concentration) brings to growth of values $H_c$ and $\Delta H_c$. The dependencies $H_c(R_S)$ and $\Delta H_c(R_S)$ are shown in fig.1. The increased values of $H_c$ and $H_e$ (in comparison with Ga-substituted compositions) are characteristic feature of magnetic garnet films of a (Ca,Ge)-system [1] and in doing so the nature of high values of this parameters is at present finally not established. The linear dependence between coercive force and molar parameter $R_S$ ($R_S=0.03+0.625$) was received also by Hibiya T. with the co-authors [3] for $(YSmLuCa)_s(FeGe)sO_{12}$ and $(YEuTmCa)_s(FeGe)sO_{12}$ films.

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In this case the low-temperature peak corresponds to $V_{o^2}$ vacancy (F$^+$-centre) and high-temperature one to $V_{o^2}$ vacancy. In [3,7] it is supposed that the reason of high coercivity of magnetic garnet films of (Ca,Ge)-systems are oxygen vacancy. According to estimates on the basis of our data the concentrations of these vacancies constitute:

$N_{t_1}=5.0-7.2 \times 10^{18}$ $V_{o^2}$ sm$^{-3}$; $N_{t_2}=5.5-7.8 \times 10^{18}$ $V_{o^2}$ sm$^{-3}$ for composition with content of 0.03 redundant

Ca$^{2+}$ ions per formula unit (that corresponds to concentration $1.27 \times 10^{20}$ sm$^{-3}$);

$N_{t_1}=1.5-2.2 \times 10^{19}$ $V_{o^2}$ sm$^{-3}$; $N_{t_2}=1.3-2.5 \times 10^{19}$ $V_{o^2}$ sm$^{-3}$ for composition with content of 0.1 redundant

Ca$^{2+}$ ions per formula unit (that corresponds to concentration $4.22 \times 10^{20}$ sm$^{-3}$).

However, the concentration of $V_{o^2}$ and $V_{o^2}$ vacancies has not enough for complete charge neutralization of Ca$^{2+}$ ions. As far as XRPES have not found out the Fe$^{4+}$ ions and the p-centres O{$^-$}, in all probability, the part of redundant Ca$^{2+}$ ions passes in interstitial sites. It can promote precipitation of neutral oxygen vacancies (F-centres) into Ca$^{2+}$ ions. Their charge neutralization is executed predominantly by $V_{o^2}$- and $V_{o^2}$- vacancies. As one of variants of such clusterization, it is probably the formation of "vacancy pores" from F-centres about small groups of interstitial calcium ions [7]. A reasoning conducted for coercive force holds true and for anisotropy. When the oxygen vacancies have enough large concentration (up to $1 \times 10^{21}$/f.u.) and complete ordering, they can result to occurrence of uniaxial anisotropy with $K_{o^2}=5 \times 10^4$ J/m$^3$, that is 2-3 times more than the value under observation [8]. Thus, the model of ordered distribution of oxygen vacancies is quite applicable for the explanation of $\Delta H_K$ growth with the increase $R_S$.

4. CONCLUSION

As a result of our researches it is established: a magnetic garnet films (YSmLuCa)(FeGe)O$_3$ at $R_S=0.31 \pm 0.50$ have the overstoichiometric content of Ca$^{2+}$ ions. Their charge neutralization is executed predominantly by $V_{o^2}$- and $V_{o^2}$- vacancies. Specified vacancies result in the increased values $H_K$ and $H_S$ of (Ca,Ge)-substituted films at Ca$^{2+}$/Ge$^{4+}>1$. In this case the growth magnetic anisotropy is stipulated by two factors: occupation of non-equivalent dodecahedral positions by rare-earth ions; oxygen vacancy ordering determined, obviously, by distribution of Ca$^{2+}$ ions.

References