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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 $R_5 = 0.31 - 0.50$ the magnetic garnet films $(Y\text{SmLuCa})_3(\text{FeGe})_5\text{O}_{12}$ have overstoichiometric amount of Ca^{2+} ions. Their concentration grows with the increase R_5 . It is established that charge neutralization of excess Ca^{2+} ions is executed predominantly by $V_{\text{O}^{2-}}^+$ и $V_{\text{O}^{2-}}^{2+}$ 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_5 on properties and defectivity of magnetic garnet films with $(Y\text{SmLuCa})_3(\text{FeGe})_5\text{O}_{12}$ composition.

2. OBJECTS OF RESEARCHES AND EXPERIMENTAL TECHNIQUES

Films were fabricated by a method of liquid-phase epitaxy from a solution in flux $\text{PbO-B}_2\text{O}_3$ on the substrates $\text{Gd}_3\text{Ga}_5\text{O}_{12}$ with (111) crystallographic orientation. The molar parameters (molar ratios of components in the melt [1]) R_1 - R_4 and R_6 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 $\mu\text{m}/\text{min}$.

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_k) and designed (H_k) values was defined as:

$$\Delta H_k = H_k - H_k^*,$$

where $H_k^* = H_G + H_\sigma - M_s$, H_G и H_σ 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 (TSCSC) and polarization-optic technique. Microanalysis of samples has allowed to find out that the R_5 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_5 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_5 (representing of overstoichiometric Ca^{2+} concentration) brings to growth of values H_c and ΔH_k . The dependencies $H_c(R_5)$ and $\Delta H_k(R_5)$ are shown in fig.1. The increased values of H_c and H_k (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_5 ($R_5=0.03\div0.625$) was received also by Hibiya T. with the co-authors [3] for $(Y\text{SmLuCa})_3(\text{FeGe})_5\text{O}_{12}$ and $(Y\text{EuTmCa})_3(\text{FeGe})_5\text{O}_{12}$ films.

Figure 1: The R_5 -dependence of the magnetic film characteristics.

In this case the low-temperature peak corresponds to $V_{O_2}^{2+}$ vacancy (F^+ -centre) and high-temperature one to $V_{O_2}^{2+}$ 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:

$$N_{t1} = (5.0 \pm 7.2) \cdot 10^{18} V_{O_2}^{2+} \text{ cm}^{-3}; N_{t2} = (5.5 \pm 7.8) \cdot 10^{18} V_{O_2}^{2+} \text{ cm}^{-3} \text{ for composition with content of 0.03 redundant}$$

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

$$N_{t1} = (1.5 \pm 2.2) \cdot 10^{19} V_{O_2}^{2+} \text{ cm}^{-3}; N_{t2} = (1.3 \pm 2.5) \cdot 10^{19} V_{O_2}^{2+} \text{ cm}^{-3} \text{ for composition with content of 0.1 redundant}$$

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

However, the concentration of $V_{O_2}^{2+}$ and $V_{O_2}^{2+}$ 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 $O^{\cdot}$, 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 clusters causing to the increased H_c values. 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 $1 \cdot 10^{-3} / \text{f.u.}$) and complete ordering, they can result to occurrence of uniaxial anisotropy with $K_G = 5 \text{ kJ/m}^3$, that is $2 \div 5$ times more than the value under observation [8]. Thus, the model of ordered distribution of oxygen vacancies is quite applicable for the explanation of ΔH_k growth with the increase R_5 .

4. CONCLUSION

As a result of our researches it is established: a magnetic garnet films $(Y\text{SmLuCa})_3(\text{FeGe})_5\text{O}_{12}$ at $R_5 = 0.31 \div 0.50$ have the overstoichiometric content of Ca^{2+} ions. Their charge neutralization is executed predominantly by $V_{O_2}^{2+}$ and $V_{O_2}^{2+}$ vacancies. Specified vacancies result in the increased values H_c and H_k 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.

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