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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 $(YSmLuCa)_3(FeGe)_5O_{12}$ 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 $V^{+}_{O^{2-}}$ и $V^{2+}_{O^{2-}}$ 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_5 on properties and defectivity of magnetic garnet films with $(YSmLuCa)_3(FeGe)_5O_{12}$ composition.

2. OBJECTS OF RESEARCHES AND EXPERIMENTAL TECHNIQUES

Films were fabricated by a method of liquid-phase epitaxy from a solution in flux $PbO\text{-}B_2O_3$ on the substrates $Gd_3Ga_5O_{12}$ 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 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_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 (TSCCSC) 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÷0.625) was received also by Hibiya T. with the co-authors [3] for $(YSmLuCa)_3(FeGe)_5O_{12}$ and $(YEuTmCa)_3(FeGe)_5O_{12}$ films.

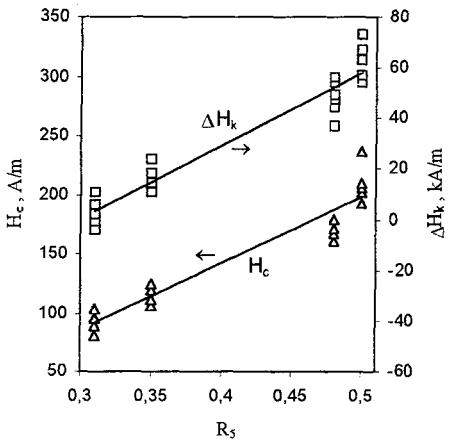

Figure 1: The R_5-dependence of the magnetic film characteristics.

The film etching in H_3PO_4, polarization-optic measurements, X-ray topography and X-ray crystallographic analysis, TSCCSC, as well as data, given by Shupegin M.L. [4], allows to conclude that the increased values of H_c are not stipulated by action of non-uniform elastic stress or fixing (pinning) of domain boundaries on dislocations. It is standard opinion that the redundant Ca^{2+} ions should be compensated by the Fe^{4+} ions (see, for example, [1]), because on a microanalysis data the tetravalent ions, such as Ge^{4+}, Pt^{4+} are not enough for this.

For all available specimens the TSCCSC spectra consist of two peaks with temperature maxima at T_{m_1}=(443÷445)K and T_{m_2}=503K. To greater concentration of redundant Ca^{2+} ions there corresponds larger intensity of peaks. It was established that these peaks correspond to deep capture centres with activation energy E_{t_1}=0.87 eV and E_{t_2}=1.1 eV respectively. Results by Larsen P.K. and Metselaar R. [5,6] and our calculations given the basis to conclude that the found out local centres are stipulated by presence of oxygen vacancies in objects of research.

In this case the low-temperature peak corresponds to $V^{+}_{O^{2-}}$ vacancy (F^{+}-centre) and high-temperature one to $V^{2+}_{O^{2-}}$ 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)·10^{18} $V^{+}_{O^{2-}}$ sm^{-3}; N_{t_2}=(5.5÷7.8)·10^{18} $V^{2+}_{O^{2-}}$ sm^{-3} for composition with content of 0.03 redundant Ca^{2+} ions per formula unit (that corresponds to concentration 1.27·$10^{20}sm^{-3}$);

N_{t_1}=(1.5÷2.2)·10^{19} $V^{+}_{O^{2-}}$ sm^{-3}; N_{t_2}=(1,3÷2,5)·10^{19} $V^{2+}_{O^{2-}}$ sm^{-3} for composition with content of 0.1 redundant Ca^{2+} ions per formula unit (that corresponds to concentration 4.22·$10^{20}sm^{-3}$).

However, the concentration of $V^{+}_{O^{2-}}$ and $V^{2+}_{O^{2-}}$ 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 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 1·10^{-3}/f.u.) and complete ordering, they can result to occurrence of uniaxial anisotropy with K_G=5 kJ/m^3, that is 2÷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 $(YSmLuCa)_3(FeGe)_5O_{12}$ at R_5=0,31÷0,50 have the overstoichiometric content of Ca^{2+} ions. Their charge neutralization is executed predominantly by $V^{+}_{O^{2-}}$ and $V^{2+}_{O^{2-}}$ 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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