H_C–T magnetic phase diagrams of DyIG at low temperatures

Mahieddine Lahoubi[a]

[a]*Badji Mokhtar Annaba University, Laboratory LPS, Physics Department, Annaba, Algeria.*

Magnetization, differential of magnetization and paraprocess susceptibility measurements have been performed on DyIG single crystals below the compensation temperature T_{comp} = 218.5 K and down to 1.5 K in DC magnetic fields up to 50 kOe. Critical fields $H_C(T)$ are observed and H_C–T magnetic phase diagrams (MPDs) are constructed for the three principal directions <111>, <110>, and <100>. They include H_C lines of first and second-order phase transitions and a critical point of the liquid-vapor type. They are discussed taking into account the ferromagnetic paraprocess and the strong anisotropy of magnetization, the predicted 'Belov point' T_B ~ 42 K and the spontaneous spin reorientation temperature T_{SR} = 14.62 K between the high-T coaxial phase along the easy axis <111> and the angular <uuw> phases.

Keywords: dysprosium iron garnet; anisotropy of magnetization; Belov point; spin reorientation; magnetic phase diagram

1. Introduction

The bulk magnetic properties of the rare-earth iron garnets $RE_3Fe_5O_{12}$, where RE is a rare-earth element, were studied in detail and a considerable amount has been paid to the investigation of spontaneous spin reorientation phase transitions (SRPTs) where a change of the easy axis of magnetization occurs with change of temperature (T) in zero internal magnetic field (H). It was developed in the same period a great interest to the study of the field induced phase transitions (FIPTs) which occur between collinear and canted magnetic structures. The H_C–T magnetic phase diagrams (MPDs) with critical lines (H_C) which may be either first or second order, were constructed for weakly anisotropic cubic ferrimagnets with two and three sublattices, especially close to the compensation point (T_{comp}) [1]. Since the previous investigation of these FIPTs in DyIG near T_{comp} = 218.5 K [2], only the effects of a high DC magnetic field up to 160 kOe on the SRPT at T_{SR} = 14.62 K, between the coaxial phase along the easy axis <111> and the angular <uuw> phases, were investigated up to 50 K [3]. In this paper, magnetization, differential of magnetization and paraprocess of susceptibility measurements are carried out on DyIG single crystals in fields up to 50 kOe, well below T_{comp} = 218.5 K and down to 1.5 K knowing that it was reported previously that a strong magnetic anisotropy of magnetization occurs at low temperatures [4].

2. Results and discussion

Fig. 1 show the H_C-T MPDs corresponding to the three directions of the field H due to the development of FIPTs between canted (or angular), and coaxial (or collinear) phases accompanying some orientation transitions. When H is applied along the hard <100> and the intermediate <110> directions, the corresponding critical lines AR1 and BR2 are observed with H_C equal to 46 and 41 kOe from T = 10 and 1.5 K, respectively. When T increases, they exhibit an exponential decay with a rapid change in the region of the Belov point T_B ~ 42 K [5] and show an asymptotic variation.

Despite the effects due to the existence of the spontaneous noncollinear magnetic structure of the Dy moments along <111> in the 1.45-130 K range and the appearance of the anisotropy of magnetization at Ta1= 125 K (resp. Ta2 = 75 K) between <111> and <100>(resp. <110>) [4], these two H_C lines, seem to reach those of the lower-part of the associated H_C-T MPDs previously constructed in the vicinity of T_{comp} = 218.5 K, and thus remain of second-order type [2]. A nearly constant curved OO' line characterized by the first-order nature with H_C ~ 15 kOe at 1.5 K, begins in the canted phases which originate from <uuw> directions of the angular phase at H = 0 and ends abruptly at an isolated critical point of the 'vapor-liquid' type at T_{SR} close to the boundary of the coaxial phase <111>. The small curved KC line for H//<100> in the phase of magnetic domains observed by Kang et *al.* [6] in their studies of the magnetodielectric effects in DyIG was reported for comparison. The points K and C of this line are defined, respectively by: H_C = 3.5 kOe, T = 4.5 K; H_C = 0 kOe, T = 16 K. The form of the H_C–T MPDs is discussed with a special attention to the effects of the manifestation of the low-T ferromagnetic paraprocess below T_{comp} and around T_B.

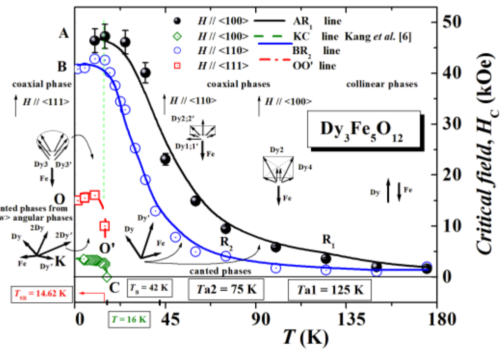

Figure 1: H_C-T phase diagrams of DyIG for H applied along the three principal directions at low temperatures. In these conditions, for the Dy^{3+} ions in the Wyckoff site {24c}, there is a reduction of the six magnetically inequivalent sublattices, Cj and C'j with (j = 1-3) in: two inequivalent sites with a multiplicity (3:3) if H//<111>, two inequivalent sites with a multiplicity (4:2) if H//<100>, three inequivalent sites with a multiplicity (4:1:1) if H//<110>.

References

[1] A. K. Zvezdin, "Field induced phase transitions in ferrimagnets". In Handbook of magnetic materials, K. H. J. Buschow (Ed.), Elsevier Science, Amsterdam, Vol. 9, Chapter 4, 1995, pp. 405-543.
[2] M. Lahoubi *et al.*, J. Alloys Compds **275-277** (1998), 598.
[3] M. Lahoubi *et al.*, J. Phys.: Conf. Ser. **150** (2009), 042108.
[4] M. Lahoubi *et al.*, J. Phys.: Conf. Ser. **200** (2010), 042108.
[5]. K. P. Belov, Phys. Usp. **39** (1996), 623.
[6] T. D. Kang *et al.*, Phys. Rev. B **86** (2012), 144112.