THE TRANSMITTANCE TEMPERATURE DEPENDENCE AND SPIN GLASS-LIKE BEHAVIOR IN THE NANOCOMPOSITE Fe – In_2O_3 THIN FILMS

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The ferromagnetic Fe-In_2O_3 nanocomposite thin film has been synthesized by the thermite Fe_2O_3 + In → Fe-In_2O_3 reaction. The transmittance (400 – 1100 nm) was measured at temperatures from 320 to 5 K. It was found that the transmittance increases when temperature decreases. For wavelength 600, 700, 800, 900 and 1000 nm maximum change of transmittance was ~ 3.2, 4.2, 4.8, 5.1 and 5.4 %, respectively. From transmittance spectra, spin glass-like behavior was observed near ~ 36 K and confirmed by magnetization measurements. The Verwey transition was identified at ~ 127 K by magnetization measurements. We have shown direct relationship between transmittance and magnetization of nanocomposite Fe – In_2O_3 thin film near ~ 36 K and give proposed possible mechanism this phenomena.

Introduction

The control of magnetic properties by light is an area of research that has attracted considerable attention in the recent years [1, 2]. One of the clearest examples is photoinduced magnetism [3, 4]. The photoinduced magnetism is understood as a change in the properties of the magnetic materials by light. For example, it has shown that the change of magnetic state in the $Mg_{1.5}FeTi_{0.5}O_4$ spinel ferrite films from a spin glass to ferrimagnet has been achieved over a wide temperature range below 160 K by means of light irradiation [5]. Photo-induced bias of the hysteresis loop in ferrites at room temperature has been reported [6]. It has reported that room-temperature-photoinduced magnetization was observed in spinel ferrite $Al_{0.2}Ru_{0.8}Fe_2O_4$ thin films [7]. An increase in the critical temperature from 16 to 19 K was observed as a result of red light illumination of cobalt-iron cyanide [8]. On the other hand, a reverse process of photoinduced magnetism is changes of the optical properties that depending on the magnetic state of material. In such a case, optical transmittance spectroscopy can be applied for study if transparent or semitransparent magnetic materials are used.

Recently, we have successfully synthesized ferromagnetic Fe-In_2O_3 nanocomposite thin films which have magnetic properties at room temperature [9]. Our ferromagnetic Fe-In_2O_3 nanocomposite thin films have semi-transparency in visible region because of a large amount of iron atoms was used in the solid phase reaction (1In:1Fe). Moreover, research of nanocomposite thin films based on indium oxide which contain magnetic phases become an urgent task. So, the use of optical transmittance spectroscopy to investigate properties of Fe-In_2O_3 nanocomposite thin films and other similar nanocomposite films in the context of magnetic properties is actual problem.

Here, the first time the transmittance temperature dependence of Fe-In_2O_3 nanocomposite thin film is demonstrated in the wavelength range 400 – 1100 nm at temperature from 320 to 5 K. It was shown that temperature transmittance change is in correlation with the change of the magnetization. The maximum increase of transmittance at decreasing temperature was ~ 5.4 %. The spin glass-like behavior in the nanocomposite Fe – In_2O_3 thin films was also first time observed at ~ 36 K by optical transmittance spectroscopy. This spin glass-like behavior is confirmed by the magnetization temperature measurements.

Experimental procedure

The nanocomposite Fe – In_2O_3 thin films were first time obtained by the exothermic reaction in the In/Fe_2O_3 bilayer. This synthesis method is detail described in our previous work [9]. To measure transmittance temperature dependence of Fe-In_2O_3 nanocomposite thin film, we have used Fourier spectrometer Bruker Vertex 80V with closed cycle cryostat Oxford Instruments. Magnetic measurements were carried out by MPMS-XL SQUID magnetometer (Quantum Design) in-plane magnetic fields.

Results and discussion

The transmittance of Fe-In_2O_3 film versus wavelength (400 – 1100 nm) at different temperatures is shown in Fig. 1. It is clearly seen that the transmittance increases with decreasing temperature. It should be noted the relative change in transmittance to be rather observed in the near infrared range. On the other hand, we have produced undoped In_2O_3 thin films on a glass substrate by autowave oxidation and measured transmittance spectra (400 – 1100 nm) at temperatures from 320 to 5 K. We have not noticed any changes of transmittance spectra.

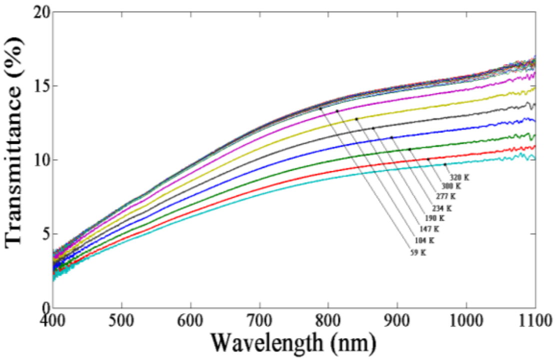

Fig. 1. The Fe-In_2O_3 thin transmittance spectra measured at temperatures from 320 to 5 K.

We have conducted magnetization temperature measurements of nanocomposite Fe – In_2O_3 thin film such as zero field cooling (ZFC) and field cooling (ZF) at 500 Oe in the sample plane. These measurements were necessary to analyze the observed optical phenomenon at 36 K with magnetic properties of Fe – In_2O_3 thin film. Fig. 2 shows the relative magnetization of nanocomposite Fe – In_2O_3 thin film depending on the temperature. The relative magnetization was defined as $M(T)/M(300)$. With decreasing temperature the magnetization measured at ZFC and FC increases up to 127 K. Below 127 K sharp decrease of magnetization was observed. It is worth noting that our nanocomposite Fe – In_2O_3 thin films contain also a part of Fe_3O_4 phase (~ 35 %).

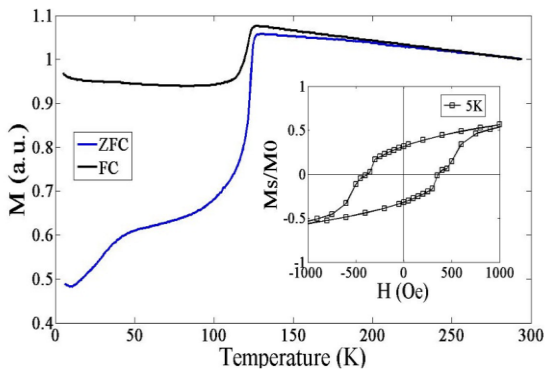

Fig. 2. The relative magnetization temperature dependence of nanocomposite Fe – In_2O_3 thin film measured at ZFC and FC. The inset is the hysteresis loop measured at 5 K, where M0 is a saturation magnetization.

The inset of Fig. 2 shows the hysteresis loop measured at 5 K. The hysteresis loop form clearly indicates the existence of two magnetic phases (α-Fe and Fe_3O_4) [9]. Thus, we assume that this sharp decrease of magnetization is associated with Verwey transition which is typical for Fe_3O_4. As shown in Fig. 2, the magnetization measured at ZFC has peculiarity near ~ 40 K. However, this peculiarity is not observed at FC measurement. Similar behavior of the magnetization is often associated with spin glass transition.

Conclusions

In conclusion, we have synthesized ferromagnetic Fe-In_2O_3 nanocomposite thin film and conducted temperature transmittance (400 – 1100 nm) and temperature magnetization measurements. It has been shown that at decreasing temperature, the transmittance increases. For wavelengths of 600, 700, 800, 900 and 1000 nm the maximum change of transmittance was ~ 3.2, 4.2, 4.8, 5.1 and 5.4 %, respectively. Spin glass-like behavior was observed near ~ 36 K by optical transmittance spectroscopy and confirmed by magnetization measurements.

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