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INFLUENCE OF FILLER VOLUME ON THE MAGNETIC CHARACTERISTICS OF COMPOSITES

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Abstract- In this study, we effectively synthesized $(CuInSe_2)_{1-x}$ $(FeSe)_x$ x=0.1 (SS) chalcopyrite-based solid solution and polymer-based composites with different solid solution mass ratios. X-ray diffraction was used to analyze the structure and magnetic characteristics of the samples, and the magnetic parameters of the samples were measured using a Lakeshore 7404 VSM magnetometer at room temperature. We investigated the major parameters Hc, Mr, Ms, and M for magnetic composites based on the percentage of filler volume.

Keywords: Solid Solution, Composite Materials, Magnetic Parameters.

1. INTRODUCTION

Magnetic materials are a broad category of materials that are employed in a variety of applications. Magnetic materials are used in the generation and distribution of electricity, as well as in the majority of the products that use it.

They are utilized to store information on audio and video tapes, as well as computer disks. They're hooked to or inserted into the body in body scanners and a number of other medical uses. In the home entertainment sector, magnetic materials are employed in PCs, CD players, televisions, game consoles, and loud speakers. Magnetic materials are becoming increasingly crucial in the growth of modern society, and it is difficult to conceive a world without them. Improved magnetic materials and designs are required for efficient electricity generation and usage.

It is known that magnetic materials are categorized according to their magnetic characteristics and applications. A soft magnetic material is one that is easily magnetized and demagnetized, whereas a hard (or permanent) magnetic substance is one that is difficult to demagnetize [1-5].

Materials that fall in between hard and soft are almost solely utilized as recording media, and there is no other designation for them. Subsets of soft or hard materials, such as magneto-strictive and giant magneto-resistive materials, are other classifications for magnetic materials. Magnetic materials are well-documented in the literature. The complexity of synthesis conditions, as well as the magnetic characteristics, distinguishes these magnetic materials. One of the current challenges, as is well known, is acquiring new magnetic materials (including single-domain magnetic nanoparticle systems) or ensuring broad usage of new magnetic materials with record magnetic parameters and excellent magnetic and electrical characteristics in technology [1-10].

Multicomponent semiconductor compounds, which have a wider range of electrophysical, magnetic, and optical properties than elementary and binary semiconductors, are currently receiving a lot of interest. Semiconductors with a chalcopyrite structure $CuInSe_2$ have a particular position among them [11]. When atoms of transition elements with empty d-shells are introduced into ternary semiconducting compounds of the I-III-VI^2 type, new materials with semiconducting and magnetic characteristics are created. It is possible to generate materials with a broad variety of physical properties such as band gap, energy location of emission bands, type of conductivity, and electrical conductivity in a controlled way by altering their chemical composition, synthesis conditions, and doping. Our previous papers provide detailed information on the electric and zone structure of $CuInSe_2$ based solid solutions [11-13].

The aim of this study is devoted to analysis of the magnetic properties of composite films based on polyethylen and solid solutions of the type $(CuInSe_2)_{1-x}(FeSe)_x$, x=0.1.

2. EXPERIMENTAL PART AND DISCUSSIONS

Special-purity materials (In of the In-000 brand, Se of os.ch. 17-3 grade, electrolytic Cu, Fe of carbonyl qualification according to TU-6-09-3000-78) were used to make the $CuInSe_2$ ternary compound and crystal FeSe (Technical Specifications). The samples were synthesized in quartz ampules evacuated to 0.1 Pa residual pressure in a vertical furnace. The temperature of the furnace was raised to 700°C at an initial rate of 80 K/h, and the ampules were maintained at this temperature for 2 hours before being raised to 1050-1100°C. The synthesis lasted for 8 hours, during which time the contents of the ampules were combined multiple times in the liquid form using mechanical vibration.

The composite components were nonpolar polymer polyethylene (PE) and SS based on chalcopyrite compounds. The composites were made by pressing a homogenous mixture of powdered components together in a hot press. The component composition ranged from 30, 40, and 50 percent SS, and 70, 60, and 50 percent PE, respectively.

From X-ray and band structure analysis of SS in our previous work (semiconductor journal), we can surely say that synthesized crystals are mono faze materials with a chalcopyrite structure.

The magnetization curves at room temperature were used to determine the dependency of magnetic parameters (the saturation of magnetization, residual magnetization, and coercive force) on the concentration of magnetic particles in the composite. Table 1 shows the values of the collected results.

Table 1. Changes in the magnetic properties of composites

Samples	Ms,emu/sm^3	Mr,emu/sm^3	Hc,Oe
(X=10mol%FeSe+90mol%$CuInSe_2$)			
30%X+70%PE	0.0042	0.079	10.2
40%X+60%PE	0.016	0.117	4.2
50%X+50%PE	0.0054	0.0619	17.2

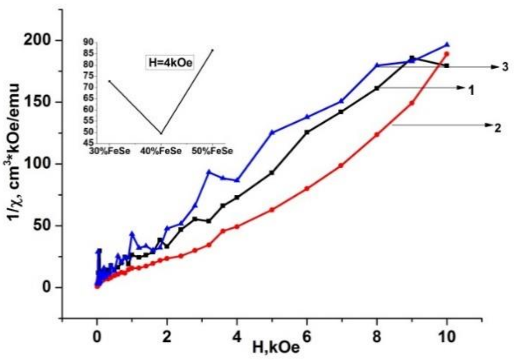

Figure 1. Dependence of the inverse value of the magnetic permeability of composites on the magnetic field, 1- 30%SS+70%PE, 2- 40%SS+60%PE, 3- 50%SS+50%PE

It should be noted that, according to the literature, the dependence of the saturation value of magnetization (M_s) and the percentage of residual magnetization (M_r) on the volume of the filler in the study samples is similar regardless of the type of filler in magnetic materials. As a result, the value of both parameters rises as the percentage of filler volume rises, while the value of the coercive (H_c) force falls (Figures 1, 2 and 3).

It is worth noting that one of the reasons for the increase in H_c as particle size decreases may be that the coercive force in magnetic domains tends to decrease as the probability of spins rotating in the opposite direction relative to the initial state increases. In multi-domain systems, such a transformation can also occur as a result of domain boundary displacement. The number of domains decreases as particle size decreases, and the role of the domain boundary in the magnetization process become less noticeable. As a result, as d decreases, the coercive force of the particles increases up to the d_{cr} critical size. However, as particle size decreases, it becomes single-dominated, and the likelihood of thermal fluctuations increases. This explains why Hc decreases when $d<d_{cr}$ [14-16].

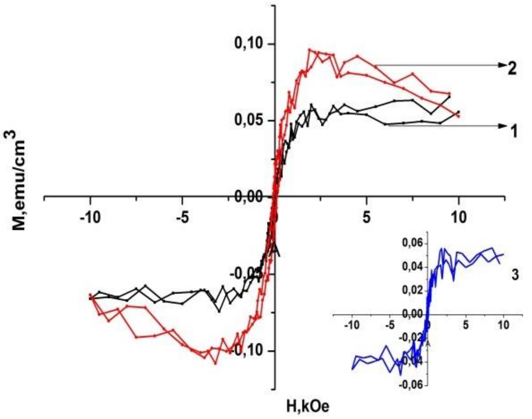

Figure 2. Dependence of the magnetization of composites on the magnetic field, 1- 30%SS+70%PE, 2- 40%SS+60%PE, 3- 50%SS+50%PE

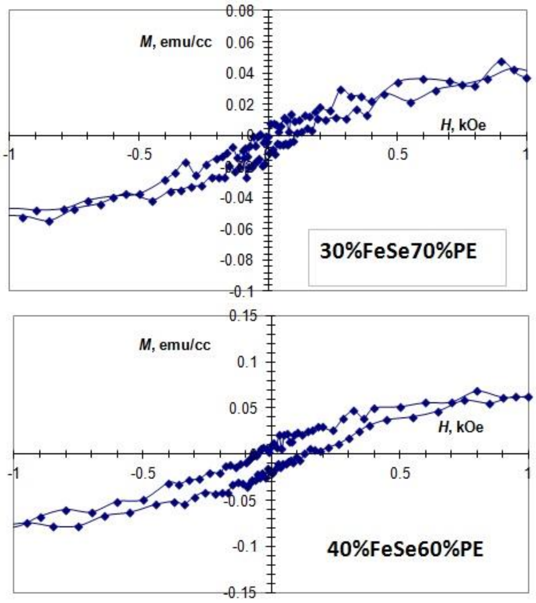

Figure 3. Dependence of the magnetization of composites on the magnetic field (from -1kOe till 1kOe)

Moreover, an increase in particle size will change the mechanism of magnetization reversal, and thus the coercivity value: coherent rotation (Stoner-Wohlfarth)-> magnetization reversal via nonhomogenous state (curling, fanning, etc.) -> magnetization reversal via domain wall motion (typical for bulk ferromagnets) [14-16].

In Table 1, we see that there is a deviation in the values of the magnetic parameters observed in the sample of the 50% FeSe composite. The explanation of this observed fact is not fully known. It is possible that a percolation effect occurred.

Despite the fact that the chalcopyrite crystal $CuInSe_2$ is diamagnetic, an antiferromagnetic material was synthesized by including the transition element Fe in the chalcopyrite system. Magnetic properties were thus observed in solid solutions and thin-film samples based on polymers containing transition elements without disrupting the chalcopyrite structure.

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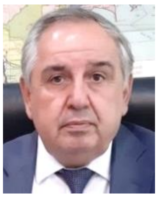
BIOGRAPHIES

Ulkar Farruk Samadova was born in Azerbaijan on 03.12.1984. She graduaed in Molecule and atom Physics from Baku State University, Baku, Azerbaijan in 2005, was postgraduate student in 2008-2014 and received Ph.D. degree in 2014. She worked as Leading Scientific Researches in Institute of Physics, Azerbaijan National Academy of Sciences, Baku, Azerbaijan since 2007, At the present is a senior scientist. Her researches areas are investigation of the composite materials based on dielectric, semiconductor and conductive matrix with the micro magnetic nanoparticles exhibits a number of unusual properties of the galvanomagnetic.



Arif Mamed Hashimov was born in Shahbuz, Nakhchivan, Azerbaijan on September 28, 1949. He is a Professor of Power Engineering (1993); Chief Editor of Scientific Journal of "Power Engineering Problems" from 2000; Director of Institute of Physics of Azerbaijan National Academy of Sciences (Baku, Azerbaijan) from 2002 up to 2009; and Academician and the First Vice-President of Azerbaijan National Academy of Sciences from 2007 up to 2013; and Director of Azerbaijan Research Institute of Energetics and Energy Design from 2014 up to 2020. From 2021 up to now he is Director of Institute of Physics of Azerbaijan National Academy of Sciences (Baku, Azerbaijan). He is laureate of Azerbaijan State Prize (1978); Honored Scientist of Azerbaijan (2005); Cochairman of International Conferences on "Technical and Physical Problems of Power Engineering" (ICTPE) and Editor in Chief of International Journal on "Technical and Physical Problems of Engineering" (IJTPE). He is also a High Consultant in "Azerenerji" JSC, Baku, Azerbaijan. His research areas are theory of non-linear electrical Networks with distributed parameters, neutral earthing and ferroresonant processes, alternative energy sources, high voltage physics and techniques, electrical physics. His publications are 350 articles and patents and 5 monographs.

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