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Amplification of Magnetooptical Response in the «Nanocomposite-Bismuth Telluride» Multilayer System

G.S. Zykov[1,*], E.A. Gan'shina[1], A.I. Novikov[1], Yu.E. Kalinin[2], A.V. Sitnikov[2]

[1] *Lomonosov Moscow State University, GSP-1, Leninskie Gory, 119991 Moscow, Russian Federation*
[2] *Voronezh State Technical University, Moscow Ave., 394026 Voronezh, Russian Federation*

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The presented work is devoted to the study of magneto-optical properties of «nanocomposite-semiconductor» ($(Co_{40}Fe_{40}B_{20})_{33.9}(SiO_2)_{66.1}/Te_3Bi_2$)) multilayer structures. It has been found, that the adding of Te_3Bi_2 spacer regardless of composite's compound increases a magneto-optical response and the amplification of it is the biggest among the other spacers such as Si, SiC and Cu. There has also been established a good correlation between thickness dependencies of magnetooptical (MO) and magnetotransport properties. This correlation is related to the peculiarities of interface forming at the «FM-granule - semiconductor» edge and to percolation process in multilayer structures.

Keywords: Magnetooptical spectroscopy, Transversal Kerr effect, TKE, Multilayer, Bismuth telluride.

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1. INTRODUCTION

One of the most important demands for spintronics materials is an integration of magnetic and semiconducting properties. That's why multilayer systems based on ferromagnetic (FM) metals and semiconductors are being investigated. In previous works [1-3] it had been shown that the adding of a semiconducting layer leads to a anomalous behavior of electric, magnetic and magneto-optical properties of the «nanocomposite – semiconductor» ($CoFeZr-Al_2O_3/Si$) multilayer systems in the range of small thicknesses of silicon. That kind of behavior is connected with the interface forming peculiarity at the «FM-granule-semiconductor». It was interesting to investigate, how the properties would change, when the composite and semiconductor compounds are different.

2. SAMPLES

Multilayered nanostructures $[(Co_{40}Fe_{40}B_{20})_{33.9}(SiO_2)_{66.1}/[Te_3Bi_2]$ were prepared by ion-beam sputtering. Nominal thicknesses of the studied samples ranged from 2.70 to 5.52 nm for composite layers and from 0.12 to 1.03 nm for semiconductor spacer, number of bilayers was 101.

Concentrations of metal in the composite layers were below the percolation threshold in the bulk samples with the same metal concentration. The characteristic granule size in bulk composites at given concentrations was 2-3 nm.

3. MEASURING PROCESS

Magneto-optical properties of samples have been measured in the TKE geometry. TKE measurements have been performed in the energy range 0.5 ÷ 4.0 eV at the light incidence angle of 68° and in magnetic fields up to 3.0 kOe. The sensitivity of the experimental set-up was 10^{-5}.

4. RESULTS

TKE spectra of $[Co_{40}Fe_{40}B_{20})_{33.9}(SiO_2)_{66.1]}/[Te_3Bi_2]$ multilayer samples are presented on Fig. 1.

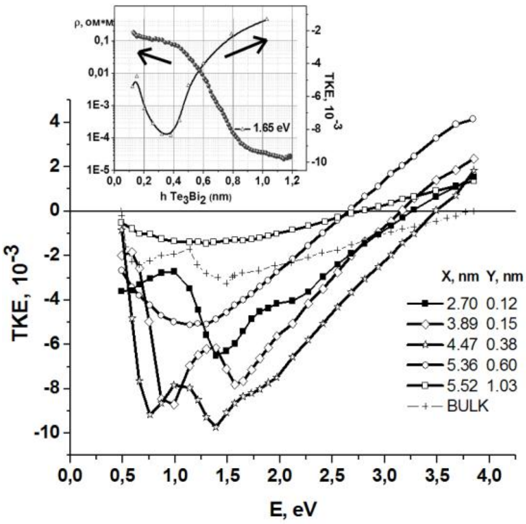

Fig. 1 – Spectral dependencies of TKE for $[(Co_{40}Fe_{40}B_{20})_{33.9}(SiO_2)_{66.1})](X\ nm)/[Te_3Bi_2](Y\ nm)$ multilayer samples. On the inset there are TKE and specific resistance ρ dependencies from thickness h of semiconducting spacer Te_3Bi_2

TKE spectra with different thickness of the layers differ from each other in magnitude, but in general their shape corresponds to the form of the composite spectra $(Co_{40}Fe_{40}B_{20})_Z(SiO_2)_{1-Z}$ with different concentrations Z. Adding a Te_3Bi_2 spacers led to an essential increase of TKE. The effect increased by 3 times compared to the bulk nanocomposite with the same concentration of FM phase. On the field

* V0tum-Separatum@yandex.ru

dependencies TKE (see Fig. 2) one can see, that the adding a thin layer of spacer makes the system more soft magnetic.

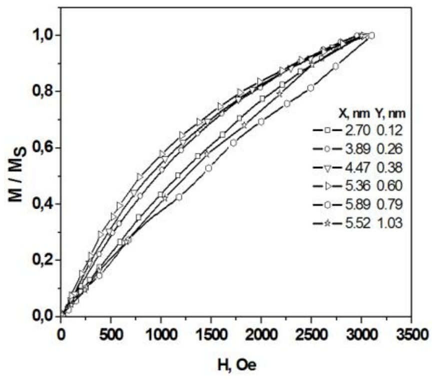

Fig. 2 – Field dependencies of TKE for $[(Co_{40}Fe_{40}B_{20})_{33.9}(SiO_2)_{66.1}]$(X nm)/$[Te_3Bi_2]$(Y nm) multilayer samples with various thicknesses

It is known [4] that MO response for layer-by-layer deposited nanocomposites depends on the thickness of the layer. So we also carried out the research of the MO properties changes for nanocomposite deposited layer-by-layer without a spacer to determine, whether the thickness of a composite layer contributes the TKE. These TKE spectra are presented on Fig. 3.

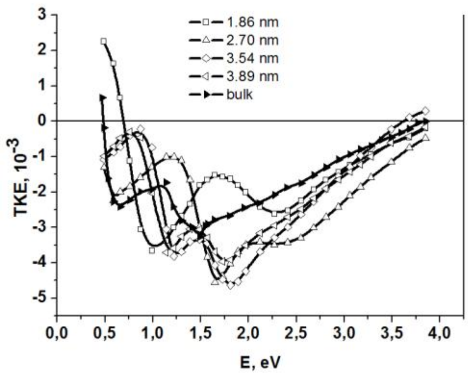

Fig. 3 – Spectral dependencies of TKE for composite deposited layer-by-layer with various thicknesses of the layers.

As the thickness of each layer increases, the maximum TKE magnitude variation is insignificant, but the shape changes of spectra are appreciable – they shift towards the ultra-violet spectral range, which indicates the micro-structural changes of each layer. A comparison to multilayer system (see Fig. 4) with the same thickness of the composite indicates that the major contribution is made by Te_3Bi_2 spacer in particular.

Note that the addition of bismuth telluride spacer leads to maximum growth of the MO response for «nanocomposite-semiconductor» multilayer structures compared with the other semiconductor spacers (Si, SiC, Cu).

Dependence of TKE magnitude from semiconducting spacer thickness is nonlinear: at a range of small thicknesses TKE magnitude increases and then gradually decreases (see the inset of Fig. 1). This curve has a good correlation with the specific resistance dependency from spacer layer thickness – TKE magnitude maximum agrees with the beginning of the percolation in multilayer structures.

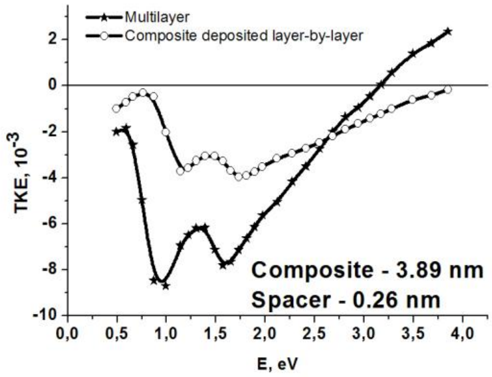

Fig. 4 – Spectral dependencies of TKE for a multilayer and a composite deposited layer-by-layer with the same thicknesses of the composite.

5. CONCLUSION

Magneto-optical properties have been studied in the wide range of thicknesses of the magnetic and semi-conductor layers for $\{[(Co_{40}Fe_{40}B_{20})_{33.9}(SiO_2)_{66.1}]/[Te_3Bi_2]\}_{101}$ and $[(Co_{40}Fe_{40}B_{20})_{33.9}(SiO_2)_{66.1}]$ multilayer structures. It has been established, that the shape of TKE spectra as well as the magnitude of the effect depend on composite and spacer thicknesses.

The amplification of MO response has been revealed in the range of a small spacer thicknesses for $\{[(Co_{40}Fe_{40}B_{20})_{33.9}(SiO_2)_{66.1}]/[Te_3Bi_2]\}_{101}$ multilayer system. This amplification is the biggest among the other spacers (Cu, SiC, Si).

The good correlation between thickness dependencies of magnetooptical and magnetotransport properties has been found. This correlation is related to peculiarities of interface forming at the «FM-granule - semiconductor» interface and to percolation process in multilayer structures.

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