COMPUTER SIMULATION OF ELECTRICAL PROPERTIES OF NANOGRANULAR COMPOSITE $(CoFeZr)_x(CaF_2)_{(100-x)}$ PRODUCED BY ION-BEAM SPUTTERING IN Ar AND O_2^+ ATMOSPHERE

VITALII BONDARIEV

Department of Electrical Devices and High Voltage Technology, Faculty of Electrical Engineering and Computer Sciences
Lublin University of Technology, Lublin, Poland
E-mail: v.bondariev@pollub.pl

Abstract - This paper presents an analysis of the results of measurements of electrical properties of nanogranular composite $(CoFeZr)_x(CaF_2)_{(100-x)}$ with metallic phase content x = 72.5 at.%. produced by ion-beam sputtering in mixed atmosphere Ar and O_2^+. Frequency dependencies of conductivity $\sigma(f)$ and frequency coefficient $\alpha(f)$ were subjected to analysis. Based on the model of hopping conductivity a computer simulation of electrical properties of nanocomposite $(CoFeZr)_x(CaF_2)_{(100-x)}$ and verification of the above model were performer.

Keywords - Nanocomposites, Annealing, Simulation, Conductivity, Frequency Coefficient.

I. INTRODUCTION

Nanocomposites, in contrast to analogous massive composites, exhibit fundamentally different new properties and are interesting from the point of fundamental research as well as their application in different fields. Nanogranular composites exhibit number of unique mechanical [1], electrical [2], magnetic[3], optical [4] properties and different combination of these properties. Many factors, such as chemical composition, type of metallic phase particles, size, shape, surface condition and no less significant surrounding matrix and interaction with it have an influence on the character of metal-dielectric nanocomposites. Thus, changing the composition, structure and morphology can influence the properties of nanocomposites. So far, quite a lot of research has been devoted to nanocomposites in which as the metallic phase were used ferromagnetic alloys (FeCoZr, FeCoB, CoNbTa) [5, 6], dielectric metal oxides (Al_2O_3, SiO_2, $Pb(Zr,Ti)O_3$) [5, 7] or anaerobic dielectric (MgF_2) [8] and other [9, [10]]were generally present as dielectric. High values of tunnel magnetoresistive effect ($(FeCoZr)_{(x)}(Al_2O_3)_{(100-x)}$ [[10]]), large field of anisotropy and magnetic coercivity (Co-Al-O [14]) are characteristic for these nanocomposites. A model of hopping conductivity for direct and alternating current was presented in the previous works [13, 14]. This model assumes that in the material there are wells of potential that are close enough to each other. Wells are the metallic phase nanoparticles in which electrons are located. In the outer electrical field electrons jump through these particles. When electron jumps from one well to another he stays in it for a time τ. After this time, the next hop is taken in the direction that is defined by the outer field to the next well with probability p or to the previous with probability (1–p).

The aim of this paper is computer simulation of electrical properties of nanocomposite $(FeCoZr)_{(x)}(CaF_2)_{(100-x)}$, namely conductivity σ, frequency coefficient α and the verification of the proposed model of hopping conductivity.

II. DETAILS EXPERIMENTAL

The granular composites consisting of ferromagnetic alloy particles FeCoZr which are randomly distributed in dielectic matrix CaF_2 were selected in this work. Material was obtained by twosources ion-beam sputtering in mixed atmosphere argon Ar and high content of O_2. Sample with metallic phase content x = 72.5 at.% was selected for the study of electrical properties on the alternating current. Measurement of sample properties was performed in the frequency range from 50 Hz to 1 MHz, and in the measurement temperature range from 77 K to 373 K. After each measurement, the sample was subjected to 15-minute annealing in a tubular furnace, starting from 398 K to 773 K with a 25 K step.

III. RESULTS AND DISCUSSION

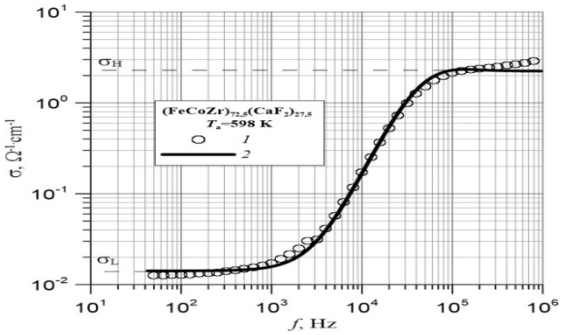


Fig.1. Results of computer simulation of conductivity σ of nanocomposite (FeCoZr)72,5(CaF2)27,5: 1 – experimental data, 2 – computer simulation

Based on the obtained results and on the basis of the model of hopping conductivity on the direct and alternating current, computer simulation of conductivity σand frequency coefficient αwas

performed and verification of the above model. Waveforms for annealing temperature T_a = 598 K and measurement temperature T_p = 248 K were selected for simulation. A computer program was developed to calculate the theoretical waveforms σ(*f*) and α(*f*).

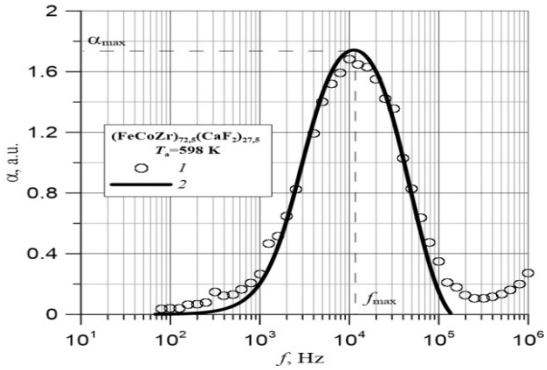


Fig.2. Results of computer simulation of frequency coefficient α of nanocomposite $(FeCoZr)_{72,5}(CaF_2)_{27,5}$: 1 – experimental data, 2 – computer simulation

From the above figures it can be seen that the data obtained by the simulation with high accuracy coincide with the experimental data, as evidenced by the high value of correlation coefficient between the corresponding waveforms χ = 0.98.

CONCLUSIONS

The electrical properties of the nanocomposite sample $(CoFeZr)_x(CaF_2)_{(100-x)}$ were investigated and their computer simulations were performed.The results of the simulation with high accuracy coincide with the experimental data, which proves that the proposed model of hopping conductivity has been positively verified.

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