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Ferroelectromagnetic solid solutions on the base piezoelectric ceramic materials for components of micromechatronics

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ABSTRACT

In the presented work, a ferroelectromagnetic solid solutions based on PZT and ferrite powders have been obtained. The main aim of combination of ferroelectric and magnetic powders was to obtain material showing both electric and magnetic properties. Ferroelectric ceramic powder (in amount of 90%) was based on the doped PZT type solid solution while magnetic component was nickel–zinc ferrite $Ni_{1-x}Zn_xFe_2O_4$ (in amount of 10%). The synthesis of components of ferroelectromagnetic solid solutions was performed using the solid phase sintering. Final densification of synthesized powder has been done using free sintering. The aim of the work was to obtain and examine in the first multicomponent PZT type ceramics admixed with chromium with the following chemical composition $Pb_{0.94}Sr_{0.06}(Zr_{0.46}Ti_{0.54})O_3+0.25$ at% Cr_2O_3 and next ferroelectromagnetic solid solution based on a PZT type ferroelectric powder ($Pb_{0.94}Sr_{0.06}(Zr_{0.46}Ti_{0.54})O_3+0.25$ at% Cr_2O_3) and nickel–zinc ferrite ($Ni_{0.64}Zn_{0.36}Fe_2O_4$), from the point of view of their mechanical and electric properties, such as: electric permittivity, ε; dielectric loss, $\tan\delta$; mechanical losses, Q^{-1}; and Young modulus, E.

1. Introduction

A possibility to use a ferroelectromagnetic solid solutions on the base piezoelectric ceramic materials in the electronic industry, in micromechatronics, electroacoustics or to build elements of medical equipment is conditioned mainly by stability of its mechanical and electric parameters [1,2].

The PZT ceramics belongs to a family of multicomponent solid solutions type $(1-x)PbZrO_3$–$(x)PbTiO_3$ that present broad isomorphism which allows for doping the base composition in positions A and B of the component with various foreign ions [3]. At room temperature the solid solution between lead titanate $PbTiO_3$ and lead zirconate $PbZrO_3$ presents two ferroelectric phases, a tetragonal phase on the titanium rich side of the pseudobinary system and a rhombohedral one on the zirconium rich side [4–6]. Proper selection of the composition, doping and technological conditions for obtaining this type of materials allows for producing ceramics with numerous applications in various types of piezoelectric transducers, electric band filters, as sensors, generators, servomotors, phase modulators, frequency multipliers, electromechanical, electroacoustic, pyroelectric transducers, memory elements, etc. [7].

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The nickel–zinc ferrite ($Ni_{0.64}Zn_{0.36}Fe_2O_4$) belonging to so-called soft ferrites with high magnetic permeability and high resistance (working frequency within the range from 50 to 1000 MHz) [8], is used during signal processing (telecom filters, proximity sensors, delay lines), in EMI filters and wide-band transformers, among others.

The aim of the work was to obtain and examine in the first multicomponent PZT type ceramics admixed with chromium with the following chemical composition $Pb_{0.94}Sr_{0.06}(Zr_{0.46}Ti_{0.54})O_3$+0.25 at% Cr_2O_3 and next ferroelectromagnetic solid solution based on a PZT type ferroelectric powder ($Pb_{0.94}Sr_{0.06}(Zr_{0.46}Ti_{0.54})O_3$+0.25 at% Cr_2O_3) and nickel–zinc ferrite ($Ni_{0.64}Zn_{0.36}Fe_2O_4$), from the point of view of their mechanical and electric properties, such as: dielectric permittivity, ε; dielectric losses, $tan\delta$; mechanical losses, Q^{-1} and Young modulus, E.

2. EXperiment

2.1. Technology

A tested material was, in the first multicomponent PZT type ceramics with the composition of $Pb_{0.94}Sr_{0.06}(Zr_{0.46}Ti_{0.54})O_3$+0.25 at% Cr_2O_3 (in the work designated as PSZTC), which is included into a group of ferroelectrically hard materials. The test material was obtained as a result of synthesis of simple oxides: PbO, ZrO_2, TiO_2, Cr_2O_3 and carbonate $SrCO_3$ according to the reaction: $0.94\ PbO + 0.06\ SrCO_3 + 0.4\ ZrO_2 + 0.5\ TiO_2 \rightarrow Pb_{0.94}Sr_{0.06}(Zr_{0.46}Ti_{0.54})O_3 + CO_2\uparrow$. The admixture of chromium was introduced to the base composition in an amount of 0.25 at% in the form of chromium oxide (Cr_2O_3). The powder mixture components were milled using planetary mill FRITSCH Pulwerisette 6, in ethyl alcohol, by 12 h. The ceramic PSZTC type powder was synthesized using sintering of a mixture of simple oxides in solid phase under the following conditions: T_{synth}=850 °C, t_{synth}=2 h. After making of samples of the forms required on the hydraulic press, they were subjected to drying in the air atmosphere for 24 h. The compacts prepared in such a way were placed in the ceramic crucible and they were sintered in the pad of PbO and ZrO_2 mixture. Compaction of the synthesized powder (sintering) was carried out using free sintering of samples under the following conditions: T_s=1250 °C, t_s=2 h. After completion of the technological process the ceramic PSZTC samples were subjected to a mechanical treatment (grinding and polishing), in order to prepare their surfaces properly for putting electrodes by a silver paste burning method.

The second tested material was ferroelectromagnetic solid solution based on a PSZTC type ferroelectric powder ($Pb_{0.94}Sr_{0.06}(Zr_{0.46}Ti_{0.54})O_3$+0.25 at% Cr_2O_3) and nickel–zinc ferrite ($Ni_{0.64}Zn_{0.36}Fe_2O_4$). The second element of the ferroelectromagnetic solid solution with ferromagnetic properties (ferrite powder $Ni_{0.64}Zn_{0.36}Fe_2O_4$) was synthesized using calcination under conditions of 1100 °C/4 h. The synthesized ceramic powder constituted 90%, while the ferrite powder—10%, of the PSZTC–NiZn solid solution composite. After proportionally weighing and mixing components, synthesizing was carried out using sintering of the mixture in a sold phase (compaction by a free sintering method) under the following conditions: T_{synth}=1050 °C and t_{synth}=4 h. Compaction of the synthesized powder (sintering) was carried out using free sintering method under the following conditions: T_s=1250 °C/t_s=2 h. Silver electrodes were applied to surfaces of samples for the purpose of carrying out electric tests.

The synthesis temperature of the PSZTC and PSZTC–NiZn solid solutions was selected on the basis of differential thermal analysis DTA, as well as DTG and TG using a Q-1500D derivatograph (with a Paulik–Paulik–Erdey system) in the temperature range from 20 °C to 1300 °C.

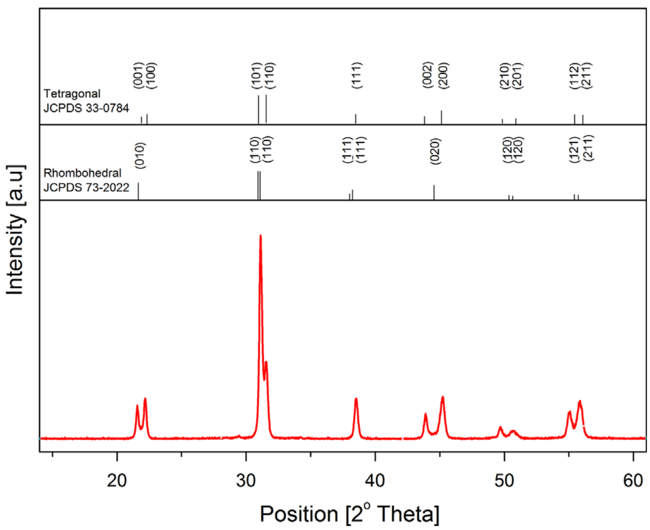

Fig. 1. X-ray spectra of the PSZTC powder.