**The new multiferroic composite materials consisted of ferromagnetic, ferroelectric and polymer components.**

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The multiferroic materials are of great interest now. Magnetoelectric effect in multiferroic composites consisted of ferroelectric and ferromagnetic components is the result of mechanical connection between components and magnetostriction and piezoelectric effects. The multilayer multiferroic composites are studied mostly. At the same time magnetorheological (magnetoactive) elastomers are so-called "smart" materials. The different parameters of composites based on elastomer polymers are tunable by magnetic field. Young's modulus, deformation and other mechanical parameters can be changed by magnetic field up to 1000%. The dielectric permittivity also can be changed in magnetic elastomers by magnetic field – magnetodielectric effect (MDE) [1]. It is assumed that the increasing of permittivity of the elastomer in the external magnetic field is due to the rotation of the magnetic moment of the filling particles and their displacement in the elastic matrix. Thus, the displacement of magnetic particles leads to internal stresses in the elastic matrix. The combination of ferromagnetic and ferroelectric filling particles can lead to new material, which properties can be changed by external both electric and magnetic fields. The two types of the powders were used as the fillers of the composites separately and in the mixtures: NdFeB powder and PZT-26 powder. All powders were obtained by milling corresponding bulk polycrystalline materials with the ball milling EMAX Retsch at the different modes. The sizes of filling particles varied from 5 mkm to 50 mkm. Three types of two-component compounds were used: SIEL ($10^4$ Pa), Dow Corning (Dc) ($10^5$ Pa) and Wacker Silicone (Ws) ($10^5$ Pa). Polymerization process of SIEL polymer was at the temperature 150 C for 1 hour. The volume ratios between ferromagnetic and ferroelectric powders were 1:1, 1:3, 1:6, 2:1, 1:0, correspondingly. The values of total particle volume concentrations ranged from 20% to 40%. Magnetic measurements were carried out with vibration sample magnetometer (VSM) LakeShore 7407 at the room temperature in the field range ±16 kOe. The hysteresis loops of initial ferromagnetic NdFeB powder and composite elastomers with the NdFeB or mixture NdFeB+PZT particles in the different polymer matrix were compared in such magnetic parameters as coercivity, specific saturation magnetization and remanence. It was found that the saturation magnetization changed proportionally to the mass concentration of ferromagnetic particles in the composite material. The specific saturation magnetization of the pure NdFeB powder was 105.1 emu/g, while the sample with the 14wt% NdFeB particles had the one 22.4 emu/g. The dependence of saturation magnetization on the mass concentration of NdFeB particle had the lineal character. The coercive field was found to depend on the matrix stiffness. It was found that the elasticity modulus decreased by adding ferroelectric particles. The mechanism of the coercivity dependence on the polymer stiffness is the rotatable of the ferromagnetic particles (not only the magnetic moment) in elastic matrix in the direction of the external magnetic field [2]. The measurements of magnetodielectric effect (MDE) were carried out with immittance meter Aktakom 3016 in the external magnetic field in the range ±5 kO at room temperature. MDE was measured for composites with pure (NdFeB) and mixed (NdFeB+PZT) fillers. The MDE dependence on magnetic field had the monotonic character for composite with ferromagnetic particles and was 21,6% in the maximum field 5 kOe. The dependence of MDE on magnetic field for composite with mixed ferromagnetic and ferroelectric particles had the non-monotonic character with the maximum 4% at the field 1 kOe, then the decreasing of MDE with increasing field was small. The measurements of magnetoelectric effect (MEE) were carried out with VSM together with the high voltage supply. The sample was placed between the plates, then it was fixed at the holder and placed between poles of electromagnet, the directions of the electric field was parallel to the magnetic field. The voltage value was chosen to achieve the electric field intensity of at least 1 kV/mm. To measure the magnetoelectric effect, the hysteresis loops were measured when the high voltage source was turned off and on. The differences between the loops indicated to the magnetoelectric effect. The mixed polymer matrix (SIEL+Ws) had the optimal stiffness properties and the value of MEE. The SIEL polymer with PZT particle had almost liquid structure and the MEE had the maximum value. The "Ws" polymer was stiffer than polymer mixture and the MEE had the minimum value. The MEE increased when the total volume concentration of particles in the same polymers increased. The dependence of MEE on the NdFeB mass concentration had monotonic increasing character. The dependence of MEE on the PZT mass concentration had nonmonotonic character with the minimum. The values of MEE in the mixed polymer samples are presented at the Table. Sample: total concentration, NdFeB:PZT MEE, emu*cm/(g*V) H(MEEmax), kOe 20 vol%, 1:1 1,175 5,5 30 vol%, 1:1 1,573 3,3 20 vol%, 1:3 1,082 6,9 The work was financially supported by the the Russian Foundation for Basic Research (Grant No. 16-32-50102).

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# MOTORS, GENERATORS AND ACTUATORS IX

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