Effect of Samarium Doping on the Structural, Magnetic and Microwave Properties of Spinel Ferrites and Magnetic Polymer Composites

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Abstract. Ferrites are important magnetic materials used in various technological and energetical devices and applications, such as, e.g., transformers, inductors, magnetic heads, microwave absorbing and shielding components, etc. The systematic studies of the rare earth influences on the ferrite structures are still an interesting research field for many research teams. In this work, the structural, magnetic and microwave properties of NiZn ferrites doped with Sm^{3+} as well as magnetic polymer composites with NiZnSm ferrite filler are examined. 60 vol% filling of magnetic active ferrite powders incorporated into the PVC polymer matrix was used. The ferrites with composition $Ni_{0.42}Zn_{0.58}Sm_xFe_{2-x}O_4$ (x = 0.00, 0.02, 0.04, 0.06, 0.08 and 0.10) were prepared by standard ceramic method involving double sintering process at the temperatures 950 °C and 1200 °C. This temperature was essential for the synthesis of ferrite samples with good compactness, high density, and low porosity ranging from 5 to 7 %.

The microstructure of prepared ferrite samples was investigated by means of X-ray diffraction (XRD) and scanning electron microscope (SEM). XRD measurements of all the samples confirmed the presence of cubic, mixed spinel structure, typical for NiZn ferrites, accompanied with the appearance of the secondary phase (orthoferrite, $SmFeO_3$) in Sm substituted ferrites. The amount of secondary phase grows with increasing contents of samarium ions in the structure, since their ionic radius (r_{Sm}3+ = 95.8 pm) is larger than that of iron ion (r_{Fe}3+ = 64.5 pm), thus causing the deformation of crystalline lattice. The Curie temperature T_C was obtained from the temperature dependencies of magnetic susceptibility. Other magnetic parameters, such as the coercive field H_c, remanent flux density B_r, hysteresis loop area A_{loop}, amplitude μ_a, and initial permeability μ_i, etc., were evaluated from the magnetization characteristics, such as the series of minor hysteresis loops and the dependencies of the amplitude permeability upon the maximum value of applied field strength. Magnetic and microwave absorption properties of synthesized ferrites and composite samples were determined from the measurements of the complex permeability $\mu = \mu' - j\mu''$ in the frequency range from 10 MHz to 6.5 GHz. The peak value of the real part, μ', decreases with growing amount of Sm in both compact ferrites and composite samples. In the case of ferrites, hints of resonant behavior can be seen, manifesting as a global maximum on the non-monotonic $\mu'(f)$ dependence, meanwhile pure relaxation dispersion mechanism is observed in the composites, i.e., μ' monotonically decreases with f. The imaginary part, μ'', is first nearly constant, or increases slowly, then abruptly reaches a sharp maximum which corresponds to the critical frequency limit called resonance/relaxation frequency f_{res}, further increase of the frequency is associated with more moderate drop of μ'' values.

The analyses of magnetic properties at room temperature point out that the substitution of Sm strongly influences the resulting magnetic behavior of studied material in both compact as well as polymer composite form. Moreover, adding defined amount of Sm, the magnetic parameters can be easily controlled by a straightforward way and thus tailored for any application in common practice.