

IR ANALYSIS OF COPPER DOPED Ni-Zn NANOFERRITES

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Nanocrystalline ferrites Ni_{0.4}Zn_{0.6-x}Cu_xFe₂O₄ (x=0-0.6) were synthesized by a high-temperature method based on metal oxides. The IR measurements showed the presence of noticeable bands caused by vibrations of metal ions and which are a feature of the formation of the spinel ferrite phase. A shift in the IR bands due to doping concentration was observed.

Keywords : nanoferrit, IR analysis, sublattice

INTRODUCTION

Ferrites are materials of great practical, technological and theoretical importance. High magnetic permeability, mechanical strength, electrical resistivity, high thermodynamic and chemical stability, heat resistance and corrosion resistance make these materials important [1]. The demand for this type of magnetic materials is increasing with the development of technology. Ferrite materials are used in almost every element of electrical devices manufactured today [4, 5, 6]. The properties of ferrites depend on several factors: composition, manufacturing method, temperature, doping with various cations, grain size and location, etc. Ferrites, which make up the main group of ferromagnets, have the general formula MeFe₂O₄, where Me is a divalent metal ion, such as Me - Mn²⁺, Fe²⁺, Co²⁺, Ni²⁺, Cu²⁺, Zn²⁺, Mg²⁺ and Cd²⁺. The spinel lattice is a face-centered cubic lattice with oxygen anions (O²⁻) at the nodes. Two types of sublattices are formed between the position: The Me²⁺ ion is located in the tetrahedral A-sublattice, and the Fe³⁺ cation is located in the octahedral B-sublattice. The spinel lattice consists of 32 oxygen ions and 24 metal ions. According to their structure, spinels are divided into 3 groups: normal, reverse and mixed. In transformed spinels, the Me²⁺ ion is in sublattice B, and the Fe³⁺ ion is in sublattices A and B. In mixed spinels, Me²⁺ and Fe³⁺ ions are in both sublattices [4, 8, 9]. Scientific papers have published about Ni-Zn ferrites, mainly electrical, magnetic, optical, etc., which are of interest from the point of view of the practical application of these ferrites. More attention was paid to studying its characteristics. However, the dependence of these characteristics on their composition and structure has not been sufficiently studied. It is from this point of view that the study of ferrite materials in this area is relevant. In the presented work, the replacement of the Zn ion by the Cu ion in Ni-Zn ferrite was investigated. These elements differ in their atomic mass, ionic radius [7, 10].

PREPARATION OF SAMPLES

The properties of ferrite materials, which have a wide range of applications, differ significantly from each other depending on their chemical composition, raw materials used, processing and synthesis methods. Information about the technology of ferrite synthesis

was published in [1]. It is known that for each ferrite, taking into account the required properties, a suitable technological method must be developed. There are many methods for synthesizing ferrite materials: oxide mixing, thermal decomposition, co-precipitation method, etc. The most common synthesis method for obtaining pure ferrite material of good quality is the high-temperature "ceramic" method. Ferrites with a cubic structure are formed as a result of a diffusion reaction in mixtures of metal oxides in the solid phase at high temperatures. The chemical activity of the components, particle sizes and homogeneity largely influence the completeness of the diffusion reaction between mixtures of metal oxides in the solid phase and, as a consequence, the properties of the resulting ferrites. The disadvantage of this method is that the process occurs at high temperatures (above 1200°C), which causes an increase in the size of ferrite particles and a weakening of the magnetic properties. Various methods are used to reduce the synthesis temperature of Ni-Zn ferrites. [1, 2, 3] showed that the addition of Cu ions to Ni-Zn ferrites makes it possible to obtain composites at lower temperatures, but Cu ions reduce the resistivity of the samples, which is unfavorable for their use at high frequencies. Taking into account the above, nanopowders of the general formula Ni_{0.4}Zn_{0.6-x}Cu_xFe₂O₄ were obtained by high-temperature synthesis. For this purpose, stoichiometric amounts of the corresponding metal oxides ZnO, NiO, CuO, Fe₂O₃ (purity 99% in all cases) were used as raw materials. The process was carried out in several stages. Initially, the corresponding metal oxides were calcined at 900°C for 3 hours and then tempered at 950°C for six hours. The quality of the synthesized ferrite powders was assessed using an XRDD8 ADVANCE X-ray diffractometer (Bruker, Germany) [2, 5, 6]. The infrared spectra of Ni_{0.4}Zn_{0.6-x}Cu_xFe₂O₄ ferrite powders were studied in a vacuum chamber in the spectral range of 4000-400 cm⁻¹ with a standard spectral resolution of 0.5 cm on a Vertex70 infrared Fourier spectrometer (Bruker, Germany) with an Easi DiffTMM attachment for measuring diffuse reflections (PIKETechnologies, USA).

RESULTS AND DISCUSSIONS

Infrared analysis is one of the important methods for studying the formation of the spinel ferrite phase, in addition to X-ray diffraction analysis. In the case of

spinel ferrites, the most interesting part of the IR spectra is in the range of 800 – 250 cm⁻¹. According to Waldron and Hafner [11, 12], the bands around 600 cm⁻¹ (ν₁) are attributed to stretching vibrations in tetrahedral positions and the bands around 400 cm⁻¹ (ν₂) in octahedral positions.

Table 1.
Variation of band position ν₁ and ν₂ (cm⁻¹) for Ni_{0.4}Zn_{0.6-x}Cu_xFe₂O₄ (x=0-0.6) nanoparticles

x	ν ₁ (cm ⁻¹)	ν ₂ (cm ⁻¹)
0.0	563	476
0.12	562	480
0.24	554	475
0.3	570	485
0.36	552	481
0.48	561	471
0.6	587	482

The change in the position of the ν₁ and ν₂ bands of Ni_{0.4}Zn_{0.6-x}Cu_xFe₂O₄ is shown in Table 1. The change in the position of the ν₁ peak for samples with different x indicates that with a change in composition, structural

changes occur in the tetrahedral positions. The position of the band and its shape are significantly affected not only by the chemical composition of the sample, but also by a number of uncontrolled parameters, such as synthesis conditions, annealing temperature, etc. A shift of the ν₁ band towards lower wave numbers is observed with increasing x. over the entire composition range. This indicates a weakening of metal-oxygen bonds at tetrahedral sites. Thus, we can conclude that a change in the size of nanoparticles causes a change in the positions of ν₁ and ν₂ of the infrared bands [13].

CONCLUSIONS

Ferrite nanoparticles Ni_{0.4}Zn_{0.6-x}Cu_xFe₂O₄ (x=0-0.6) were synthesized by a high-temperature method based on metal oxides. IR spectra is one of the important methods for studying the formation of the spinel ferrite phase. IR analysis showed noticeable bands due to vibrations of metal ions. The positions of the bands were found to be very sensitive to doping conditions. Structural changes were confirmed by a shift in the position of the bands due to Cu doping.

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