SYNTHESIS AND NEEL TEMPERATURE DETERMINATION OF FERRITES FROM THE CuO–ZnO–Fe$_2$O$_3$ SYSTEM

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Abstract

Conditions were established and individual and mixed ferrites with the general formula Cu$_x$Zn$_{1-x}$Fe$_2$O$_4$ ($x = 0; 0.1; 0.2; 0.3; 0.4; 0.5; 0.6; 0.7; 0.8; 1.0$) were synthesized from the CuO–ZnO–Fe$_2$O$_3$ system. X-ray phase analysis, Mössbauer spectroscopy and microscopic examinations revealed that the obtained ferrites are monophase samples.

A magnetic device was attached to the Q-Derivatograph (MOM, Hungary) and successfully used for sample investigation in a magnetic field, and in particular for Curie (Neel) temperature determination. The ferrite composition and the thermal treatment conditions were shown to correlate with the Neel temperature of the synthesized ferrites.

Keywords: CuO–ZnO–Fe$_2$O$_3$ system, ferrites, Neel temperature

Introduction

The mixed ferrites of zinc with manganese, magnesium, lithium, nickel, etc. have found wide-ranging application in modern radiotechnical, automation, computer and video techniques [1–3]. Less attention has been paid to the mixed copper–zinc ferrites [4–7]. Their study is of importance, however, for the preparation of new magnetic materials and for elucidation of the kinetics and mechanism of their formation in the processing of natural complex copper–zinc raw materials [8, 9].

The copper ferrite CuFe$_2$O$_4$ has unique properties as compared to the other ferrites [10, 11]. Its stable low-temperature phase is an inverse spinel. The Cu$^{2+}$ occupies mainly octahedral B sites, while the Fe$^{3+}$ populates B sites and tetrahedral A sites in approximately equal amounts.

The cation distribution of CuFe$_2$O$_4$ over non-equivalent sites is variable and strongly dependent on temperature [11]. A Jahn-Teller type distortion of the sites has been observed, due to the presence of Cu$^{2+}$. This leads to more distinct non-equivalent sites than in other spinels.
The zinc ferrite ZnFe$_2$O$_4$, in contrast with CuFe$_2$O$_4$, is a normal spinel [7] and the Zn$^{2+}$ occupies mainly tetrahedral A sites. Moreover, at room temperature ($T_R$), ZnFe$_2$O$_4$ is in a paramagnetic state, whereas CuFe$_2$O$_4$ is in a ferrimagnetic state [11]. The mixed ferrites of the CuO–ZnO–Fe$_2$O$_3$ system are to be expected to possess many important properties not found in most of the binary oxides.

The instruments for thermal analysis allow different measurements simultaneously [12–15]. Some of them can be used for Curie (Neel) temperature determination [14, 15].

In this connection, the aim of the present work was to synthesize individual and mixed ferrites of copper and zinc, to investigate the thermal magnetic transition and to determine the Neel temperatures of the ferrites obtained.

**Experimental**

On the basis of the conditions established earlier [16], copper–zinc ferrites of the type Cu$_x$Zn$_{1-x}$Fe$_2$O$_4$ ($x = 0.1; 0.2; 0.3; 0.4; 0.5; 0.6; 0.7; 0.8; 1.0$) were synthesized by using a ceramic technology. They were produced at 1000°C for 300 min, and quenched in water. They are stable compounds which do not change or dissociate when heated to 1200°C. No changes were observed in their TG and DTG curves.

X-ray phase analysis was performed with a TUR-M62 apparatus, using CoK$_{\alpha}$ radiation and an iron target. Mössbauer spectra were recorded with a standard Mössbauer spectrometer working at the constant acceleration of the $^{57}$Co source in a Pd matrix.

To determine the Neel temperatures of the copper and zinc ferrites, a device was constructed for attachment to the Q-Derivatograph (MOM, Hungary), applied for differential thermal and thermogravimetric analysis. In addition to the conventional measurements of temperature, enthalpy, sample mass change and mass rate change, this device allows Curie (Neel) temperature determination on the basis of the magnetic interaction between the sample and the magnetic field induced by the device.

**Results and discussion**

The X-ray phase analyses and microscopic observations showed that monophase samples were obtained. The ferrite cubic crystal lattice parameter decreased linearly from 0.8444 nm for ZnFe$_2$O$_4$ to 0.8386 nm for CuFe$_2$O$_4$.

The Mössbauer spectra of the ferrites Cu$_x$Zn$_{1-x}$Fe$_2$O$_4$ obtained at $T_R$ displayed a smooth change in type, from two sextets at $x = 1$ to a doublet at $x = 0$ (Fig. 1). Zinc substitution into CuFe$_2$O$_4$ led to the occurrence of a paramagnetic