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# Electromagnetic wave absorption by an organic resin solution based on ferrite particles with a spinel crystal structure

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**Abstract**

We have investigated an organic resin solution designed for EM wave absorption based on a magnetic filler, composed of phases within the $Mn_{0.66}Zn_{0.27}Fe_{2.07}O_4$ system, embedded in an absorber composite with concentration ratios of 50:50, 75:25 and 90:10 by weight. The formation of the manganese zinc ferrite particles, as the principal magnetic phases, was achieved via the conventional ceramic method. The electromagnetic parameters of the composites were measured with a vector network analyser at 100 MHz to 10 GHz. The subject of the paper was a study of the electromagnetic absorber properties and the rheological properties of the resin composite based on ferrite particles with respect to using the materials in architectural coatings.


*Keywords:* D. Ferrites; Electromagnetic waves; Magnetic composite; Ferromagnetic materials; Microwaves

## 1. Introduction

Although electrical equipment provides convenience in our lives, the resulting EM radiation leads to pollution of the environment and harm to human beings. Therefore, the need to protect people or devices from harm and to keep a device from being detected by other instruments is leading to the development of novel EM-waves-absorbing materials [1–6]. The ideal EM wave absorber should possess light weight, high EM-wave absorption and multi-functionality [7–9].

Ferrites exhibit substantial magnetic losses in the vicinity of their natural resonance (FMR). Because of this they are one of the best materials for EM wave absorbers. Ferrites with a spinel crystal structure can be applied in the frequency range from several hundred MHz to several GHz [10]. $AM_2O_4$ spinel ferrites are binary ferromagnetic oxides from the system $Fe_2O_3$–MO, where M is usually a transition-metal element. Almost any divalent transition-metal ion can be used to form a spinel ferrite. The magnetic properties of ferrites can be considered in terms of the Neèl model of ferrimagnetism. One of the attractive properties of ferrites is the possibility to prepare different compositions and thereby modify the magnetic properties.

By varying the chemical composition it is possible to control the electromagnetic properties, such as the saturation magnetization, the magnetocrystalline anisotropy, the permeability and the permittivity of a ferrite composite. In addition, the microstructure of the ferrites has an additional impact on their properties, and consequently on the EM-wave absorption.

In general, EM-wave absorbers can be prepared in the form of ceramics or as composites, where the ceramic phases are embedded in a polymeric matrix. Here, the EM properties of the composites can be very effectively tuned, simply by varying the volume fractions of the constituent filler phases.

In addition, a synergetic effect of the constituent phases' properties may also be observed in some composites. For this reason magnetic composites are interesting for radio-frequency and microwave-frequency applications [11,12]. Furthermore, during the development of suitable absorbers, their composition and processing are equally important. By using rheological

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tests we can simulate different processes and predict the influence on the properties of the material. The measurements can be used for changes in the formulations or to study the suitability of the raw material or the process control. Rheological measurements are helpful in the development of new products, giving a better understanding of the processes and an easier prediction of the final properties of the material. The use electromagnetic absorbers in a limited wave spectrum require a specific rheological behaviour, a high solids content and a high-thickness application. In this paper we will present the influence of ferrite particles with a spinel crystal structure on the magnetic and rheological properties of the organic resin solution and/or their EM-wave absorbing characteristics in the frequency range from 100 MHz to 10 GHz.

## 2. Experimental

Ferrite powder with a composition $Mn_{0.66}Zn_{0.27}Fe_{2.07}O_4$ was prepared with a solid-state reaction from the starting oxides $Fe_2O_3$, $Mn_3O_4$ and ZnO. The mixture of oxide powders was homogenized and calcined at 900 °C in air for 4 h. The calcined powder was then milled in a planetary steel ball (Fritsch, Pulverisette 7) with water as the milling medium. The average grain size of the ferrite powder after milling was 1 μm, as measured with a laser spectrometer (Cilas HR 850). The milled and dried powder was sintered in a computer-controlled furnace at a temperature of 1370 °C for 4 h. The sintered ferrite powder was milled in a planetary mill (Fritsch, Pulverisette 7) with steel balls for different milling times. The obtained ferrite powders were dried at 100 °C for 3 h and finally characterized with scanning electron microscopy (SEM) and X-ray diffractometry (XRD). In addition, the specific surface area (BET) and the average grain size (Cilas HR 850) for each ferrite powder sample were also measured.

Ferrite absorber composites were prepared by mixing the ferrite powder and an organic solution polymer of acrylic-resin-based putty with concentration ratios of 50:50, 75:25 and 90:10, by weight. The ferrite composite suspensions were dried at 50 °C and finally pressed in the appropriate forming tool. The samples were compacted to form a toroid with an outer dimension of 6 mm, an inner dimension of 3 mm and a height of 3 mm in order to fit well into an APC-7 coaxial sample holder. Both the relative complex permittivity ($\varepsilon_r = \varepsilon' - j\varepsilon''$) and the relative complex permeability ($\mu_r = \mu' - j\mu''$) of the samples were measured using an Anritsu 37269D vector network analyser in the frequency range from 100 MHz to 10 GHz. The permeability and the permittivity were calculated from the measured scattering parameters [4].

The rheological properties of the ferrite absorber composites were measured using a Rheometer Anton Paar MC 301 with a parallel-plate measuring system (with a gap of 0.5 mm). All the rheology tests were made in the linear viscoelastic range, i.e., non-destructive shear conditions, up to $5 \times 10^{-3}$% of deformation.

## 3. Results and discussion

### 3.1. Phase analysis and SEM morphology

Fig. 1 shows an X-ray diffractogram of an MnZn ferrite sample prepared using the ceramic processing technique described earlier. The diffraction peaks in the figure correspond to pure MnZn ferrite.

Table 1 shows the average particle size and the specific surface area (BET) of the ferrite powder samples S1–S3.

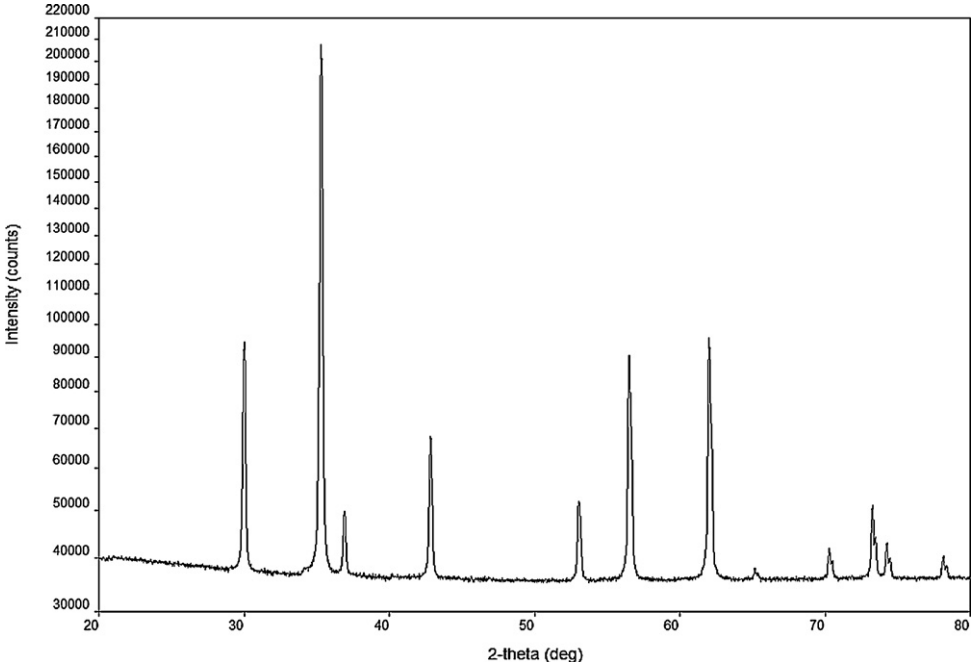


Fig. 1. X-ray diffractogram for MnZn ferrite prepared by ceramic processing.