Analele Universităţii de Vest din Timişoara
Vol. XLIX, 2006
Seria Fizică

ON THE FREQUENCY AND MAGNETIC POLARIZING FIELD DEPENDENCE OF THE COMPLEX DIELECTRIC PERMITTIVITY OF MAGNETIC FLUIDS IN THE MICROWAVE RANGE

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Abstract
This paper reports on the frequency dependence of the complex dielectric permittivity for a kerosene-based magnetic fluid, with magnetite particles, in the microwave frequency range *(0.3 to 3 GHz),* at various values of an external polarizing magnetic field *(0 to 168 kA/m).* The results obtained allow the determination of the field dependence of the activation energy corresponding to the Maxwell-Garnett-Sillars dielectric relaxation process. Changes of the activation energy by increasing the polarizing field suggest changes in the local structure of the magnetic fluid.

1. Introduction

Magnetic fluids are stable colloidal systems consisting of single-domain magnetic particles coated with a surfactant and dispersed in a carrier liquid [1].

As heterogeneous systems, in the absence of a magnetic polarizing field, the dielectric behaviour of magnetic fluids, in the microwave range, is usually explained in terms of the Maxwell-Garnett-Sillars (MGS) theory [2], [3]. In the theoretical description of the dielectric behaviour of kerosene based magnetic fluids with magnetite particles stabilized with oleic acid, the magnetic fluid is approximated as a bi-phase system. One phase consists of magnetite particles and the other phase consists of kerosene and oleic acid [3]. The validity of this approximation is based on the fact that the complex dielectric permittivity of oleic acid is approximately the same as that of kerosene.

Assuming that the particles have ellipsoidal shape, subjected to a static magnetic field two possible processes may occur: i) the particles tend to align their long axis to the magnetic field direction; ii) the particles may form particle agglomerations. In both cases changes of the local structure are produced. The aim of this paper is to present some experimental results regarding the effect of the static magnetic field on the complex dielectric permittivity, $\varepsilon(\omega,H)=\varepsilon'(\omega,H)-j\varepsilon''(\omega,H)$ in the microwave frequency range *(0.3 to 3 GHz),* at various values of an external polarizing magnetic field *(0 to 168 kA/m).* Also, assuming that

the MGS relaxation time is thermal activated and follows an exponential law,

$$\tau = \tau_0 \exp\left(\frac{W}{kT}\right) \tag{1}$$

we have evaluated $$\Delta W = kT \ln\left(\frac{\tau(H \neq 0)}{\tau(H = 0)}\right) \tag{2}$$

which represents the variation of the activation energy in the magnetic field with respect to the value of the activation energy in zero magnetic field, at a constant temperature T=300K.

2. Sample

The sample studied was a commercial kerosene-based magnetic fluid with magnetite particles and stabilized with oleic acid.

3. Results and discussion

The measurements were performed using a Hewlett Packard (HP) *50Ω* coaxial line incorporating a coaxial cell, in conjunction with a combination of the HP 8753C and HP 8722D network analyzers [4].

The frequency dependence of the complex dielectric permittivity for the magnetic fluid, in the microwave frequency range *(0.3 to 3 GHz),* at various values of an external polarizing magnetic field *((1) 0 kA/m; (2)15.2 kA/m; (3) 24.5 kA/m; (4) 35.3 kA/m; (5) 46.183 kA/m; (6) 57.073 kA/m; (7) 68.5 kA/m; (8) 79.3 kA/m; (9) 90.6 kA/m; (10)102.5 kA/m; (11) 113.5 kA/m; (12) 124.5 kA/m; (13)146.5 kA/m; (14) 157.5 kA/m; (15)168 kA/m),* was determined.

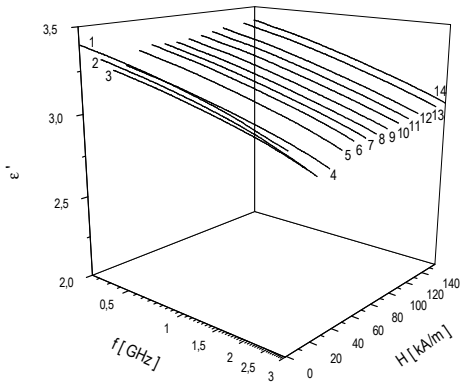

Fig. 1. Frequency and polarizing field dependence of the real part of the complex permittivity.

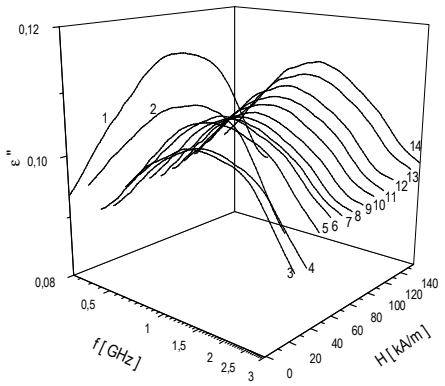

Fig. 2. Frequency and polarizing field dependence of the imaginary part of the complex permittivity.

The experimental results are presented in figures 1 and 2. For each value of the polarizing magnetic field, the frequency corresponding to the maximum of the imaginary part (ε") of the complex dielectric permittivity, f_{max}, was determined.

Assuming a Debye dependence on frequency of the complex dielectric permittivity, the relaxation time is correlated with $f_{\max}$ as follows $\omega_{\max}\tau = 1$ (3)

where $\omega_{\max} = 2\pi f_{\max}$ is the angular frequency corresponding to $f_{\max}$.

Based on the experimental results from Fig.2, we have computed the relaxation time, τ, for each value of the magnetic polarizing field. Using the values of τ obtained, we have computed the variation of the activation energy in the magnetic field with respect to the value of the activation energy in zero magnetic field, at a constant temperature *T=300K*. The results obtained are presented in figure 3. If the polarizing magnetic field has no effect on the local structure of the magnetic fluid, the activation energy must remain constant, at a constant temperature. One can observe from Fig.3, that the activation energy changes with the increase of the polarizing field. This effect can be correlated with the changes in the local structure of the magnetic fluid either by alignment of the particles to the direction of the magnetic field, or by agglomeration of particles.

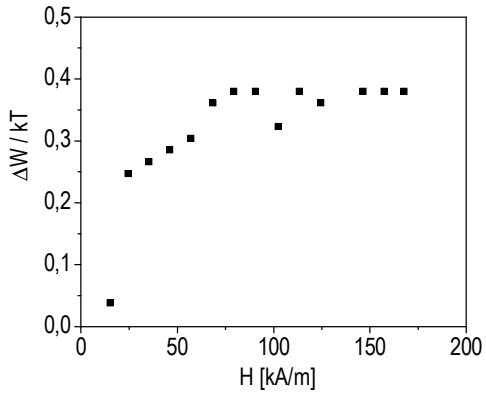

Fig. 3. The dependence on the polarizing field of the ratio ΔW / kT, at T=300K.

4. Conclusions

The results obtained allow the determination of the activation energy of the MGS relaxation process in the microwave range, for the studied magnetic fluid, in the presence of a static magnetic field.

Changes of the activation energy resulting from an increase in polarizing field suggest changes in the local structure of the magnetic fluid.

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