Capacitive Sensing Element with a Magnetic Fluid for Detecting of Change of Magnetic Field

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Abstract— The article presents the results of an experimental study of capacitive magnetic field sensors with magnetic fluid. The sensor is based on a change in the capacitance of a magnetic fluid capacitor at influence of magnetic field. The effect of an external magnetic field on a sensitive capacitive element with a magnetic fluid at different concentrations of a magnetic particle is studied. Change of capacity of the lamellar condenser from concentration of magnetic powder in polymethylphenylsiloxane (PFMS-4) liquid is shown.

1. INTRODUCTION

The most important characteristics of sensors of magnetic fields are the sensitivity, a sensitivity threshold, dynamic range and accuracy. It is possible to improve the specified characteristics of magnetic sensors by use of perspective magnetic materials.

The magnetic fluids or ferromagnetic fluids represent colloidal suspensions of the magnetic particles dispersed steadily in liquid carrier. The properties of the magnetic fluid is determined by the size of the magnetic particle, the property of this particle, the surfactant and the carrier liquid. Magnetic properties of magnetic fluid in many respects depend on the listed factors. Magnetic fluids due to their properties are perspective materials with a huge scope in various areas of measurement technology. These fluids have unique physical phenomena in the form of a combination of strong magnetic properties and fluidity [1–5].

Changing parameters can change the magnetic properties of magnetic fluids. Article [6] said that the extended (in the form of "needles") particles or flat (in the form of "disks") particles easily give in to magnetic texturing (ordering of the directions of the magnetic axes of the particles). Furthermore, non-spherical particles have an additional source of magnetic anisotropy (shape anisotropy) [6]. In an external magnetic field, particles form the chains extended along a vector of this field. The processes of association and aggregation of particles in external magnetic fields are central to the physics of magnetic colloids and also they determine magnetic, optical, acoustic, and other rheological properties of magnetic fluid. The change of the magnetic properties of magnetic fluid due to the formation of aggregates is considered in [7–12] with different points of view.

Now the increased interest in the magnetic fluids shown from theorists and experimenters is caused by the fact that this substance have property which are in many respects unique and difficult predicted. The uniqueness of these properties and the possibility of practical use in various industries contribute to the development of fundamental research on their study and practical application in complex technical problems. For example, using magnetic fluids developed technologies for cleaning water surfaces from oil products in case of accidents and catastrophes; Magnetic fluids allowed to create dampfers and shock absorbers with controlled rigidity; Magnetic fluids are investigated in the THz region to create filters, polarizers; Magnetic fluids became the basis for creating acceleration, tilt, level sensors; on the basis of the magnetic fluid, magnetic-fluid bearings, suspensions and bearings have been created; at present, physicists from the Michigan University of Technology have developed a new type of engine for small space vehicles. They resemble ionic engines, but the working substance in them is an ionic magnetic fluid. Thus, the use of a magnetic fluid expands, there are new areas of their application [12–20].

The relevance of a research can be caused by the practical application of its results for creation of sensors of weak magnetic fields.

2. EXPERIMENTAL STUDY OF MAGNETIC FLUIDS AS A SENSITIVE ELEMENT TO A CHANGE IN THE MAGNETIC FIELD IN THE SPACE

The sensitive structure consisted of glass plates with a structure deposited on them (capacitor). The condenser is made of gold. The photo of the capacitor is shown in Figure 1.

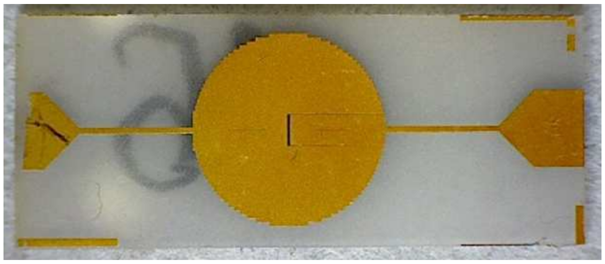

Figure 1: Capacitor on a ceramic plate.

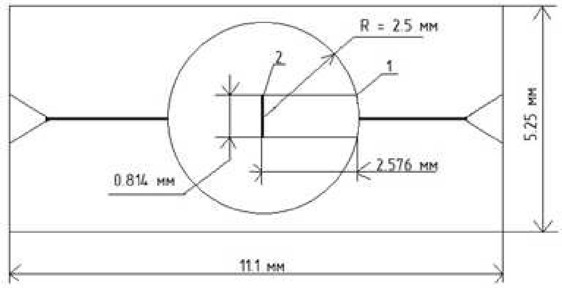

Figure 2: Capacitor on a ceramic plate.

The scheme of the capacitor is shown in Figure 2.

The thickness of the a ceramic plate is equal to 470 microns. The thickness of gold plating is equal to 6.21 μm. Before applying ferromagnetic fluids on the capacitor it is checked for integrity, Figure 3.

As a result of the inspection, a defect was detected on one of the plates, which led to its further rejection, Figure 4.

Figure 3: Integrity check.

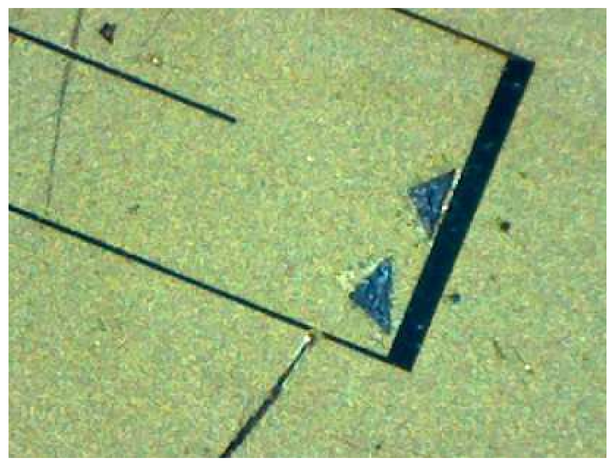

Figure 4: Condenser plate defect.

At the next stage, a magnetic fluid consisting of polymethylphenylsiloxane (PFMS-4) and iron powder was fabricated and applied on capacitors.

Application and features of PFMS-4 liquid [21]:

- PFMS-4 liquid is absolutely transparent;
- PFMS-4 fluid has a high thermal stability;
- PFMS-4 fluid has high lubricating properties;
- PFMS-4 liquid does not have a corrosive effect on metals.

In the experimental work 6 capacitor plates were used. Plates number 1 and number 2 were taken as reference (clean). On plate No. 3, No. 4, No. 5 and 6 was applied to the magnetic fluid with the concentration of iron powder, 10%, 20%, 30% and 40% respectively. The photo with applied magnetic fluids is shown in Figure 5.

The capacity change of the cell was measured by digital L, C, R meter type E7-12 with an adapter which reduces of influence of stray parameters on the frequency of the measuring signal of 1 MHz. To study the influence of the magnetic fluid on the electrical parameters of the cell, external magnetic field was affected on the cell. The measurements of cell capacity were made under the influence of the magnetic field which was parallel and perpendicular to measuring electric field. Figure 6 shows the experimental setup.

The measurement results are shown in Table 1.

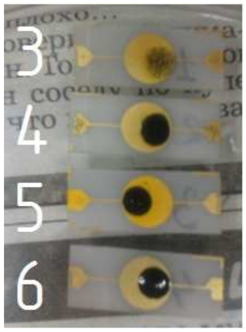

Figure 5: Condenser with applied magnetic fluids with different concentrations of magnetic particles.

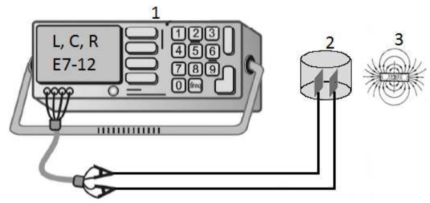

Figure 6: Experimental installation of research of the magnetic field influence on the magnetic fluid in the condenser, where 1 — meter L, C, R type E7-12; 2 — the measuring cell filled by the studied liquid; 3 — magnet.

Table 1: Results of measuring the dependence of the capacitance of sensor elements under the influence of a magnetic field.

Condenser plate number	powder concentration in magnetic fluid	C, pF Capacitance of the sensitive element without the action of a magnetic field		C, pF Capacity of a sensitive element under actions of magnetic field			$\Delta C, \%$
		Measurement No. 1	Measurement No. 2	Measurement No. 3	Measurement No. 4	Measurement No. 5	
1	C_{Fe}= 0%	0.808	0.806	-	-	-	-
2	C_{Fe}= 0%	0.819	0.820	-	-	-	-
3	C_{Fe}= 10%	0.923	0.924	0.915	0.911	0.911	1.1
4	C_{Fe}= 20%	1.048	1.048	1.052	1.063	1.063	1.43
5	C_{Fe}= 30%	1.252	1.249	1.189	1.186	1.190	5.01
6	C_{Fe} = 40%	1.386	1.386	1.183	1.181	1.163	15.2

3. CONCLUSION

Experimental studies showed that electric parameters of this cell change much under the by influence of magnetic field, that is, they show considerable sensitivity to changes in the magnetic field at different concentrations of magnetic powder. In the future, it is planned to measure the sensitivity of a capacitive sensor by magnetic induction and to investigate the limiting sensitivity of the sensor in weak fields.

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