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Magnetic field intensity effect on plane capacitors based on hybrid magnetorheological elastomers with graphene nanoparticles

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Hybrid magnetorheological elastomers (hMREs) are prepared using silicone rubber (SR), silicone oil (SO), carbonyl iron (CI), graphene nanoparticles (nGr) and cotton fabric. For volume concentration of SO and CI fixed at 20%, and various volume concentrations of SR and nGr we obtain four plane electric capacitors (FCs). We measure the electrical capacitance C of FCs as a function of the intensity of a magnetic field H. Using elements of elasticity theory we determine the components of elasticity ϵ_{xx} and of mechanical tensions τ_{xx}, as well as the modulus of elasticity E. We present and discuss the obtained results.

Keywords: hybrid magnetorheological elastomers, graphene nanoparticles, carbonyl iron, dielectric permittivity, plane capacitor;

I. INTRODUCTION

Hybrid magnetorheological elastomers (hMREs), together with magnetorheological suspensions (MRSs), gels (MRGs) and elastomers (MREs) belong to the class of magnetic active materials (MAMs). They consist from a non-magnetizable phase, which is liquid for MRSs [1, 2] and solid for MREs [3, 4], in which a magnetizable phase is dispersed. The later phase consists usually from magnetizable microparticles. In MREs, the magnetizable phase is fixed to the elastic matrix, such as silicon/natural rubber, acrylonitrile or polybutadiene [5, 6], and thus it is not able to settle. Depending on whether a magnetic field is present, two main classes of MRE can be produced: isotropic (without magnetic field) [7, 8] and anisotropic (with magnetic field) [9]. By aligning the magnetizable phase under the influence of a magnetic field, a drastic change of physical properties may be induced, in particular, changes of the dynamic viscosity of MRSs [1], of the elasticity coefficients of MREs [10], and a change of the main shear tensions in both MRSs and MREs. Tunning rheological properties [1] and the elasticity state [11] makes hMREs susceptible for various applications including bio-medicine [1], seismic protection [12] or adaptive vibration absorbers [13].

When MRSs or MREs are introduced between two electrodes, they act either as magnetoresistors or as electric capacitors whose output signals can be modified in magnetic field. Depending on the volume fraction of magnetizable phase and/or of the volume fraction of additives, consisting of electroconductive nano-micrparticles, the conduction state [14, 15], dispersion and absorption characteristics of the electromagnetic field of medium frequency can be sensibly modified in the presence of a magnetic field [16].

Avoiding the remanence of response function under the influence of a magnetic field is still an open issue. In Ref. [16] has been produced a hMRE in which the electrical conductivity (σ), as a function of both magnetic field intensity (H) and of hydrostatic pressure (p) applied to MRE, takes the same values when both H and p are increased and, respectively decreased. Thus, the functions $\sigma = \sigma(H)$ and $\sigma = \sigma(p)$ take the same values with a good precision and makes MREs susceptible for various practical applications.

In this paper, we address this open issue, and membranes based on on hMREs are produced. They are obtained using silicone rubber (SR), silicone oil (SO), carbonyl iron (CI) and graphene nanoparticles (nGr) deposited on a cotton fabric, situated between two Cu electrodes. They are used as dielectric materials in electrical capacitors (FCs). The electrical capacitance C is measured in magnetic fields with intensities up to $H \lesssim 300\ kA/m$. We show that nGR has an influence on the electrical capacitance of FCs, and the capacitance C increases sensibly with H, for fixed values of volume concentrations of nGr. Furthermore, from the dependence $C = C(H)$ we obtain deformations field ϵ_{xx}, mechanical tensions field τ_{xx}, and the modulus of elasticity E. We show that the quantities ϵ_{xx} and E depend also on the volume concentration of nGr, and are sensibly influenced by H. The obtained results can be used for various industrial, technical and medical applications.

II. EXPERIMENT

A. Materials

The materials used for producing hMREs are the following: silicone oil (AP 200 type) from Sigma-Aldrich,

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