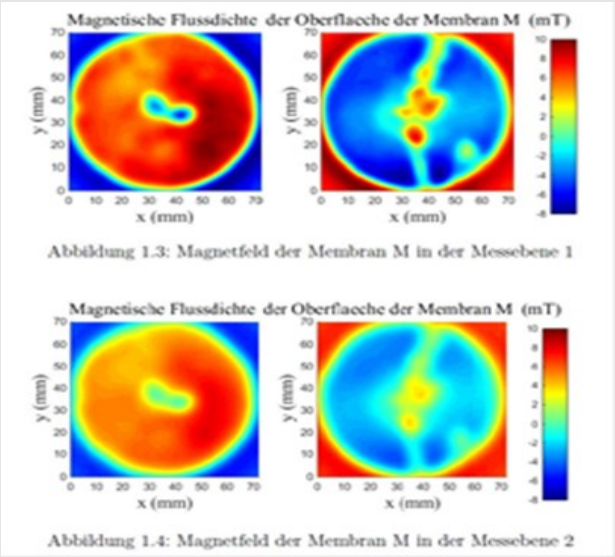
# RFBR Project № 19-53-12039

## «Magnetic Field-Sensitive Properties of Hybrid Magnetic Elastomers with Complex Interior Interactions »

The purpose of this work is investigation of the specifics of interactions among micro- and nanosized particles filling the polymer matrix of a composite material influenced by an exterior magnetic field. Affected by the field, hybrid magnetic elastomer (HME) suffers interior structuring manifesting itself in changing the particles distribution, which results in the variation of such parameters as the elasticity, viscosity, transparency, and the capability to conduct electric current.

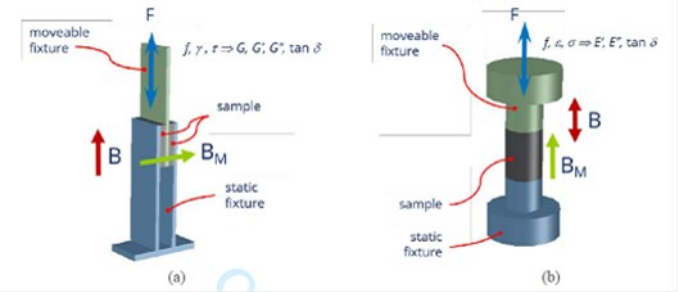
# Achievements in 2019

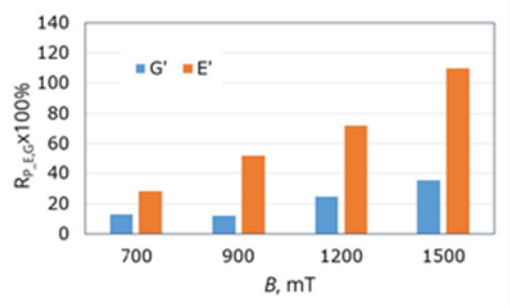
· There were synthesized hybrid magnetic elastomers containing a magnetically hard component, being a Q-grade NdFeB-powder, coercivity 2.5-3.0 kOe, pure and in combination with carbonyl iron powders; the polymer matrix is based on silicone resin forming from the СИЭЛ preparation, a product of Russian State Scientific Institute for Chemical Technologies of Organoelement Compounds.
· In co-operation with a research group at TU Dresden (Gremany), there were obtained samples of HME containing spherical NdFeB-particles with a coercivity of 9 kOe.
· There were fabricated polyurethane-based polymer matrices with elastic moduli in the range 2-100 kPa. Samples filled with magnetic powders were also considered.
· Within the frames of a joint project with a research group at TU Ilmenau (Germany), there were manufactured plate-shaped HME-samples to be utilized in designing acceleration sensors.



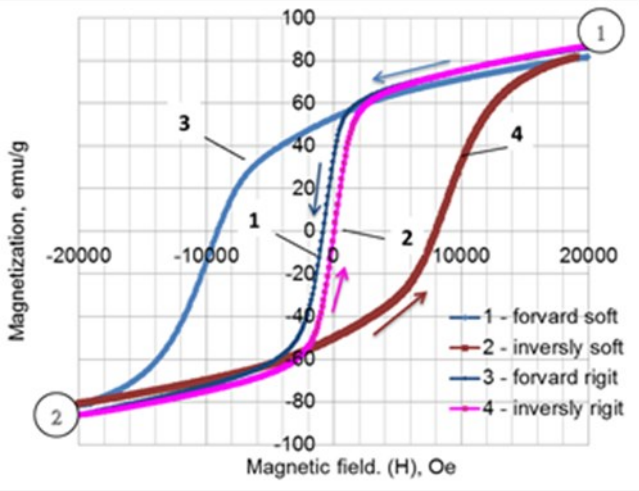

*Distribution of magnetic field inside an HME-plate*

- · There was studied the increasing of the elastic modulus of HME in response to magnetizing in various magnetic fields

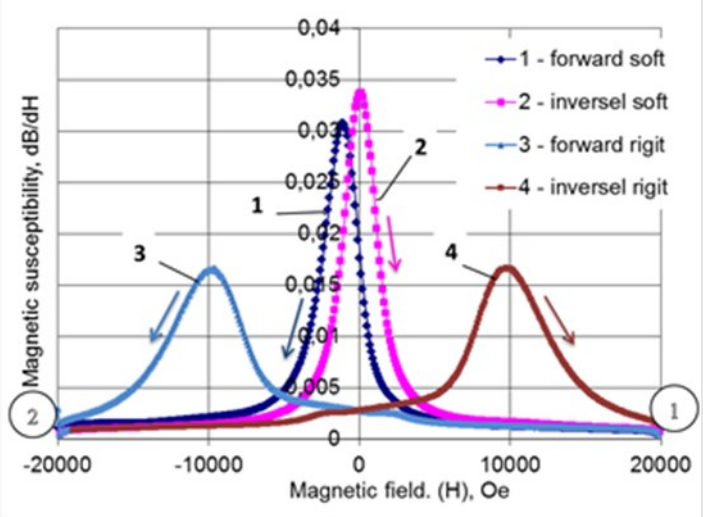



- · As a result of measurements carried out on a magnetometer, there were recorded hysteresis loops characteristic of magnetic elastomer samples with different elasticities:



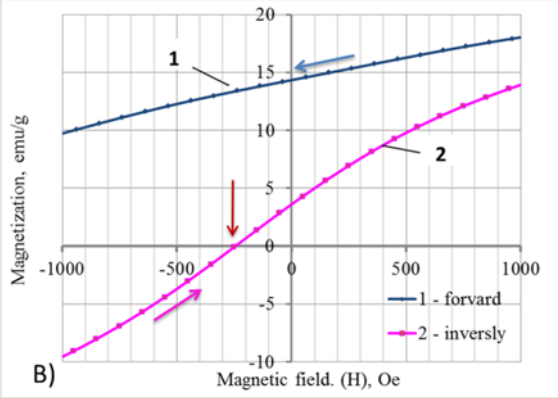

*a) Integral curves produced by samples with a soft (1-2) and rigid (3-4) matrices.*




*b) Differential magnetic susceptibility curves.*

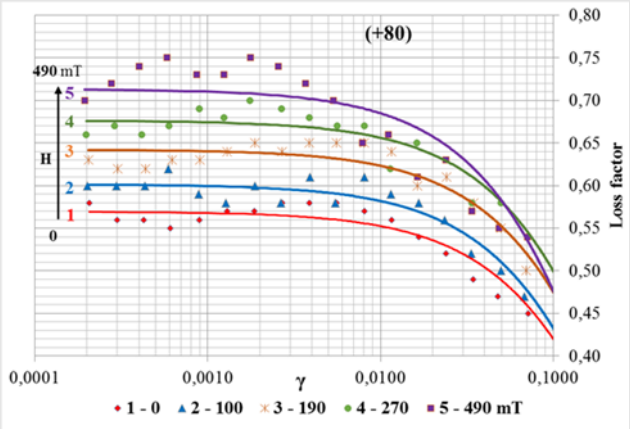
· It was established that the particles filling the polymer matrix are capable of forming buildups and rotating when the sample is influenced by a magnetic field. At a certain relation of magnetic field strength, remanence intensity, and polymer rigidity, the magnetic susceptibility curves may reflect polarity reversal as well as particles rotation (lines 1-2 in Fig. 4 a) and b)).

- It was found out that the hysteresis loop may be asymmetric, which is determined by the vector of the primary magnetic field applied to an HME sample. In some cases, the ascending branch of the loop may intersect the abscissa from the left side of the origin thus resulting in a ‘negative coercivity’.




*‘Negative coercivity’*

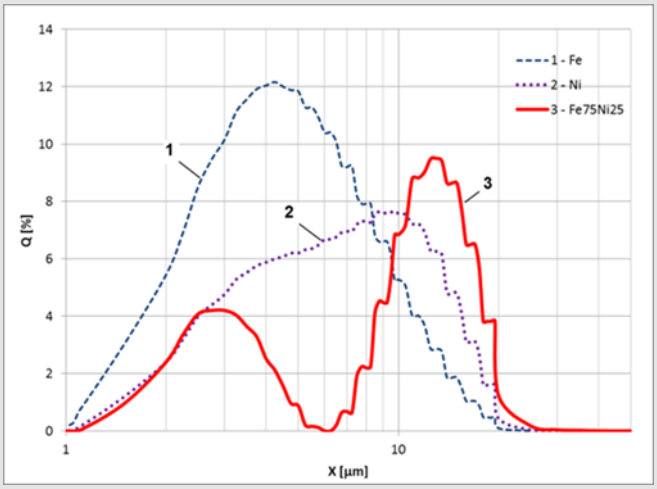
- · There were studied the rheological properties of HME

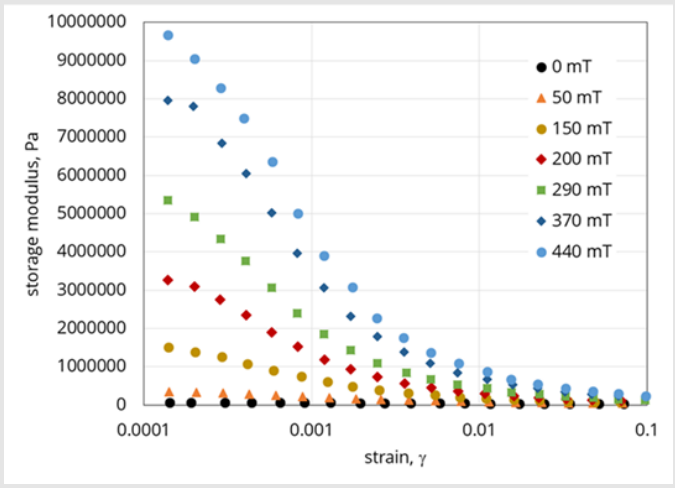



*In magnetic fields up to 500 mT, anomalously high damping properties of HME tend to increase over the entire range of strains.*

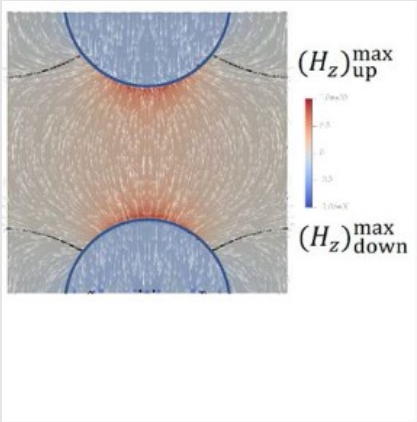
# in 2020

· Using the mechanochemical fusion method, there were obtained permalloy powders to be utilized as magnetic fillers with bimodal particle size distribution. As a result, it became possible to synthesize a magnetoactive elastomer (MAE) showing a high magnetorheological effect, at small strains amounting to 8 MPa in a field of 440 mT.

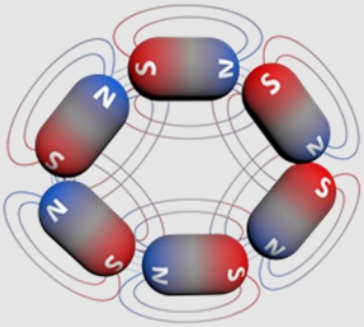


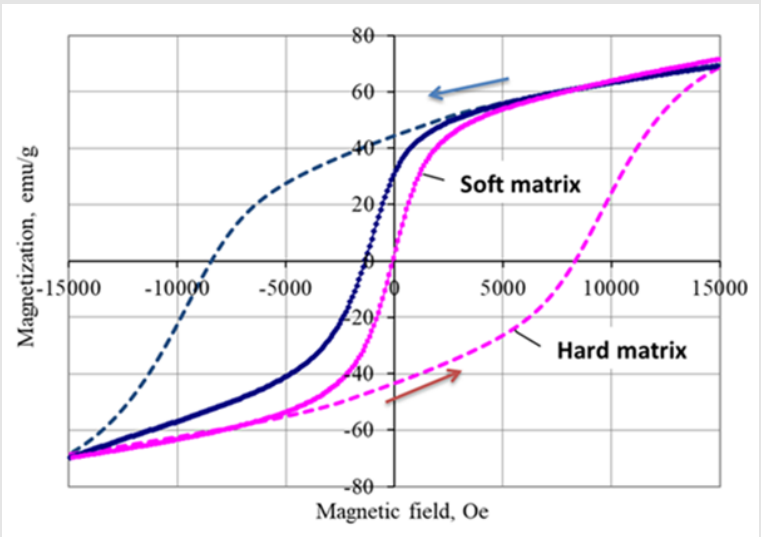

- · A study was given to the structuring processes occurring in HME containing magnetically hard spherical NdFeB-particles with a coercivity of 9 kOe. The magnetizing processes, including polarity change, of such a composite lead to the formation of interior chain-like and circular buildups, whose existence explains the anomalously low coercivity and remanence of the composite sample.



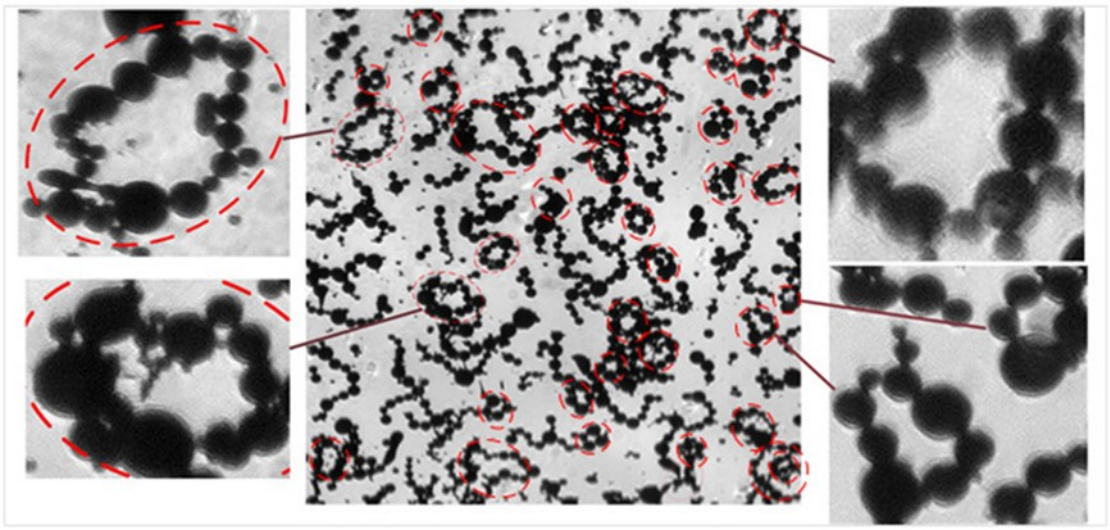

*Formation of circular structures resulting from dipole interaction inside the polymer matrix*



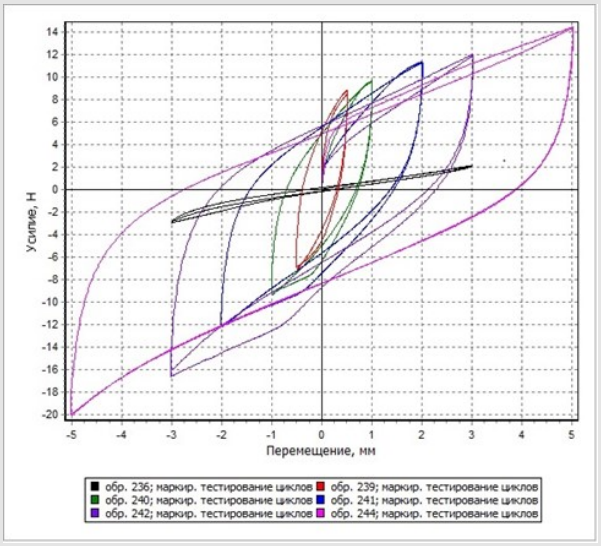
**MAGNETIC MEASUREMENTS**



## OPTICAL OBSERVATIONS



The particles filling the polymer matrix are capable of structuring and rotating when influenced by a magnetic field. At certain magnitudes of magnetic induction, filler remanence, and polymer elasticity, the formation of circular buildups is possible; the overall remanence of the sample approaches zero, meanwhile.




*Elastic properties of HME in magnetic field*

*Resonance curves recorded on a vibrostand under various loads.*