SUBPROJECT 4: Modeling of magnetoactive elastomers with preformed magnetizable structures

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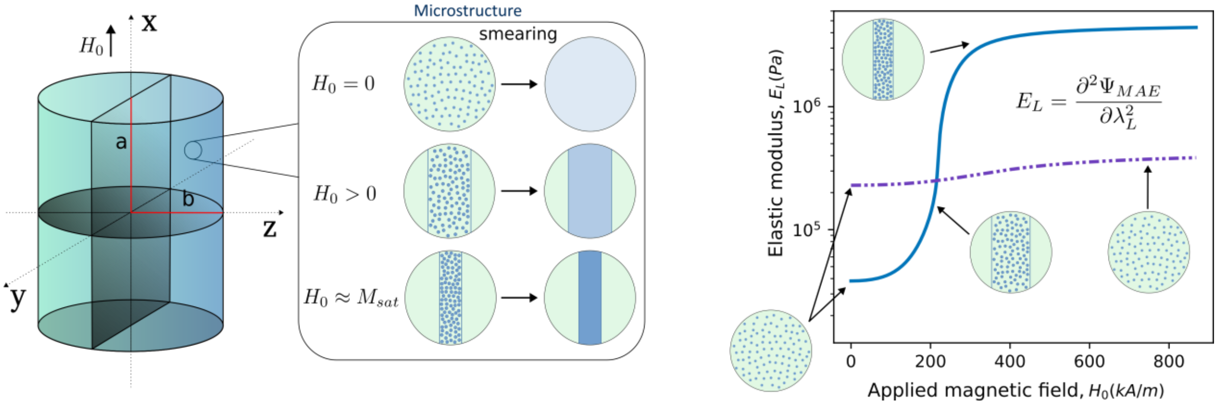
Motivation

Magnetoactive elastomers (MAEs) are being used in several engineering applications such as soft actuators or tunable vibration absorbers. MAEs display significant deformations and changes in mechanical moduli, when exposed to a magnetic field. The magneto-mechanical response of MAEs can be programmed by imprinting specially designed magnetizable structures into a soft elastomeric matrix. In particular, complex 3D deformations like twisting and bending should be favored by the presence of structures with intrinsic chirality.

State of the art and previous research

The magneto-mechanical behavior of MAEs has been intensively studied by two previous cohorts. The microstructure of MAEs can be designed into many different forms during manufacturing and can also be changed remotely using an external magnetic field. The evolution of microstructure is most pronounced in MAEs made of a soft elastomeric matrix and leads to the appearance of mechanical anisotropy in originally isotropic samples [1, 2]. The formation of columnar structures with increased particle density can considerably increase the elastic modulus along the magnetic field lines [3]. If the sample stiffness increases by orders of magnitude, this hinders its magnetically induced deformation. These predictions from a physically based model are compared with the experimental studies on cylindrical MAE samples [4]. The magnetization behavior is also altered by the evolution of the microstructure and by the mismatch between the direction of magnetic field and the orientation of columnar microstructures [5].



Scientific questions and project objectives

The objective of SP 4 is to understand and quantify analytically the impact of magnetizable continuous structures onto magnetically induced deformation in MAEs. To achieve complex 3D deformations like twisting and bending, it is necessary to consider various types of chiral structures, whose principal axes do not coincide with the direction of the magnetic field. The effective magnetic response of prestructured materials will be evaluated in the frame of mean-field dipole approximation. This provides the constitutive parameters, including the effective magnetic susceptibility tensor, for further modeling using finite element software. The deformations of prestructured MAE samples with ellipsoidal and cylindrical shapes will be modeled as a function of magnetic field strength.

The magneto-mechanical behavior of prestructured MAE samples will be investigated in collaboration with SP 3 using tensile tests and quasi-static shear. When possible, the deformations of prestructured MAE samples will be compared with the predictions of thermo-magneto-mechanical model of SP6.

References

[1] Chougale, S.; Romeis, D.; Saphiannikova, M.: Field-induced transversely isotropic shear response of ellipsoidal magnetoactive elastomers. Materials, 2021, 14: 3958, DOI:10.3390/ma14143958.

[2] Chougale, S.; Romeis, D.; Saphiannikova, M.: Magneto-mechanical enhancement of elastic moduli in magnetoactive elastomers with anisotropic microstructures. Materials, 2022, 15: 645, DOI:10.3390/ma15020645.

[3] Roghani, M.; Romeis, D.; Saphiannikova, M.: Effect of microstructure evolution on the mechanical behavior of magneto-active elastomers with different matrix stiffness. Soft Matter, 2023, 19: 6387, DOI: 10.1039/d3sm00906h.

[4] Roghani, M.; Romeis, D.; Glavan, G.; Belyaeva, I.A.; Shamonin, M.; Saphiannikova, M.: Simultaneous deformations and magnetorheological effects in magneto-active elastomers: Theory meets experiment. Composites Part B, 2024, *under review*.

[5] Romeis, D.; Saphiannikova, M. Effective magnetic susceptibility in magnetoactive composites. Journal of Magnetism and Magnetic Materials, 2023, 565: 170197, DOI: 10.1016/j.jmmm.2022.170197.