80th International Scientific Conference of the University of Latvia 2022

# Section Latvian-Brazilian meeting on Active and Soft Matter Physics

## MMML lab (Lab of Magnetic Soft Matter)
## University of Latvia
## &
## Condensed Matter Theory Group
## Universidade Federal do Ceará

# Abstract Book

**Thursday, 3 February 2022, 15:00, Online**



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80th International Scientific Conference of the University of Latvia 2022

## Latvian-Brazilian meeting on Active and Soft Matter Physics

Thursday, 3 February 2022, 15.00 (GMT+2), online

Topic: Latvian-Brazilian meeting on Active and Soft Matter Physics
Time: Feb 3, 2022 03:00 PM Riga

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# Programme

| Chair: Dr. Guntars Kitenbergs | | | |
|---|---|---|---|
| Time | *Speaker* | Title | Abstract |
| 15:00-15:05 | Opening | | |
| 15.05–15.20 | *Dr. Jānis Cīmurs* | Chain formation of anisotropic paramagnetic particles in a rotating magnetic field | p.3 |
| 15.20–15.35 | *Dr. Jorge Luiz Coelho Domingos* | Pattern formation in a two-dimensional system of magnetic rods driven by rotating fields - a numerical study | p.4 |
| 15.35–15.50 | *Prof. Dr. Claudio Lucas Nunes de Oliveira* | Sublinear drag regime at mesoscopic scales in viscoelastic materials | p.5 |
| 15.50–16.05 | *Dr. Mārtiņš Brics* | Dynamics of hematite cubes in rotating field | p.6 |
| 16.05–16.15 | Online coffee break | | |
| 16.15–16.30 | *Prof. Dr. Wandemberg Paiva Ferreira* | Transport of self-propelled particles in 2D substrates of convex obstacles | p.7 |
| 16.30–16.45 | *PhD student Andris Pāvils Stikuts* | Deformation of magnetic droplets in external field | p.8 |
| 16.45–17.00 | *Prof. Dr. Jeanlex Soares de Sousa* | Viscoelasticity of cells as marker for diseases | p.9 |
| 17.00–17.15 | *Dr. Guntars Kitenbergs* | Rotation and swimming of flexible ferromagnetic filaments | p.10 |
| 17.15–17.30 | Conclusions, discussions | | |

# Chain formation of anisotropic paramagnetic particles in a rotating magnetic field

Jānis Cīmurs*, Jānis Užulis
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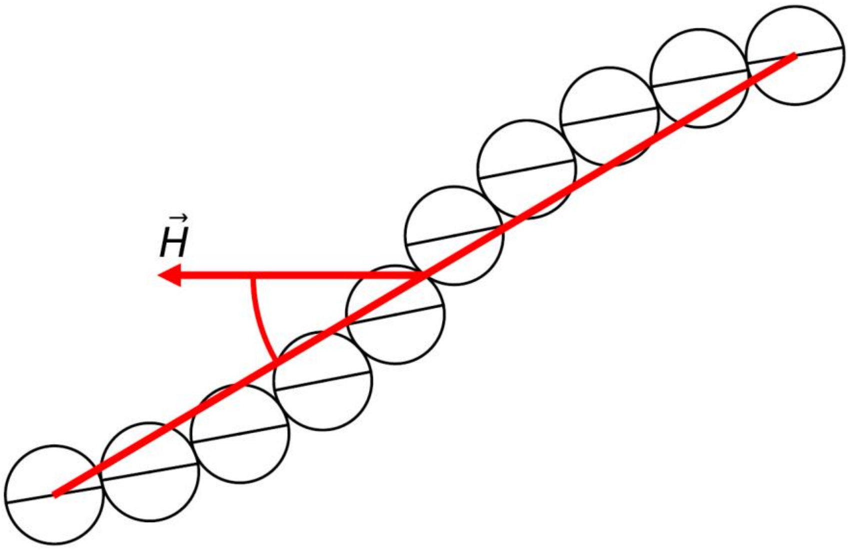
In external magnetic field paramagnetic particles magnetize and start to attract creating long chains. If the external magnetic field is rotating, the chain length can be controlled using field strength and rotation frequency. In present research we focus on the influence of magnetic anisotropy on the chain stability i.e., how magnetic anisotropy influences the chain length for the given rotating magnetic field [1].




In the presentation, I will also present the research of paramagnetic rods caried out in the Laboratory of Soft Magnetic Materials. I will show how paramagnetic rod can be used to measure micro-rheological properties of viscoelastic media [2]. Also, the equilibrium dynamics of paramagnetic rod in the precessing field will be shown in theory and experiments [3].

This study has been supported by PostDoc Latvia project 1.1.1.2/VIAA/1/16/060

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# Pattern formation in a two-dimensional system of magnetic rods driven by rotating fields - a numerical study

Jorge Luiz Coelho Domingos*, Wandemberg Paiva Ferrreira
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We investigate a two-dimensional system of magnetic colloids with anisotropic geometry (rods) subjected to a rotating external magnetic field. Different steady states can be observed depending on the extent of synchronization of the magnetic particles with the rotating field [1-3]. The structural and dynamical properties of the steady states are analyzed by means of Langevin Dynamics simulations, as a function of their aspect ratios (l), and also in terms of the strength (B) and rotation frequency ($\omega$) of an external magnetic field. The dynamical response of the magnetic rods to the external magnetic field is strongly affected by the aspect ratio of the rods. Concerning the synchronization between the magnetic rods and the direction of the external magnetic field, we define distinct regimes of synchronization and relate with the phases observed. A set of steady states diagrams are presented, showing the magnitude and rotation frequency intervals in which the distinct self-organized structures are observed (Figure 1).

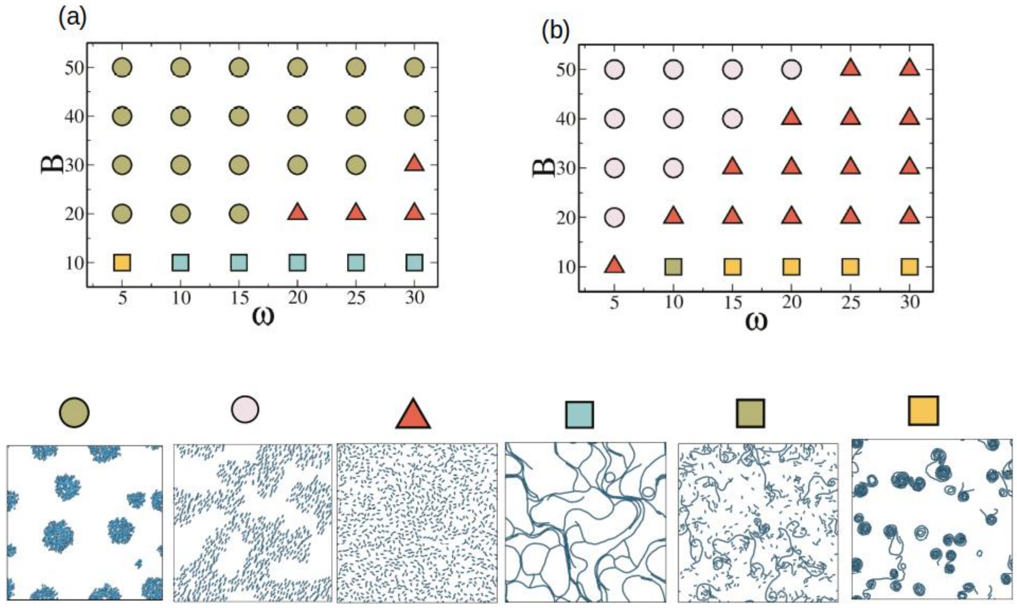


Figure 1: Non-equilibrium phase diagrams for (a) l = 2, (b) l = 3.

We acknowledge funding from CNPq, CAPES and FUNCAP.

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# Sublinear drag regime at mesoscopic scales in viscoelastic materials

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Soft materials usually present exponential or power-law viscoelastic relaxations when stressed. Although the mechanical responses are relevant to determining possible applications and designing new materials, the origins of these macroscopic behaviors in terms of their small-scale interactions and compositions are still unclear. Here, we propose a model of macromolecules arranged in a lattice immersed in a viscous fluid, similar to colloidal and polymeric solutions. The macromolecules interact with neighbors in the network (with a spring interaction $k$) and fluid through a non-linear drag regime. More specifically, the dissipative force is given by $\gamma v^{\alpha}$, where $\gamma$ is a coefficient, $v$ is the velocity of the macromolecule, and $\alpha$ an exponent. Using molecular dynamics simulations, we perform numerical indentation assays and reproduce viscoelastic signatures in the force curves of the sample as those obtained in atomic force microscopy. We perform statistical and data analyses with machine learning techniques to classify each viscoelastic material (represented by the set of parameters $k$, $\gamma$, $\alpha$) as an exponential or power-law behavior. Our results show that linear drag regimes ($\alpha$ close to $1$) recover exponential relaxation materials, which the so-called linear standard solid model can describe. However, in sublinear drag regimes ($\alpha$ close to $0.5$), the network response presents power-law relaxations. Physically, the sublinear regime of the drag forces is related to micro-deformations of the macro-molecules, while $\alpha = 1$ represents the rigid case. Therefore, our results suggest that mesoscopic-scale deformations are responsible for the material rheological responses, namely, the exponential and power-law relaxations.

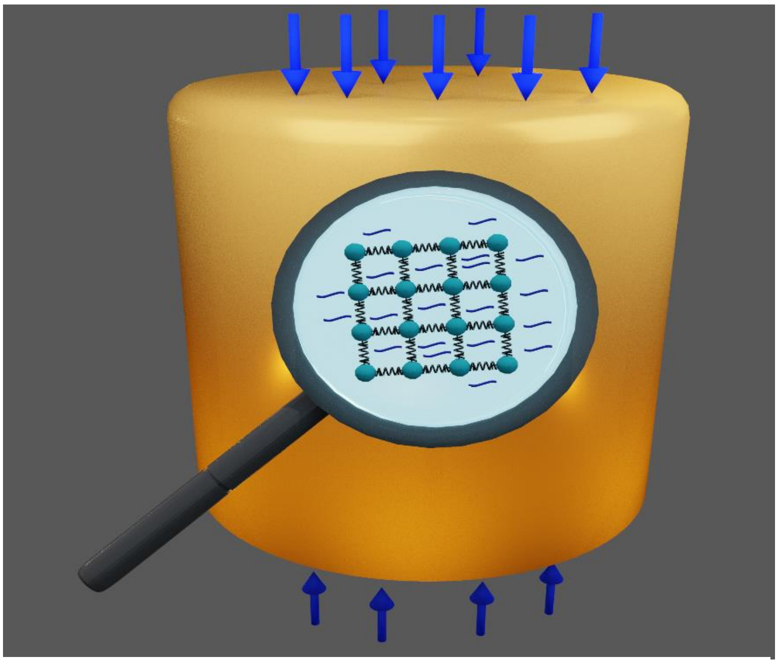

Figure 1: Illustrative image showing a loaded soft material made of a chain of molecules embedded in a fluid

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# Dynamics of hematite cubes in rotating field

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From a physical viewpoint, hematite at room temperature is a weak ferromagnetic material with unorthodox magnetization orientation. In the case of single-domain cubic-shaped hematite particles the magnetic moment makes an angle 12º with the diagonal in the plane defined by two diagonals [1]. In the static magnetic field, in a colloid at low concentrations these particles tend to align and form straight chains along the direction of the applied field. An increase in the strength of the applied magnetic field causes an additional rearrangement of the chains. Longer chains reorganise in the kinked structures [1,2]. Here we examine the behaviour of those particles in a rotating magnetic field. In this case longer chains break into straight, short chains or even individual cubes. For short straight chains we find that three motion regimes are possible: solid body rotation, back-and-forth motion, periodic break and assembly of chains. The motion of an individual chain depends on the rotation direction of the external magnetic field.

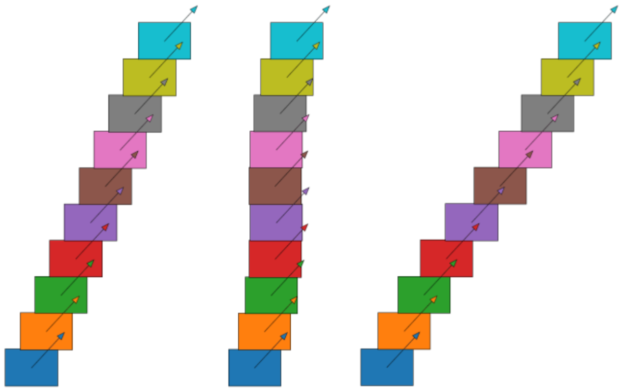

Fig. 1: Configuration of a ten particle straight chain of cubes is a static, a clockwise, and an anti-clockwise rotating magnetic fields.

The authors appreciate the financial support from PostDocLatvia grant No.1.1.1.2/VIAA/3/19/562.

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# Transport of self-propelled particles in 2D substrates of convex obstacles

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We report numerical results which show the achievement of transport of self-propelled particles (SPP) in the presence of a two-dimensional regular/random array of rigid convex obstacles. The repulsive inter-particle interaction (soft-disk) and particle-obstacle interactions present no alignment rule. We find that SPP present a vortex-type motion around convex symmetric obstacles even in the absence of hydrodynamic effects. Such a motion is not found for a single SPP, but it is a consequence of the collective behavior of SPP around convex obstacles. A steady particle current is spontaneously established in an array of non-symmetric convex obstacles, and in the absence of an external field. The direction of the particle current may be controlled according to the ordering/non-ordering array of the obstacles and density of SPP. Our results are mainly a consequence of the tendency of the self-propelled particles to attach to solid surfaces.

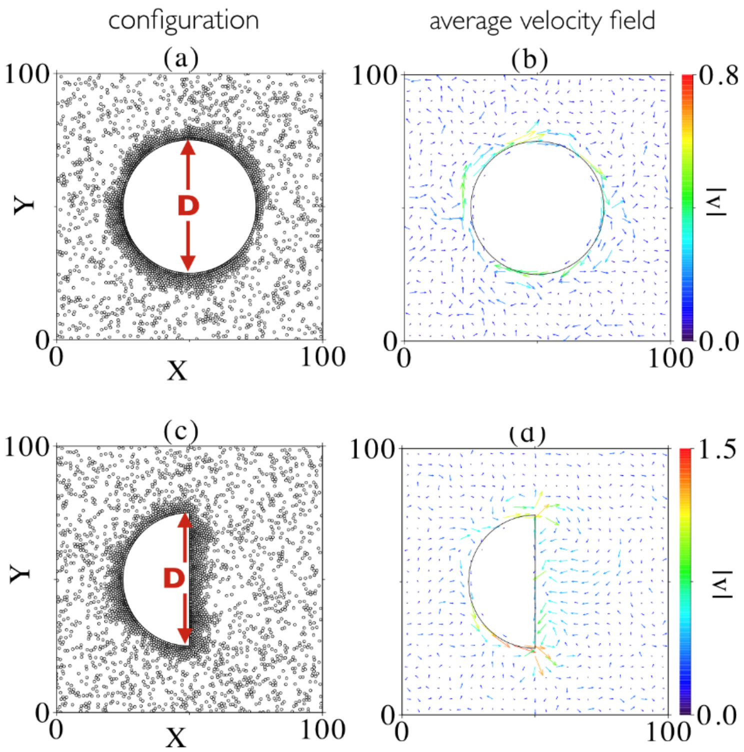


Figure 1: The configuration and average velocity field of self-propelled particles around a single obstacle are shown. The collective behavior determines the agglomeration and the dynamics of the particles around the obstacle.

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# Deformation of magnetic droplets in external field

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Magnetic fluid droplets exhibit a wide variety of interesting behavior in external magnetic fields (see Figure 1). They elongate in a constant field making sharp tips for large elongations. In a rotating field, their dynamics depend in an intricate manner on the field properties - its frequency and magnitude [1]. The droplet can take up an elongated shape and rotate with the field, it can flatten out and a crown of fingers can form on its perimeter.

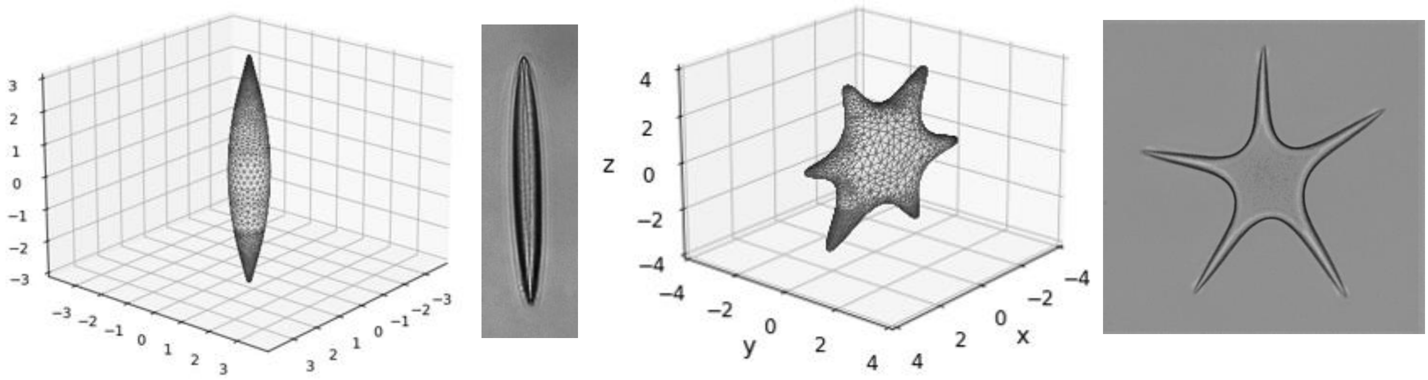


Figure 1. Shapes of magnetic droplets obtained in simulations and experiments.

Some analytic results are known for the droplet behavior, but they are mostly limited to the cases where the droplet is either treated as an ellipsoid or its shape is close to spherical. Here we focus on an algorithm which is based on boundary element methods that can be used to calculate the droplet's dynamics in an arbitrary magnetic field and arbitrary fluid viscosity ratios. We showcase some benchmarks and illustrate the methods used in it.

We acknowledge support from EU's Horizon 2020 R&I program project MAMI (No. 766007), and Latvian Council of Science project BIMs (lzp-2020/1-0149) and the project "Strengthening of the capacity of doctoral studies at the University of Latvia within the framework of the new doctoral model", identification No. 8.2.2.0/20/I/006.

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# Viscoelasticity of cells as marker for diseases

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Living cells are complex mechanical systems that exhibit power-law-like viscoelastic relaxation. In fact, cell mechanics is becoming an increasingly important research field because the mechanical properties of the cells are strongly affected by processes like cell division, movement, differentiation, aging, and by diseases as well.

In this presentation, we will discuss methods to measure power-law viscoelastic relaxation with Atomic Force Microscopy, and show that eukaryotic cells exhibit double power-law relaxation. We will also demonstrate that the mechanical properties of cells are important biomarkers for diseases like cancer.

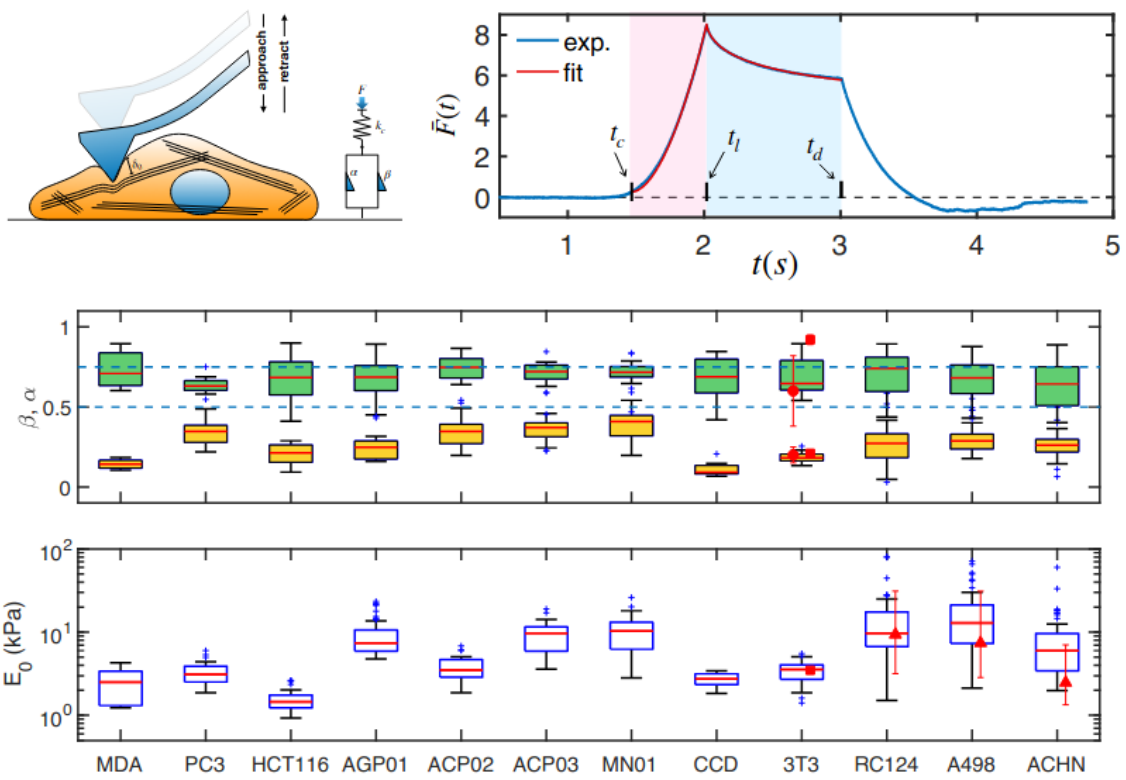


Figure 1: AFM forces curves in living cells exhibit characteristics compatible with a double power-law viscoelastic relaxation, whose characteristics are strongly affected by the health state of the cells, and can be used as biomarkers for cancer aggressiveness.

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# Rotation and swimming of flexible ferromagnetic filaments

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Ability to control microobjects with an external magnetic field is of interest both from the fundamental point of view, as well as possible applications, especially in biomedicine. Here we present how a filament that combines elastic and magnetic properties can produce versatile shapes and motion, which we investigate both experimentally and numerically.

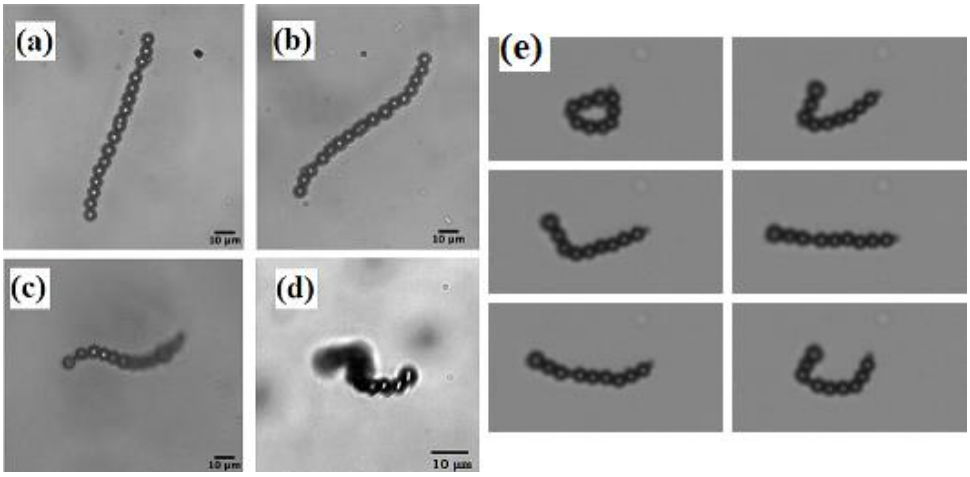


Figure 1: Filament shapes in a rotating field (a)-(d) with an increasing frequency and in a pulsed field (e) during one period.

On the experimental side, the flexible ferromagnetic filaments are synthesized by linking ferromagnetic microparticles with DNA fragments in a strong and static external field. Putting them in alternating external field induce interesting behavior (see Figure 1), which ranges from dynamically stable 2D [1] and 3D shapes [2] under a rotating field (a)-(d), to a breaststroke like swimming [3] under a field generated by pulse wave (e). Numerical results, using a modified Kirchhoff model, can reproduce the observations and show a good agreement. This can be applied to design predictable mixers and swimmers.

We acknowledge support from EU's Horizon 2020 R&I program project MAMI (No. 766007) and Latvian Council of Science project BIMs (lzp-2020/1-0149)

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# About

The idea of this section was born during the communication between Dr. Guntars Kitenbergs (University of Latvia) and Dr. Jorge Luiz Coelho Domingos (Universidade Federal do Ceará) on common research interests and possible research proposals.

The main organization of this section is done by the MMML lab (Lab of Magnetic Soft Materials) of the University of Latvia. More information about our activities and research interests can be found on our website https://mmml.lu.lv. You can also follow our twitter account @MMML_LU. The other partner of this section is the Condensed Matter Theory Group of the Universidade Federal do Ceará. You can see their website here: https://www.gtmc.fisica.ufc.br/

Section chair is Dr. Guntars Kitenbergs. Seminar organizing committee includes Dr. Mārtiņš Brics (UL) and Dr. Jorge Luiz Coelho Domingos (UFC)

For the technical support we thank the Faculty of Physics, Mathematics and Optometry.

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