78th Scientific Conference

Section: Magnetic Soft Matter

University of Latvia
Faculty of Physics, Mathematics and Optometry
House of Science, Jelgavas 3, Riga, Latvia

Book of Abstracts
February 14, 2020
Compiler: Abdelqader Zaben

Foreword

MMML (Lab of Magnetic Soft Materials, mmml.lu.lv) research group is focused on understanding the behaviour of soft matter systems influenced by the application of magnetic field. The research is carried out on both theoretical and experimental aspects. In this conference section researchers from MMML present the latest results on current research topics, as listed below.

Contents

Application of a two-phase PIV to the magnetic micro-convection

14 Feb
1:10pm
801/802

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As mixing processes are essential in most microfluidic applications, there is a notable interest in flow field investigation in order to improve the performance of micromixers. Here we revisit an instability driven (magnetic micro-convection) mixer, reported by Ergin et al. [1], with a goal to unravel the experimental details of the instability growth. Recently in [2] we improved both the accuracy and the resolution of the experimental system, using microfluidic system and advanced image processing tools. Precise system control, careful concentration calibration and Otsu thresholding method enabled us to perform phase-separated PIV analysis. First results show a detailed view of the flow velocity and flow vorticity development during mixing. We observe a sharp increase and a gradual decay, similar to crude measurements in [3]. The precision of data allows us to find better insight in instability development from the experimental view. An example of retrieved flow fields is shown in 1.

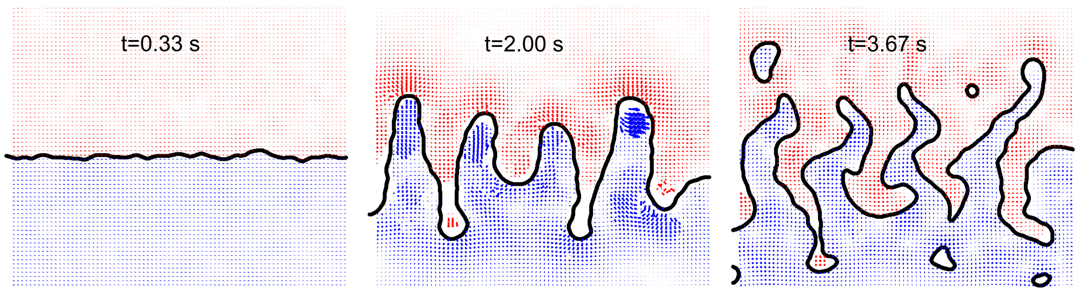

Figure 1: Magnetic micro-convection Flow field

[1] F.G. Ergin, et al. Proc. 10th ISPIV (2013).
[2] F.G. Ergin, et al. Proc. 13th ISPIV (2019).
[3] K. Ērglis, et al. J. of Fluid Mech. 714, 612 (2013).

Acknowledgement
This study has been supported by PostDocLatvia project 1.1.1.2/VIAA/1/16/197

Sedimentation potential in magnetic colloids

14 Feb
1:25pm
801/802

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The goal of the presentation is draw attention to some interesting electrokinetic phenomena which can take place at sedimentation of charged particles (in gravity field, inhomogeneous magnetic field), when the electric field due the migration of particles arises. The essential point is the boundary condition for the charge balance on the surface of the particles with zero conductivity. The obtained relation are valid when the Debay length is much smaller than the size of particle.

14 Feb
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Microphase Separation of Magnetic Polymer Brushes

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Polymer chains grafted onto substrates, i.e. polymer brushes, have been extensively studied in physics, chemistry, materials science, and other scientific and industrial fields. Polymer brushes are widely utilized for applications such as wetting, adhesion, surface patterning, and colloidal stabilization. Grafting two incompatible polymers onto a surface, these species can self-assemble horizontally into two-dimensional structures with well-defined lateral length scale (see Fig.1). Magnetic brushes are a scaled up version at a supra-molecular level of brush polymers that are created using ensembles of colloidal magnetic chains known as magnetic filaments that are grafted by one of their ends to a common surface while the rest of each filament stands freely in the bulk. A distinctive advantage of these supra-molecular magnetic polymers is that in difference to their molecular counterparts, magnetic filaments are able to keep their zero-field magnetic properties at room temperature and above if the size of the nanocolloids is chosen adequately. In present research we try to investigate how presence of magnetic elements in polymers effect structure formation in system with two grafted incompatible polymers. And we try to find how structure properties are effected by external magnetic field. Research is based on numerical simulation done in molecular dynamics simulation program Espresso. Obtained results show that in magnetic field besides horizontal segregation of polymers also vertical segregation of polymers occur forming islands of enrichment of one type polymer (see Fig.2).

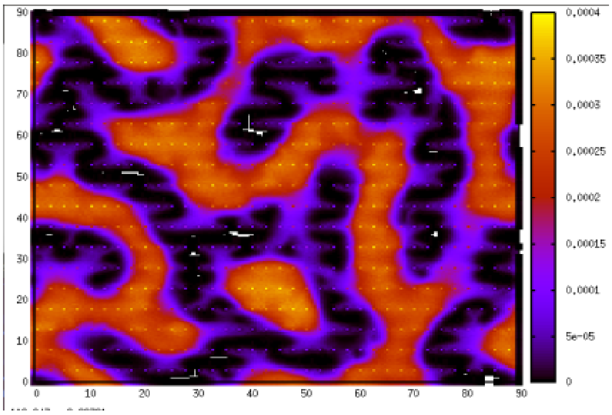

Figure 1: Probability density of type 1 polymer top view.

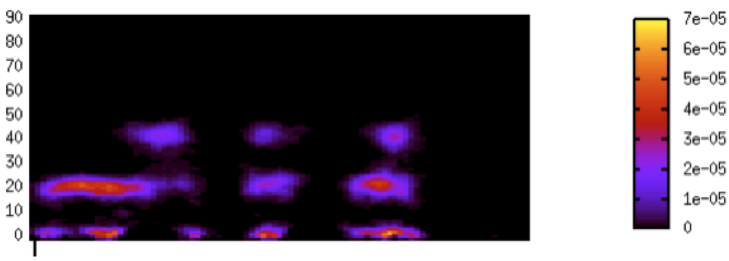

Figure 2: Probability density of type 1 polymer in vertical cut.

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

Numerical calculations of paramagnetic particle self-assembling in precessing field

14 Feb
1:55pm
801/802

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Paramagnetic particles magnetize in external magnetic field. If the particle shape is spheroid (rotational ellipsoid), then particle magnetic susceptibility in direction of symmetry axis is different than perpendicularly to the symmetry axis. Computer software has been made to do numerical simulations of particle movement in viscous fluid with precessing magnetic field applied. Numerical calculations are made to predict the structures that particles make depending on field angular velocity and precession angle. Particles mostly form planes or chains (Fig.1). Particle motion can be characterized as synchronous, if the particle symmetry axis can follow the field and asynchronous, if it runs behind and the angle between axis and field increases. In rotating field, when the field precession angle is 90 degrees, chain length measurements have been made depending on filed angular velocity. It is useful to know how to control self-assembly of particles by changing external field parameters. It can be further used in controlling fluid rheology or for creating nano scale objects that could be used in medicine and for creating materials with unique proprieties.

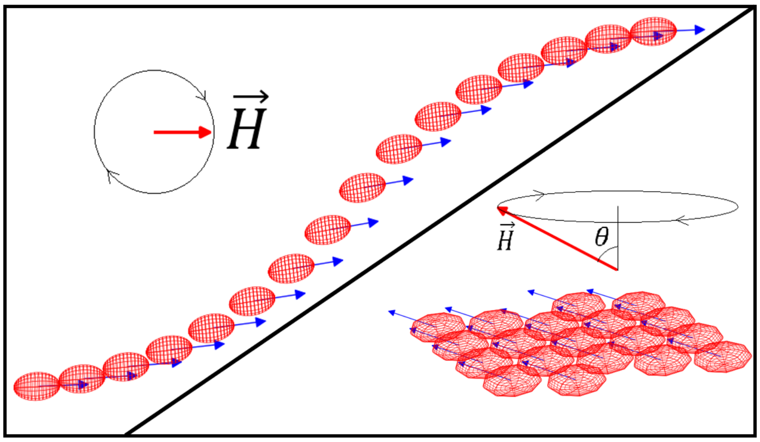

Figure 1: Example of prolate particle chain in rotating field (on the left). Example of oblate particle plane in precessing field (on the right). Red arrows show the direction of external field and blue arrows show magnetization vector for each particle.

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

Flexible ferromagnetic filaments as micro-mixers

14 Feb
2:30pm
801/802

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Different promising applications for flexible magnetic filaments have been presented in the literature [1, 2]. Mixing in microflows is an interesting application for ferromagnetic filaments made from microbeads. An interesting phenomenon observed for such filaments under a 2D rotating field is the movement in 3D, as shown in Fig.1. This contradicts with the numerical observation by L.Goyeau et al. [3], where it was seen an in-plane back and forth motion at critical frequencies. In this work, we analyze the observed regimes of filament dynamics under rotating field. The experiments were made using filaments with different lengths L, field strengths H and frequencies f. For frequencies above critical, the filament moves out of focus plane in the third dimension while the filament tip motion was found to follow a circular path. The experimental results was compared with numerical simulations and were found to have a good match. This study shall give a baseline for the design and optimization of flexible ferromagnetic filaments as micromixers.

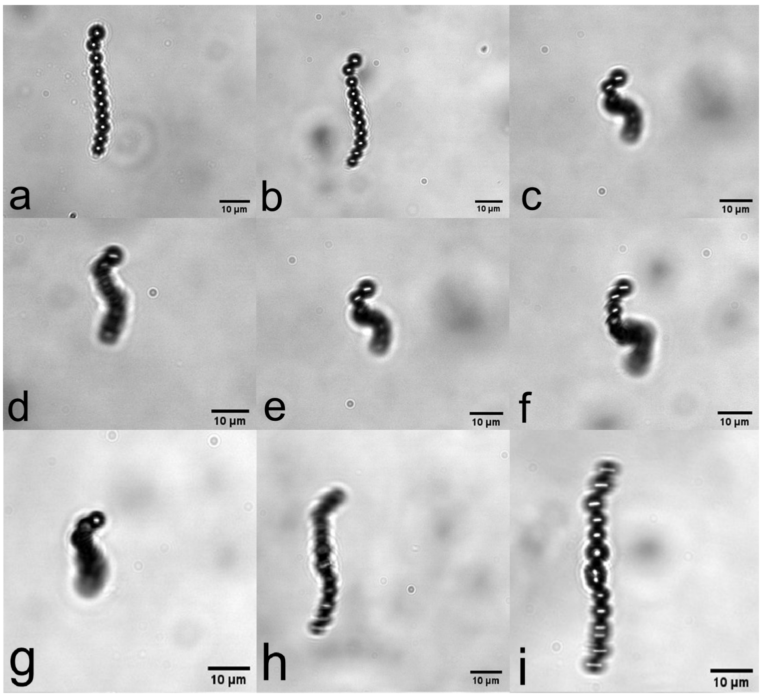

Figure 1: Deformed filaments shapes under rotating magnetic field. Filament with L = 43 μm, H = 17.2 Oe; Frequency of (a)= 1 Hz, (b)=4 Hz and (c)= 9 Hz. Filaments with H = 17.2 Oe and f = 8 Hz: , L of (d)=35 μm, (e)=43 μm and (f) = 71 μm. filament with L = 48 μm, f =5 Hz, H for (g)=4.3 Oe , (h)=12.9 Oe and (i)= 25.8 Oe

[1] Cēbers, A. (2005). Flexible magnetic filaments. Current Opinion in Colloid Interface Science, 10(3-4), 167–175.

[2] Biswal, S. L., Gast, A. P. (2004). Micromixing with Linked Chains of Paramagnetic Particles. Analytical Chemistry, 76(21), 6448–6455.

[3] Goyeau, L., Livanovičs, R., Cēbers, A. (2017). Dynamics of a flexible ferromagnetic filament in a rotating magnetic field. Physical Review E, 96(6), 062612.

Acknowledgement
This project (MaMI) was funded by the European Union’s Horizon 2020 research and innovation program under grant agreement No. 766007.

Investigations of collective behavior of rotating magnetic droplets

14 Feb
2:45pm
801/802

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In recent years, there has been a significant interest in using external fields to assemble structures on the microscopic scale. A particular way to achieve this is by using the so-called active structuring, where the particles making up the structures are not just statically attracted, but rather they form structures while being constantly driven and excited by an energy input from an external source [1].

We have previously reported a magnetic field driven assembly of magnetic droplets into rotating crystals [2]. We showed that the droplets interact hydrodynamically with one another and also with the glass surface at the bottom of the sample cell. In this talk, we present observations that the droplets not only arrange themselves on the bottom of the sample cell, but also in the volume of the fluid. Additionally, we explored the organization of droplets with different magnetic fields parameters.

[1] V. Liljeström, et al., “Active structuring of colloids through field-driven self-assembly”, Current Opinion in Colloid and Interface Science, 2019, vol. 40, pp. 25-41.

[2] A.P. Stikuts, et al., “Spontaneous order in ensembles of rotating magnetic droplets”, Journal of Magnetism and Magnetic Materials, 2020,vol. 500, 166304.

14 Feb
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A 3D BEM algorithm for simulations of magnetic fluid droplet dynamics

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Magnetic fluid droplets in external magnetic fields may be deformed in ways where complete mathematical modeling is no longer feasible, due to prohibitive computing costs. These deformations include highly stretched droplets in homogeneous fields or droplets on the verge of breaking up in rotating fields. This presentation outlines an algorithm that could be used for simulating full 3D dynamics of magnetic fluid droplets in external magnetic fields, as shown in Fig.1. The algorithm works with arbitrary fluid viscosity ratios of the magnetic fluid of the droplet and of the surrounding fluid. The algorithm is validated with known theoretical relationships and some experiments. Thus it may be used for predictions of droplet configurations as well as for indirectly calculating the viscosity, magnetic permeability and surface tension of the droplet.

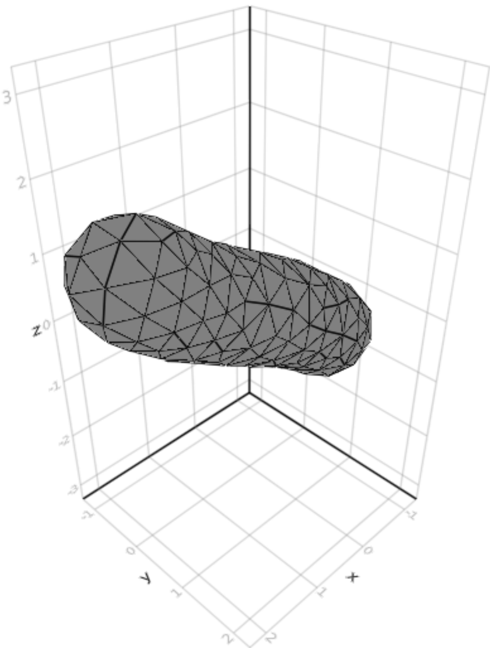

Figure 1: Magnetic fluid droplet in a rotating magnetic field undergoing a back-and-forth motion and relaxing from an elongated shape

Acknowledgement
This project (MaMI) was funded by the European Union’s Horizon 2020 research and innovation program under grant agreement No. 766007.