BSc-Assignment Project Descriptions

2021 - Spring

University of Twente
www.utwente.nl/en

UNIVERSITY OF TWENTE.

September 14, 2020

Dear USTC students,

In this syllabus you will find possible research projects you can perform at the University of Twente (UT), The Netherlands, for your BSc Assignment. Several faculties (schools) of UT invite you to join them coming spring. You will find a short introduction of the faculties, followed by project descriptions, as offered by several Research Groups or Departments of the University of Twente. You can choose between 12 research projects as offered by 6 groups.

Enjoy reading this syllabus and make your choice. For project-related questions, just contact one of the supervisors. For general questions you can contact me.

Looking forward to meeting you at UT.

Kind regards,

Louis Winnubst
UT-China Country Coordinator, Visiting Professor at USTC School of Chemistry & Materials Science.
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1 Faculty of Electrical Engineering, Mathematics & Computer Science

https://www.utwente.nl/en/eemcs/
The Faculty of Electrical Engineering, Mathematics & Computer Science offers you BSc-projects the field of Mathematics of Computational Sciences

1.1 Mathematics of Computational Sciences (MaCS)

The research interests of your supervisor from the MaCs group, Dr. Matthias Schlottbom, are in Numerical Analysis and Scientific Computing. The main focus is the development of numerical methods for partial differential equations and inverse problems. Main areas of applications are photon transport models, medical imaging, and network formation. The following BSc project are proposed:

1.1.1 A posteriori error control for differential equations

Supervisor: Dr. Matthias Schlottbom: m.schlottbom@utwente.nl

Many important applications in various areas can be modelled using differential equations; e.g., transport of light, predator-prey models, and cell movement. The complex structure of such models requires to numerically approximate a solution, and it is therefore very important to consider the accuracy of the computed numerical solution.

In this project, you will look into a posteriori error control for differential equations, which employ computable quantities, such as the numerical solution, to judge the quality of the computed solution. Besides construction and analysis of certain error estimators, you will use these to adaptively choose the discretization parameters to obtain a numerical solution as accurately as required while being as efficient as possible. You will test the developed methodology on test problems.

Necessary prior knowledge: Numerical methods for differential equations.

1.1.2 Numerical solution of eigenvalue problems

Supervisor: Dr. Matthias Schlottbom: m.schlottbom@utwente.nl

Many applications from science and engineering require to understand the spectral properties of a linear system; e.g., in the flutter analysis of long bridges to assess its structural integrity and reliability. Due to their importance, eigenvalue problems have been studied by many mathematicians, as, e.g., Euler, Lagrange, Cauchy, Sturm, Hermite, Hilbert. The matrices arising from practical applications today are so large that the study of the spectral properties requires numerical methods.

In this project, you study iterative methods for the computation of the spectrum of large matrices, and compare their complexity and convergence properties analytically and numerically.

Necessary prior knowledge: Linear algebra.

2 Faculty of Science & Technology

https://www.utwente.nl/en/tnw

Within the Faculty of Science & Technology education is in Chemical Engineering (including Chemistry and Materials Science), Applied Physics, Nanotechnology, Biomedical Engineering and Technical Medicine. The research in this faculty is focused on nanotechnology, biomedical engineering, clinical technology, sustainable energy technology and smart devices. There is a strong collaboration with industrial partners and other national and international research institutes.

2.1 Inorganic Materials Science (IMS)

https://www.utwente.nl/en/tnw/ims/

Research in the Inorganic Materials Science (IMS) group is devoted to thin film growth studies, (nano)structuring techniques, and properties of complex materials, in particular oxides. It includes materials with diverse properties, like ferroelectrics, ferromagnetics and multiferroics, piezo's, high-K dielectrics, transparent conducting oxides, non-linear optical materials, ion conductors, superconducting and related materials, and anti-reflection coatings. Its research field is focussed on thin films with modified properties by doping or by artificial layered structures and superstructures. Applications are found in, e.g., nano-electronics and spintronics, optical systems, fuel and solar cells, fluidics, bio-nano sensors. IMS offers you the following BSc project:

2.1.1 Thermal strain tuned domain structures and piezoelectric properties based on $BaTiO_3$

Supervisors: Sizhao Huang(s.huang@utwente.nl), Prof. Gertjan Koster(g.koster@utwente.nl)

Ferroelectric materials have been extensively studied due to its significant applications in microelectronic devices. $BaTiO_3$ (BTO) as one the most potential ferroelectric material, is strong interested in both ceramics and thin films. Strain engineering has shown remarkable enhancement in its thin film property and shown fascinating domain microstructures. In pulsed laser deposition (PLD) process, thin films primely consider the mechanical strain from the substrate, however, in device applications thickness, films commonly mechanically relaxed from the substrates. According to our previous research results, the thermal misfit strain takes part in a dominated role in thickness from 100 nm-1 µm in $PbZr_xTi_{1-x}O_3$, due to fact that the thermal expansion coefficients (TEC) are different. It has been neglected regarding this effect over such thickness films in properties, as well as lacking the investigations of changing microstructures.

Tasks in this assignment are:

- Fabricate a series of BTO thin films by PLD;
- Changing different TEC substrates to tune the thermal strain level in BTO films;
- Microstructure characterisation: AFM, XRD, PFM.

2.2 Physics of Interfaces and Nanomaterials (PIN)

Physics of Interfaces and Nanomaterials.

https://www.utwente.nl/en/tnw/pin/

The PIN-group is led by Prof. Harold Zandvliet and the research field involves controlled preparation and understanding of interfaces, low-dimensional (nano)structures and nanomaterials. We focus on systems that (1) rely on state-of-the art applications or (2) can potentially lead to future applications.

2.2.1 Materials with a twist: Graphene on transition metal dichalcogenides

Supervisors: Zhen Jiao (PhD student z.jiao@utwente.nl) and Harold Zandvliet (chair of the PIN group)

Graphene and transition metal (di)chalcogenides (MoS_2, WSe_2, GeSe, $MoSe_2$) are 2D van der Waals materials. Van der Waals materials have a strong intralayer (within the layer) interaction, but the interaction between the layers, the so-called interlayer interaction is very weak. Since the graphene and the transition metal (di)chalcogenides have different lattices and lattice constants one will find a moiré structure (super-lattice).

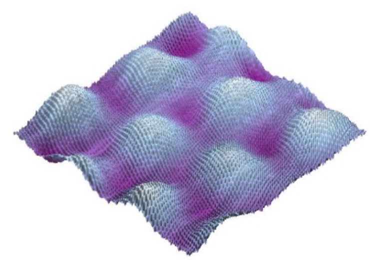
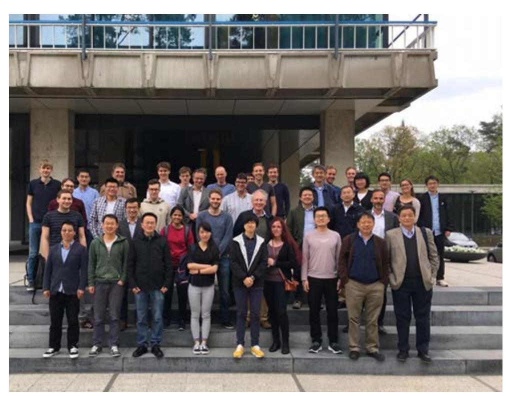


***Figure**: Scanning tunneling microscopy image of twisted bilayer graphene (twist angle 2.3 degree) measured at 77 K in the PIN group*

1. We will determine (using a model) the moiré super-lattices that can occur. We will do this for different rotation angles (twist angles).
2. We will stack a single layer of graphene on a transition metal (di)chalcogenide (WS_2 or $MoSe_2$).
3. We will measure this moiré structure with scanning tunneling microscopy and extract the twist angle.
4. We (if we have sufficient time) will use scanning tunneling spectroscopy to measure the electronic properties for different twist angles.

Cooperation between PIN group and USTC: Two joint USTC/UT workshops on 2D materials were organized by Prof. Zhenyu Zhang (USTC) and Prof. Harold Zandvliet (UT)

2018 (Hefei)



2019 (Enschede)

2.3 Inorganic Membranes (IM)

https://www.utwente.nl/en/tnw/im/

The Inorganic Membranes group treats the field of molecular separations under extreme conditions, for instance high temperature, elevated pressure, and chemically demanding environments, using inorganic and hybrid membranes. The group combines Materials Science on the sub-nanometer range length scale with Process Technology on macroscopic scale.

2.3.1 Organically-modified ceramic membranes for solvent tolerant nanofiltration (NF)

Supervisors: Nikos Kyriakou (n.kyriakou@utwente.nl) Marie-Alix Pizzoccaro-Zilamy (m.d.pizzoccaro@utwente.nl), Louis Winnubst (a.j.a.winnubst@utwente.nl)

Ceramic materials exhibit high thermal, chemical and mechanical stability. As a result, ceramic membranes are suitable for filtration processes under harsh conditions. An interesting and upcoming separation process is nanofiltration (NF), which deals with separations on molecular level, *i.e.* molecular sizes in the range of 200-1000 g mol^{-1}. The importance of NF processes and, by extend, of NF membranes lies on the possible recovery of valuable materials, such as transition metal catalysts and synthetic products, reuse of solvent mixtures, reduction of energy consumption for separations involving thermal treatments etc.

NF membranes must have pore sizes of approximately 1 nm or smaller, however inorganic membranes, depending on the material used, show pore sizes larger than the NF limit (ca. 1 nm). On the other hand, hybrid ceramic membranes (ceramic substrates with a covalently-grafted thin polymeric layer, operating as the membrane) have tunable pore size distributions and can be used for NF applications in chemical industry. In our group the preparation of such membranes involves the grafting of polymeric brushes on gamma-alumina (γ-Al_2O_3) substrates *via* simple condensation reactions, in solution or in vapor phase (an example is schematically given in the Figure). A simple reaction which, depending on the polymer used, can deliver a wide range of membranes with different properties.

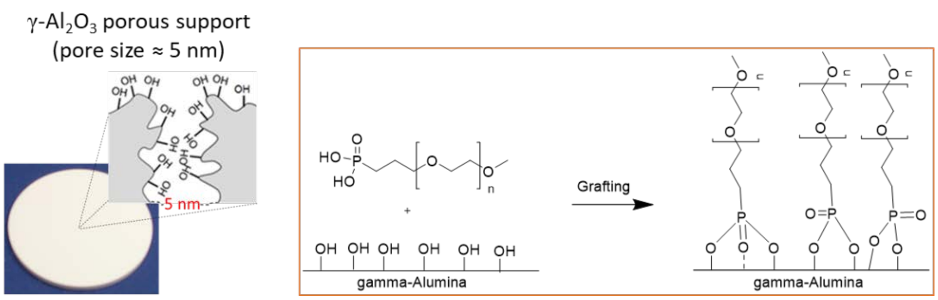


Figure: Grafting of phosphonic acid terminated polyethylene glycol on a γ-alumina porous support as an example of an organically-modified ceramic membrane.

The assignment in the IM group can be adjusted depending on your preference. It can be focused on synthesis of the membranes, characterization of the structure, study of membrane performance and/or understanding of the separation mechanisms as summarized below:

1. **Fabrication of polymer-grafted membranes on porous alumina supports**. Here synthesis and understanding of the chemistry for fabrication of hybrid membranes are important aspects.
2. **Characterisation of the as-prepared membranes** by various techniques like water contact-angle, FTIR and cyclohexane permporometry.
3. **Study of the performance and stability of membranes in water/solute mixtures.** Solvent permeability and solute rejection tests under NF conditions will be performed.

2.4 Physics of Fluids (P0F)

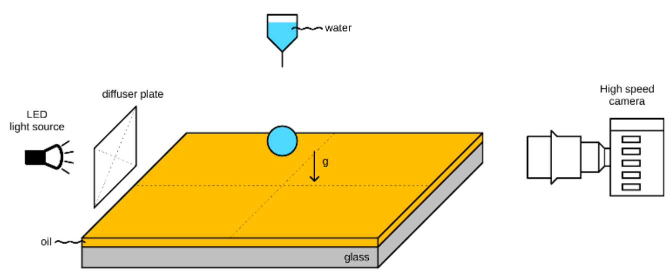
https://pof.tnw.utwente.nl/

The Physics of Fluids (PoF) group works on a variety of aspects in fluid mechanics, in particular on those related to bubbles. The focus of our work is the fundamental understanding of the phenomena of the physics of fluids, bubbles and jets, which we undertake by experimental, numerical, and theoretical means. Our research is embedded in the MESA+ institute, the Research Institute for Biomedical Technology and Technical Medicine (MIRA) of the University of Twente and the J.M. Burgers research centre for fluid mechanics (JMBC). The group receives external research funds mainly from FOM, but also from STW, NWO, SenterNovem, EU and several industrial partners.

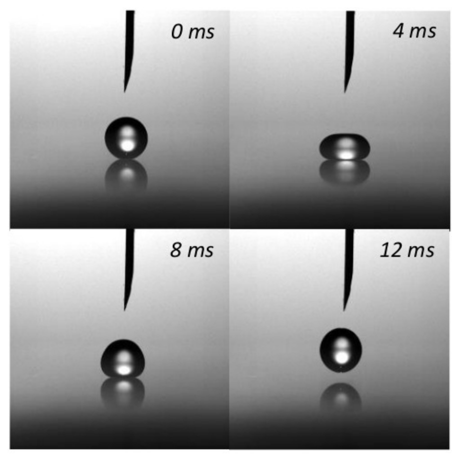
2.4.1 Bouncing drops on oil coated surfaces

Liquid drops impacting a dry surface can have different impact outcomes [1], e.g. deposition, bouncing, splash- ing. At low impact speeds, it is observed that, drops can bounce over a thin film of air, where, large viscous forces provided by thin film of air reverses the direction of the impacting drop. However, the bouncing process is not sustained indefinitely, since, a small amount of energy is lost in every bounce event which eventually brings the droplet to rest.

Present experiments focuses on energy budget analysis of liquid drops bouncing (over air film) on oil coated surfaces. Here, the impact energy is lost in the impacting liquid droplet, thin film of air and in the oil film, the contributions of which are not well understood. An experimental schematic of the setup is shown in Figure 1a. A typical bouncing event is shown in Figure 1b. In our experiments, we will measure the restitution coefficient (ratio of the droplet velocity after and before impact) from side-view visualizations, which would help in understanding the energy loss mechanism.



(a) Experimental set up; schematic



(b) Visualization

Figure 1: Experimental setup and visualizations of a bouncing process

The prospective student can choose to do experiments∗ or computations+ in the project. In the course of the experimental project he/she will learn,

a) Spincoating silicone-oil film on dry glass surfaces. Measure oil film thickness using Spectrometer.
b) Side-view visualizations, using high speed camera. *Shadowgraphy* visualization as in Figure 1b.
c) Image processing and analysis. Programming language like *Python* (or *MATLAB*) will be used.

The prospective student will closely work with some *Digital Holographic Microscopy* and *Color interferometry* experiments by Srinath Lakshman and *Volume of Fluids* simulations by Vatsal Sanjay.

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Prof. Detlef Lohse	d.lohse@utwente.nl	Meander 261

References

1. Yarin, A.L., 2006. Drop impact dynamics: splashing, spreading, receding, bouncing, . Annu. Rev. Fluid Mech., 38, pp.159-192.

2.4.2 How does travelling capillary waves entrain air?

Description

When an oil drop falls on a water pool, a cavity is formed (Figure 1(1.75 ms – 8.5 ms)). Oil spreads on the top of this cavity (Figure 1(6.5 ms – 8.5 ms)). In a recent publication from our group (Jain et al., 2019), we observed that capillary waves travelling on water-oil and oil-air interface interacts with each-other to entrain air bubbles (Figure 1(18.5 ms – 45.5 ms)). This air bubble rests inside an oil drop, which is surrounded by water pool (Figure 1(45.4 ms)). For further details of the process, please visit: https://www.youtube.com/watch?v=n8Ou-SDNkAg or refer to Jain et al. (2019).

We would like to understand the mechanism of this entainment of air bubble. In particular, we will focus on the propagation of capillary waves on different interfaces to study the entrainment process. In our simulation, we will use an in-house developed read-to-use code to solve the problem of the oil drop impact on water pool. We will focus on the hydrodynamics of the process. We will use a first of its kind three-phase contact line model for these simulation.

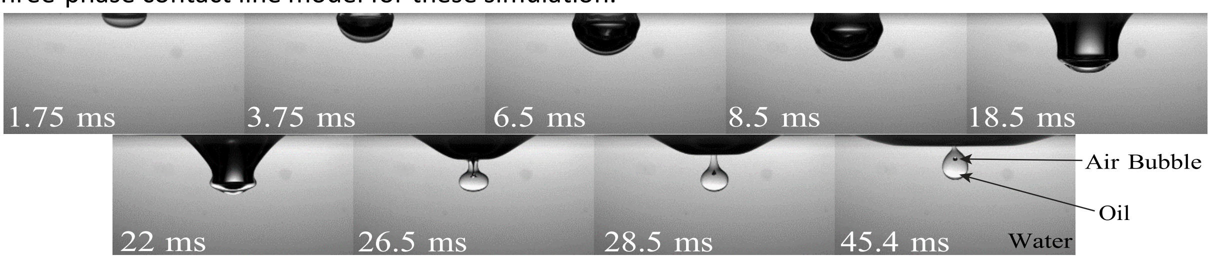

Figure 1: Temporal sequence of the air-entrainment process.

What you will do and what you will learn:

In the Physics of Fluids group, we are looking for enthusiastic students.

1. You will learn about fundamental fluid dynamics and capillary waves propagation.
2. You will get hands-on experience with Computational Fluid Dynamics (CFD).
3. You will learn how to do basic and advance data analysis.
4. You will work closely with experimentalists to understand the process.

If you have any questions, fell free to contact Vatsal or Utkarsh (details below).

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References: Jain, Utkarsh, Maziyar Jalaal, Detlef Lohse, and Devaraj Van Der Meer (2019). “Deep pool water-impacts of viscous oil droplets”. In: Soft matter

2.4.3 Direct numerical simulations of supersonic isotropic turbulence

Description

Compressible turbulence is of fundamental importance to a number of natural phenomena and industrial applications, including interstellar medium, solar winds, star-forming clouds in galaxies, high-temperature reactive flows, supersonic aircraft design, and inertial confinement fusion. Regardless of its fundamental importance, the non-linear supersonic turbulence has been paid to of little attention because the lack of available tools. On the one hand, the nonlinear phenomena of the compressive mode are too strong such that traditional linear theories and asymptotic series expansions are no longer valid. On the other hand, shocklets are more frequently generated from turbulent fluctuations as turbulent Mach number M_t increases, requiring higher challenges to the numerical methods.

While the pseudo-spectral method for incompressible homogeneous isotropic turbulence in a periodic domain has been well established, such a standard method is no longer suitable for compressible turbulence at high M_t due to the notorious Gibbs phenomenon. This barrier can be overcome by either the shock-fitting or shock-capturing approach. For Navier-Stokes turbulence, however, almost all literatures focus on the flow with M_t belonging to subsonic or near-sonic regime. Aiming to understand the statistical properties of the supersonic isotropic turbulence, Liu et al. (2019) developed a novel hybrid scheme that, for the first time, is applicable to the simulations of Navier-Stokes turbulence with M_t significantly greater than unity. The scheme utilizes an 8th-order compact scheme for smooth regions and a 7th-order WENO scheme for highly compression regions**.**

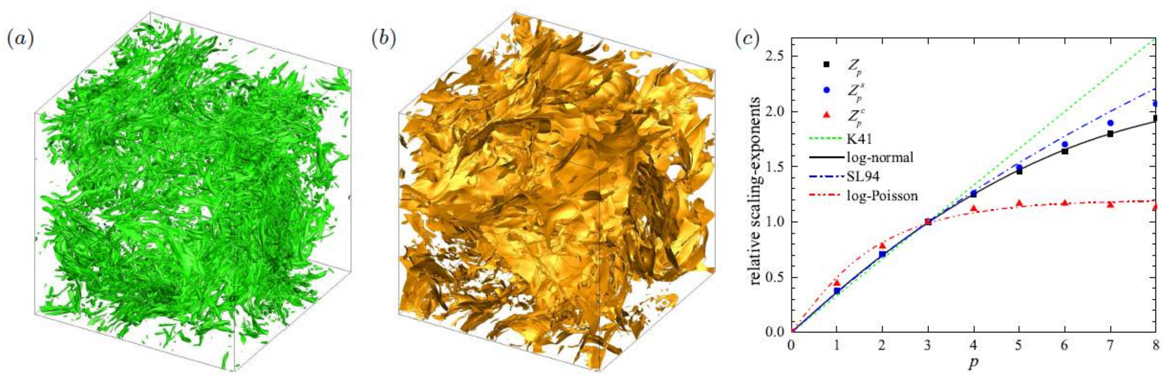

Figure 1: Numerical simulations of stationary supersonic isotropic turbulence with $M_t = 2$ and $R_\lambda = 200$. (a) Instantaneous contour of vortices. (b) Instantaneous contour of shocklets. (c) Relative scaling exponents of total velocity Z_p, shearing velocity $Z^s{}_p$ and compressive velocity $Z^c{}_p$.

Assignment

In this project, you will use state-of-the-art direct numerical simulations with hybrid scheme to figure out the scaling, statistics, and kinetic energy cascade in the supersonic isotropic turbulence.

More information can be found in https://stevensrjam.github.io/Website/.

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2.4.4 Evaporating particle-laden droplets on SOCAL surfaces: The investigation of final particle distributions

Description

The evaporation of particle-laden droplets is relevant to various scientific and industrial processes. Within most of the practical applications, e.g., inkjet printing, the final distribution of particles left by the drying droplet is crucial for the quality of the printing or patterning. The coffee stain effect is the main issue which almost applications try to avoid. Previous researches have been studied on how to suppress this effect for years. The phenomena is susceptible to many properties, i.e., contact line movement, concentration gradient, Marangoni effect, etc.
SOCAL surface has been studied due to its unique and robust wetting properties with liquids. How does a particle-laden droplet evaporate on a SOCAL surface and how do the particles distribute eventually?

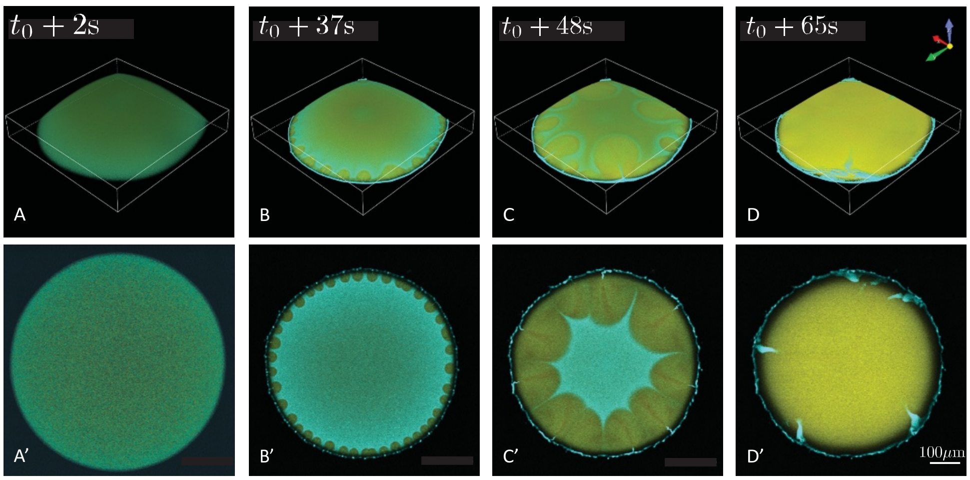

Figure 1: The experimental images of an evaporating 1,2-hexanediol-water binary droplet recorded by the confocal microscopes.

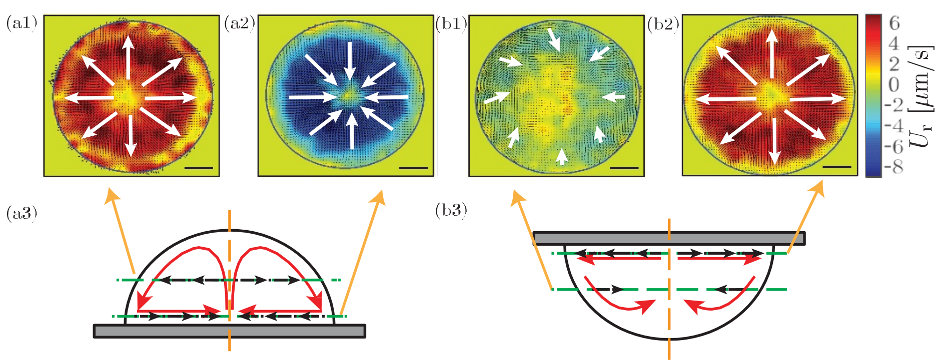

Figure 2: The MicroPIV measurement of an evaporating glycerol-water binary droplet.

Assignment

Here we plan to study the evaporation behavior of a particle-laden droplet on SOCAL surface. We will use confocal microscope to look into the droplet and do the MicroPIV measurement. Furthermore, we will use the camera to measure the geometrical parameters of the droplet by recording the evaporation process.

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2.4.5 Gentle water entry in an ethanol pool

Description:

Mixing and spreading of two miscible liquids are universal in nature as well as in daily life. It also plays an important role in industrial applications such as ink-jet printing, cosmetic and beverage industries, lab-on-a-chip devices and polymer processing.

It has been shown that when a drop of alcohol (iso-propanol) is deposited on a pool of water, solutal Marangoni flow will help dissolve it, as shown in Fig.1. Yet, little is known about the reverse process – what will happen if a drop of water is gently deposited on a pool of ethanol?

We are interested in the mixing (and spreading) process after a water drop is gently deposited in an ethanol pool – How will gravity influence the process, since water is denser than ethanol? Will Marangoni flow play a role? What's the interplay between diffusion and Marangoni convection?

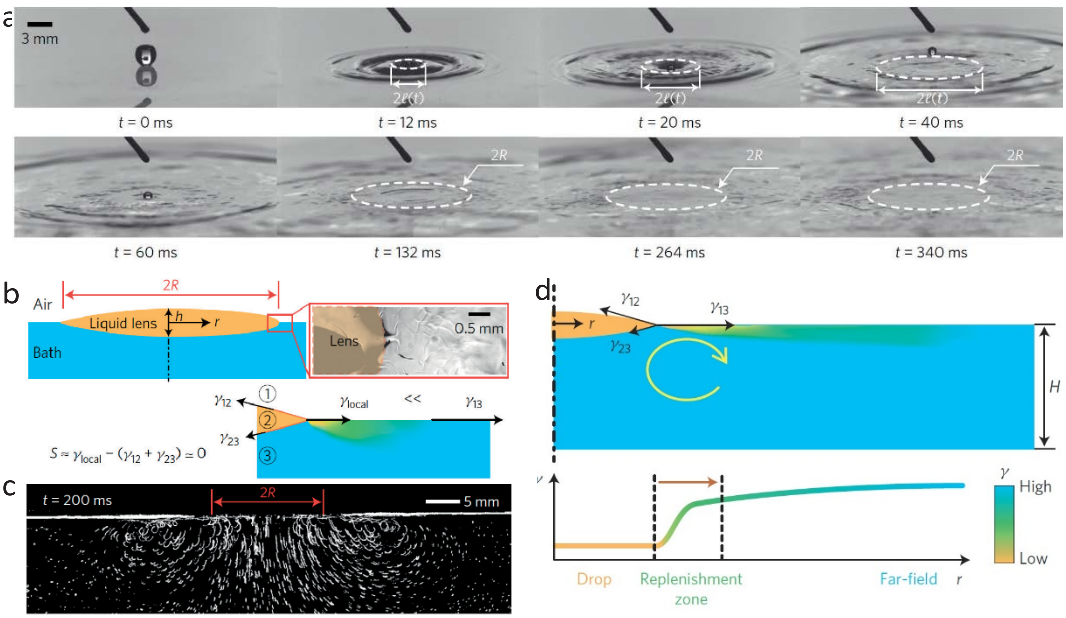

Figure 1: **a.** A drop of isopropanol (fully miscible) mixing and spreading on a water surface ($a = 1.2mm$). The dashed circles indicate the rim of the deposited droplet and the radius is $l(t)$. **b.** Schematic of the interfacial tensions of a static liquid lens of IPA on water where the spreading coefficient S becomes zero. **c.** Side-view trajectories of particles (diameter $D = 100\,\mu\text{m}$) illustrating the mixing pattern in the bath. **d.** Schematic of an interfacial tension (γ) profile of a deposited fully miscible drop on a pure solution of higher γ.

Assignment:

- Vary the pool depth H (or V/H ratio, see Fig.2) to see what will happen after the water drop is gently deposited in an ethanol pool.
- Perform PIV and/or shadowgraph and/or confocal microscopy to understand the flow field as well as the concentration distribution.

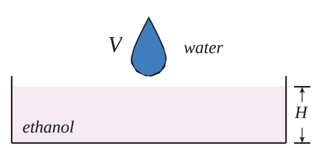

Figure 2: Variables

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3 Faculty of Engineering Technology

https://www.utwente.nl/en/et/

The vision of the faculty Engineering Technology (ET) is to be an international leading centre for intelligent production, processes and smart devices in the areas of Health Technology, Maintenance, Smart Regions, Smart Industry and Sustainable Resources. The faculty will focus on the initiation, formulation, design and development of technical solutions for current and future societal problems. This mission with its focus on societal and human challenges seamlessly fits into the University's strategy of High Tech, Human Touch.

3.1 Multiscale Mechanics (MSM)

The Multiscale Mechanics Group (MSM https://www.utwente.nl/en/et/tfe/research-groups/MSM/) of the University of Twente studies several topics of condensed matter physics, such as granular materials and powders, micro-fluidic systems and self-healing materials. In general, our research approach consists in developing models of complex materials that capture the physics at every relevant lengthscale. In the recent years, MSM has accumulated the specialized but interdisciplinary knowledges on multiscale analysis and modelling. The MSM group offers you the following possibilities for a BSc assignment.

3.1.1 Energy Propagation in Granular Systems

Contact: Dr. Kianoosh Taghizadeh (k.taghizadehbajgirani@utwente.nl)

Motivation:
Energy transfer is one of the essentials of mechanical wave propagation (along with momentum transport). The diffusive (scattering) characteristics of energy during wave propagation is focus of many ongoing investigations. Predicting the energy propagation characteristics in real and wavenumber space through disordered (simplified) model, granular media like chains can assist in understanding the overall properties of wave propagation through real inhomogeneous media like soil; this eventually, can assist in seismic prospecting, non-destructive testing or designing metamaterials.

Goal:
The effect of disorder on energy propagation is first examined using an impulse propagating in a disordered granular chain, where disorder is given by the standard deviation of the stiffness distribution of the elements/granules. At first, a Master Equation is developed to analyze the criss-cross transfer of energy across different wavenumbers for a granular 1D chain. Later, the proposed model is extended for 2D and 3D granular systems.

Tasks:
- Literature review
- To develop a master equation for 2D and 3D particulate systems
- To compare the model with DEM simulations
- Interpretation and discussion of results

Requirements:
- Fundamentals of continuum mechanics and numerical methods
- Interest in theoretical framework
- Basic programming skills, e.g. Matlab

3.1.2 Studying wave propagation in granular mixtures (soft-stiff)

Contact: Dr. Kianoosh Taghizadeh (k.taghizadehbajgirani@utwente.nl)

Motivation:
Granular mixtures play a significant role in industrial processes; for instance, mixtures of asphalt and concrete have been widely used to construct roads. Exploring and understanding the effects of granular composition on the physical properties can help in optimizing the amount of asphalt required to make the pavement robust and enduring for longer.

Goal:
The study of wave propagation allows inferring many fundamental properties of granular materials such as elastic constants and dissipation mechanism. In this work, wave propagation is studied numerically through various mixtures of granular materials in order to fine tuning stiffness with respect to different material mixtures. Finally, numerical results are compared by experimental tests to validate simulation data.

Tasks:
- Literature review
- DEM simulation of granular packings
- Post-processing
- Interpretation and discussion of results
- To develop Micro-based constitutive model

Requirements:
- Fundamentals of continuum mechanics and numerical methods
- Interest in learning an open-source DEM platform
- Programming skills, e.g. Matlab, Shell scritp, C++