LAMBERT Pierre

Master thesis and/or internships proposals for the summer 2019 and the academic year 2019-2020

Master thesis and internships proposed by Prof. Pierre Lambert and his team.

Internships positions may be discussed to go at TU Delft (https://www.tudelft.nl/en/eemcs/current/humans-of-eemcs/massimo-mastrangeli/) or FEMTO-ST (https://www.femto-st.fr/fr/Departements-de-recherche/AS2M/Presentation).

Contents

1. Break up of liquid bridge between two nonparallel surfaces

Promoter: Pierre Lambert **Supervisor:** Youness Tourtit – ytourtit@ulb.ac.be

Context:

Liquid bridge formation between two surfaces is encountered in nature and in many industrial applications such as offset printing processes, capillary adhesion, drop deposition, liquid dispensing systems… When both surfaces are not parallel (Figure below), instability of the liquid bridge formed may appear. So the liquid bridge may move itself towards to the confined region. This phenomenon can be used for example for harvest condensed water drops [1], mixture separation [2], liquid dispensing through a liquid bridge stretching …

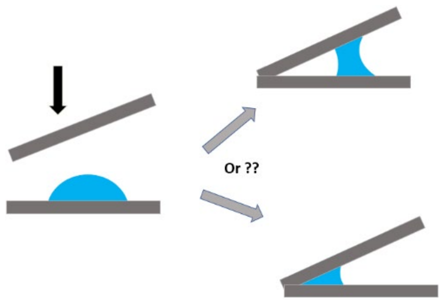

Figure 1: Liquid bridge between two non-parallel surfaces

Goals:

The objective of this study is to understand why such liquid bridge instabilities are observed between two nonparallel surfaces? What are the critical parameters that influence the liquid bridge stability? What will be the amount of liquid transferred to the inclined surface when the rupture of the liquid bridge occurs in the two cases? In which case will we have a maximum of transfer? Starting by a literature review, an experimental parametric study will be conducted by the student to answer these questions taking account all the parameters that can have influence on the liquid bridge instability, the tilt angle of the upper surface, the characteristics of the liquid, the contact angle of the liquid on the surfaces… Design of experiments methodology will be applied, and data will be further analysed with Matlab / Python / Octoave.

References:

[1] X. Heng, C. Luo, Bioinspired plate-based fog collectors, ACS Appl. Mater.Interfaces 6 (2014) 16257–16266.

[2] Wei Xu, Zhong Lan, Benli Peng, Rongfu Wen, Yansong Chen & Xuehu Ma, Directional Movement of Droplets in Grooves: Suspended or Immersed?, Scientific Reports 6, Article number: 18836 (2016)

Suggested additional reading:

- Satish Kumar, Liquid Transfer in Printing Processes: Liquid Bridges with Moving Contact Lines, Annu. Rev. Fluid Mech. 2015. 47:67–94
- Mohammadmehdi Ataei, Tian Tang, Alidad Amirfazli, Motion of a liquid bridge between nonparallel surfaces, Journal of Colloid and Interface Science 492 (2017) 218–228
- Cheng Luo and Xin Heng, Separation of Oil from a Water/Oil Mixed Drop Using Two Nonparallel Plates, Langmuir 2014, 30, 10002−10010

2. Study of a liquid bridge between two parallel surfaces

Promoter: Pierre Lambert **Supervisor:** Youness Tourtit – ytourtit@ulb.ac.be

Context :

The current trend to miniaturization leads to the production and robotic manipulation of sub-millimeter components, sometimes engineered down to the nanoscale. These micro-components must be picked and placed, then linked to each other. The conventional, macroscopic pick and place techniques (vacuum suction, tweezing, electrostatic or magnetic force) find their lower limit of operation for components of about 100µm. In order to manipulate smaller components even faster, a new pick-and-place technology is developed based on capillary adhesion. Capillary forces dominate over gravitational forces at these scales, so they are particularly efficient for micro-robotics. Nevertheless, for placing such components the liquid bridge should be broken, consequently liquid remains on the component and it is not suitable which leads to the scientific question, how can we handle the liquid bridge rupture in order to minimize the maximum possible the amount of the liquid remaining on the components.

Goal of the project:

This project deal with the study of the liquid bridge rupture between two parallel surfaces in terms of the bridge height rupture and liquid transfer ratio. In the first case, the bottom (component) and the upper (gripper) surfaces are similar to each other and in the second case the upper surface is linked to a capillary tube through a hole and open from both sides as can be seen on Figure1. The aim of this project is:

1- To quantify the influence of adding to the capillary tube on the rupture of the liquid bridge and consequently on the liquid remaining on the bottom surface.
2- Identify parameters that could be interestingly varied in order to minimize the amount of the liquid remaining on the bottom surface.

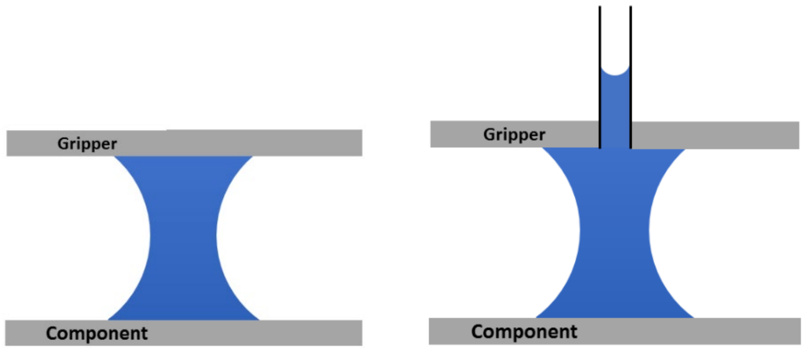

Figure 2: Liquid bridge between two parallel surfaces (left). The hole of the upper surfaces is linked to a capillary tube which allows the free interface of the liquid bridge inside the tube (right).

Tasks and planning:

1- To do the state of the art.
2- Design and fabricate (Nanoscribe) surfaces and mount the appropriate experimental setup.
3- Experiments: place a water drop on the bottom surface, move the upper surface toward the drop to create the liquid bridge then record the bridge dynamics from the side, as a function of the gap between the two surfaces.
4- Interpret experimental results: transfer ratio, rupture height of the bridge.

3. Instrumented nasal cast for nose-to-brain drug delivery

Promotors: Benoit Haut & Pierre Lambert (pierre.lambert@ulb.ac.be)

Context:

Nose-to-brain drug delivery is a very promising way to deliver drugs. For this purpose, the airflow generated by a spray device mush convey the drug particles through the nose and deposit them in the so-called olfactive area. Since each patient nose anatomy is different, this process must be optimized to become patient specific.

Goals:

According to the student profile, we can consider two different goals (the topic can be duplicated):

- Transform a nose cavity MRI image into a CAD file used in Ansys-Fluent and model the transport equations to be implemented in the digital simulation
- Transform a nose cavity MRI image into a stl file to be printed and adapted to include sensors (pressure, PIV…) to analyse the air flow and drug deposition experimentally

This work would be the follow up of a very promising ongoing master thesis.

References:

- A. Dastan, O. Abouali, G. Ahmadi. CFD simulation of total and regional fiber deposition in human nasal cavities. Journal of Aerosol Science 69 (2014) 132–149
- R. Hughes, J. Watterson, C. Dickens, D. Ward and A. Banaszek. Development of a nasal cast model to test medicinal nasal devices. Proc. IMechE, Vol. 222 Part H: J Engineering in Medicine (2008) 1013–1022
- K. Inthavong, Q. Ge, C. Se, W. Yang, J. Tu. Simulation of sprayed particle deposition in a human nasal cavity including a nasal spray device. Journal of Aerosol Science 42 (2011) 100–113
- K. Inthavong, Z. Tian, J. Tu, W. Yang, C. Xue. Optimising nasal spray parameters for efficient drug delivery using computational fluid dynamics. Computers in Biology and Medicine 38 (2008) 713–726
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- J. Xi, F.E. Yuan, Y. Zhang, D. Nevorski, Z. Wang, Y. Zhou. Visualization and Quantification of Nasal and Olfactory Deposition in a Sectional Adult Nasal Airway Cast. Pharmaceutical Research 33 (2016) 1527–1541
- J. Xi, Z. Wang, D. Nevorski, Th. White, Y. Zhou. Nasal and Olfactory Deposition with Normal and Bidirectional Intranasal Delivery Techniques: In Vitro Tests and Numerical Simulations, Journal of Aerosol Medicine and Pulmonary Drug Delivery 30 (2017) 118–131

4. Thermocapillary pump

Promoters: Benoit Scheid & Pierre Lambert (pierre.lambert@ulb.ac.be)

Context:

To create fluid motion in microfluidic devices, pumps are used. Over the last fifty years, different pumping principles have been invented: from centrifugal pumps to thermocapillary pumps. The pumping principles can be divided into two categories: mechanical pumps and non-mechanical pumps. Among the latter ones, Marangoni thermocapillary flows are a promising solution [Amador2018] enabling micropump without any moving mechanical parts. The working principle is based on the presence, in the pumping device, of some geometrical features to maintain liquid-air interfaces in the device. When exposed to a temperature gradient, such an interface develops a surface tension gradient, and therefore a surface stress creating the fluid flow.

Goals:

A numerical study has been conducted providing orders of magnitudes of the flow rate and the blocking pressure developed by a Marangoni pumping device. The effect of design parameters (fluid, channel gap and width, number of Marangoni driving pockets…) is now better understood.

The work expected in this master thesis is the production of PDMS prototypes using photolithography and molding. A proper experimental set up to characterize the pumping device must be developed, and the experimental campaign has to be achieved to validate the numerical results. The solution will be benchmarked with respect to Amador's results.

References:

Amador GJ, Tabak AF, Ren Z, Alapan Y, Yasa O, Sitti M. Thermocapillary-driven fluid flows within microchannels. 2018

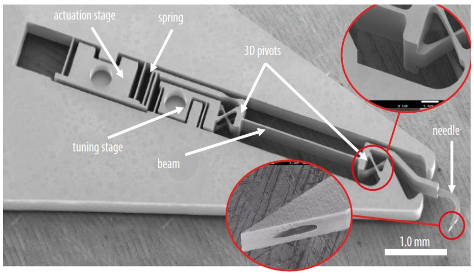
5. 3D microfabrication of a glass force sensor

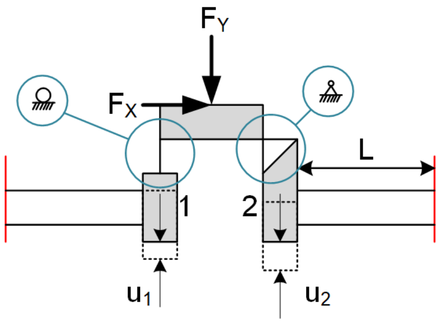
Promoters: Christophe Collette & Pierre Lambert

Context:

Glass is a key material used for research, industry and society, exhibiting outstanding properties, among which low loss factor (excellent for resonators), low thermal expansion (excellent for precision mechanics), optical quality surface finish, transparent (excellent to guide light and embed photonic functions), high yield stress (very good for large range and high resolution force sensors) and optical properties excellent to measure deformation of flexures by photo-elasticity or Bragg gratings. However shaping glass at the small scale (<1mm) is very challenging.

To this aim, ULB will acquire soon (August 2019) a new dedicated microfabrication platform able (www.femtoprint.ch). An example of typical realization is given here below (left picture).





Goals:

The goal is to design and produce glass flexure hinges (ie compliant elements used in microrobotics) to create a microforce sensor array or matrix, able to characterize a variety of phenomena such as droplet sliding or insect walking. A starting point is the right figure here above, exhibiting the principle of a 2 degrees-of-freedom force sensor unit, based on thin flexure hinges of length *L*. These compliant elements conveys the force components through the structure and lead to displacement u1 and u2 to be measured.

References:

B. Lenssen et Y. Bellouard, Applied Physics Letter 101, 103503 (2012)

A. Steimle, Laser Technik Journal, 1/2018 (2018)

Y. Bellouard, On the bending strength of fused silica flexures fabricated by ultrafast lasers, September 2011 / Vol. 1, No. 5 / OPTICAL MATERIALS EXPRESS 816

Angelo Buttafuoco, Cyrille Lenders, Raymond Clavel, Pierre Lambert and Michel Kinnaert. Design, manufacturing and implementation of a novel 2-axis force sensor for haptic applications. Sensors and Actuators A, 209, 107-112 (2014)

Nguyen Thanh-Vinh et al. Sensors and Actuators A

S. Henein, Conception des guidages flexibles, PPUR, 2001

L. Howell, Compliant mechanisms, Wiley, 978-0-471-38478-6, 2001

6. 3D microfabrication of a glass resonator

Promoters: Christophe Collette & Pierre Lambert

Context:

Glass is a key material used for research, industry and society, exhibiting outstanding properties, among which low loss factor (excellent for resonators), low thermal expansion (excellent for precision mechanics), optical quality surface finish, transparent (excellent to guide light and embed photonic functions), high yield stress (very good for large range and high resolution force sensors) and optical properties excellent to measure deformation of flexures by photo-elasticity or Bragg gratings. However shaping glass at the small scale (<1mm) is very challenging.

In August 2019, ULB will acquire a new dedicated microfabrication platform (www.femtoprint.ch), allowing printing in 3D mechanism in glass with an arbitrary level complexity.

Goals:

Taking advantage of the new opportunity offered by the Femtoprint, the objective of this project is to develop a small resonator, which will be used for developing a new generation of inertial sensors. Due to the low internal dissipation of the glass, the inertial sensor will have an extremely high resolution, better than first choice commercial products [1].

The work to be conducted in the thesis will include the following steps:

- Developing and printing the glass mechanism

- Using the mechanism to build a resonator. To this purpose, we will use the mechanical part of a commercial seismometer.

- Characterizing the properties of the resonator with a high-resolution interferometer.

References:

[1] Collette C., *et al.* A., Inertial sensors for low frequency seismic vibration measurement, Bulletin of the seismological society of America (2012) vol. 102(4), 1289-1300.

7. Experimental study of the influence of defects on micro-devices self-alignment behaviour

Promoters: Pierre Lambert Supervisor: Adam Chafai – adam.chafai@ulb.be

Context: Micro-assembly and pick and place industries are facing many challenges due to miniaturization and increasingly stringent standards concerning the integrity of the handled micro-objects. The current dominant technology for the pick and place industry is using vacuum (suction) as a gripping method. This technology is reaching its limits and companies are seeking for innovative and reliable gripping technics to adjust their offer to tomorrow's micro-component industry.

A promising solution is using liquid as a bond between the gripping tool and the object to handle. This strategy (also known as capillary gripping) which is very efficient at small scales, plays an important role in preventing micro-objects from being damaged by the gripping tool.

But one of the crucial points in using capillary forces to handle micro-devices is the transportation phase. Depending on their mass and geometry, micro-devices can especially have different self-centering behaviors. As each component is slightly different (due to small defects, residual dust and other impurities on their surface) it is important to understand how these little variations can have an impact on the self-centering process (and thus on the lateral restoring forces).

Goals: The aim of this project is to assess how these fluctuations play a role in the variation of the behavior of the handled micro-objects. According to the student profile, different goals may be considered:

- Manufacturing of chips with controlled artificial defects using the FemtoPrint technology (which allows complex and high-resolution 3D printing for glass micro-devices) or other means to identify.
- Experimental characterization in order to study the influence of these variations on the dynamical behavior of self-centering.
- Experimental characterization in order to study the influence of these variations on the lateral restoring forces.

References:

- Y. Vitry, Two-dimensional dynamics of self-alignment including shift, lift and tilt (2017)
- M. Mastrangeli, Surface tension-driven self-alignment (2017)
- I. Routa, Surface Tension-Driven Self-Alignment of Microchips on Low-Precision Receptors (2013)
- P. Lambert, Spectral analysis and experimental study of lateral capillary dynamics for flip-chip applications (2010)
- H. Lu, Dynamic Analysis of Flip-Chip Self-Alignment (2005)
- P. Lambert, Capillary forces in microassemly, Springer (2007)
- P. Lambert, Surface Tension in Microsystems, Springer (2013)

8. Experimental characterization of porous samples for liquid dispensing at the nanoliter scale

Promoters: Pierre Lambert Supervisor: Adam Chafai – adam.chafai@ulb.be

Context: Micro-assembly and pick and place industries are facing many challenges due to miniaturization and increasingly stringent standards concerning the integrity of the handled micro-objects. The current dominant technology for the pick and place industry is using vacuum (suction) as a gripping method. This technology is reaching its limits and companies are seeking for innovative and reliable gripping technics to adjust their offer to tomorrow's micro-component industry.

A promising solution is using liquid as a bond between the gripping tool and the object to handle. This strategy (also known as capillary gripping) is very efficient at small scales. But the stability of such a process mainly depends on the ability to generate even volumes of liquid each time the gripper goes for a new micro-component. Using a porous media as a liquid reservoir (with which the gripper would come in contact to get a small amount of this liquid) could allow to overcome the limitations of the industrial "turnkey solutions". This droplet generation indeed becomes a real challenge when it comes to handle micro-object at high speed: the adequate volume is then about a few nanoliters and must be transferred to the gripper in only a few milliseconds. During the transfer of liquid from a porous media to the gripping tool, the capillary forces developed between the liquid and the porous media challenge the ones developed between the liquid and the gripping tool, limiting the extracted volume. The reconstitution speed of the liquid layer on the surface of the porous media, where the tool gets the liquid, is the parameter limiting the rate of extraction for the generation of droplets.

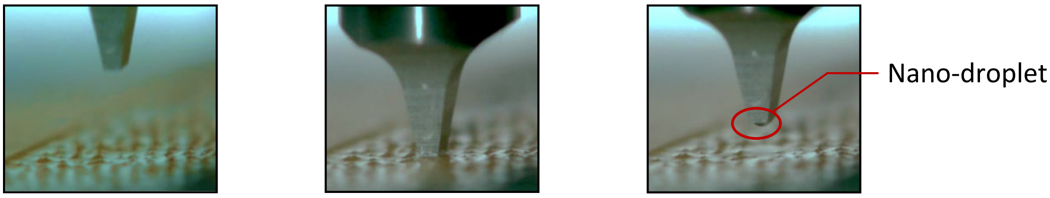


Fig.: (a-b) A metallic gripping tool coming in contact with an imbibed porous media, creating a liquid bridge. (c) After the rupture of the liquid bridge, the tool leaves with a droplet of a few nanoliters.

Goals: According to the student profile, different goals may be considered:

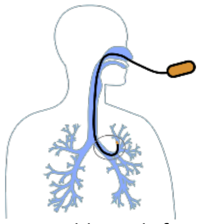
- Design of a setup allowing to automatically gather information about the ability of several porous samples to generate small and constant amounts of liquid (i.e. picking of the liquid, automatic volume assessment by image processing and statistical study of gathered data).
- Gathering/production of porous samples of different nature: fabrics, granular media, other porous media…
- Exploratory experimental study in order to characterize the samples.

References:

• A. D. Gat, Wicking of a liquid bridge connected to a moving porous surface (2012)
• K. A. N. Iyer, Modelling and simulation of drop spreading on fibrous porous media (2014)

9. Study of « smart swelling materials » for steerable medical devices

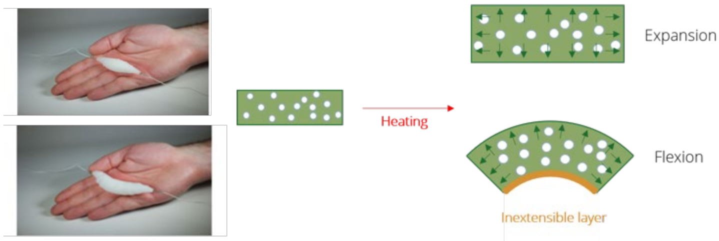
Promoter: Alain Delchambre (BEAMS) – Pierre Lambert (TIPs)
Supervisor: Gilles Decroly – gilles.decroly@ulb.ac.be



Steerable tools for navigation in endoscopy

Description : Soft robotics opens many new opportunities, but the lack of adapted actuation methods makes difficult the rise of new applications. In the medical fields of minimally invasive surgery and endoscopy, soft steerable devices (typically catheters) could enable reaching locations through tortuous trajectories in the human body, while minimizing the risk of damage on tissues. They could become an alternative to the commercially available cable actuated or magnetic steerable catheters, because of their softness, safety, ability achieve more complex movements, and low cost.

This work aims at investigating the possibility to use smart swelling materials to develop a miniaturized actuator for endoscopy. A promising soft swelling material uses the large volume variation of micro-bubbles of a fluid upon liquid-gas transition, distributed in a silicone elastomer matrix [1]. The expansion of the material is in this case generated by heating the material. A miniaturized swelling material-based actuator could allow to generate complex movements with simple, modular, and inexpensive designs. However, several challenges related to the miniaturization, the stimulus (i.e. how to generate the heat), and the characterization of the material remain.



Soft swelling materials for soft actuator: principle [1]

Goal: The goal of this project is to study the potential of swelling materials for the development of a steerable medical device. This will require to realise a state of the art comparing swelling materials, to characterize the material in term of bending/expansion as function of different parameters, and to explore underlying principles and models. According to the student profile, the emphasis can be put on various point of the project. Different fluid/elastomer combinations could be tested to optimize the material for medical applications. The development of prototypes will also be part of the project.

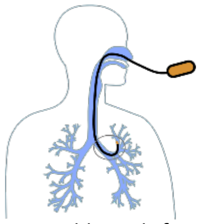
Tasks:

- Literature review / state of the art on swelling materials / understanding of the project
- Characterization of the material:
    - Fabrication of the samples (moulding)
    - Characterization tests (design of experiment, building test benches, bending test, tensile test, heating)
    - Model / study of the results (FEM if known by candidate, analytical model, statistic st udy, etc.)
- Proof of concept
    - Design and optimization of a prototype

[1] A. Miriyev et al., Soft material for soft actuators, Nat. Commun. 8 (2017).
[2] A. Miriyev et al., Functional properties of silicone/ethanol soft-actuator composites, Mater. Des. 145 (2018).

10. Mechanical programming for soft steerable medical devices

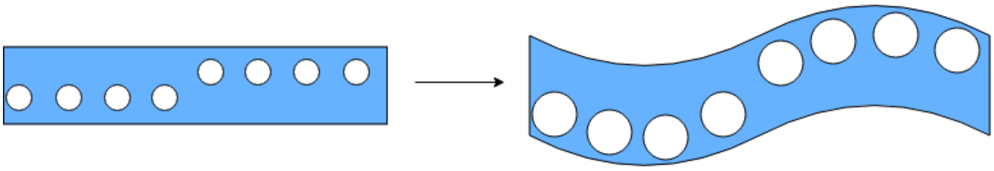
Promoter: Alain Delchambre (BEAMS) – Pierre Lambert (TIPs)
Supervisor: Gilles Decroly – gilles.decroly@ulb.ac.be



Steerable tools for navigation in endoscopy

Description : Soft robotics opens many new opportunities, but the lack of adapted actuation methods makes difficult the rise of new applications. In the medical fields of minimally invasive surgery and endoscopy, soft steerable devices (typically catheters) could enable reaching locations through tortuous trajectories in the human body, while minimizing the risk of damage on tissues. They could become an alternative to the commercially available cable actuated or magnetic steerable catheters, because of their softness, safety, ability achieve more complex movements, and low cost.

This work aims at investigating the possibilities to generate complex movements by programming them in the mechanical design. The working principle is to create bubble in a soft silicone matrix, at specific locations. By inflating these bubbles, the material will undergo anisotropic deformation, and complex movements can be obtained. Different solutions can be considered to inflate the bubbles (using fluidic actuation [1], phase-change [2]), to design complex movement (repartition of the bubbles, anisotropic inflation, …) and for the fabrication method (moulding, 3D printing, …).



Principle: generation of a complex movements programmed by the distribution of the bubbles

Goal: The goal of this project is to study the potential of mechanical programming for the development of a steerable medical device. This will require to realise a state of the art comparing the different solutions discussed above. The different solution identified will be tested, characterized, and compared experimentally, and the key parameters will be studied. A proof of concept will also be developed. The project is intentionally relatively general. According to the student profile, the emphasis can be put on various point of the project and could open various applications.

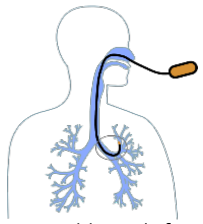
Tasks:

- Literature review / state of the art / understanding of the project
- Design (choice of the configuration, generation of complex movements)
- Experimental study and characterization
  - Fabrication of the samples (fabrication method, inflation method, …)
  - Characterization tests (identification of parameters and output, design of experiment, building test benches, …)
- Proof of concept
  - Design and optimization of a prototype

[1] B. Gorissen et al., Elastic inflatable actuators for soft robotic applications, Adv. Mater. 29 (2017).
[2] H. Matsuoka et al., Development of a rubber soft actuator driven with gas/liquid phase change, Int. J. Autom. Technol. 10 (2016).

11. Design and characterization of a triboelectric contact sensor for soft steerable medical devices

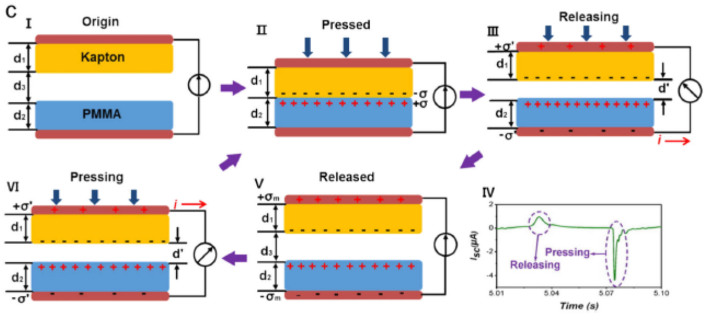
Promoter: Alain Delchambre (BEAMS) – Pierre Lambert (TIPs)
Supervisor: Gilles Decroly – gilles.decroly@ulb.ac.be



Steerable tools for navigation in endoscopy

Description : Soft robotics opens many new opportunities, but the lack of adapted actuation and feedback methods makes difficult the rise of new applications. In the medical fields of endoscopy, soft steerable devices could enable reaching locations through tortuous trajectories in the human body, while minimizing the risk of damage on tissues. They could become an alternative to the commercially available cable actuated or magnetic steerable catheters, because of their softness, safety, ability achieve more complex movements, and low cost.

This work aims at investigating the potential of the triboelectric effect for the development of embedded sensors for soft steerable catheter. Triboelectric sensors are based on measure of electric charges that appear when there is friction between two dielectrics [1]. This phenomenon can be used with silicones as dielectric and does not require external power source. It is consequently very promising for integration in soft robots. However, many challenges remain. The influence of the surface structure [2], of the material combination, and on the sensor, configuration must be further studied, to obtain a stable and reproductive signal, and allow integration in a soft steerable catheter.



Working principle of triboelectric effect [1]

Goal: The goal of this project is to study the potential of triboelectric effect for the development of embedded sensors for soft steerable medical device. This will require to realise a state of the art on the triboelectric effect, to characterize it in term as a function of different parameters, and to explore underlying principles and models. Different materials and geometrical configurations could be tested to optimize the material for medical applications. The development of prototypes will also be part of the project.

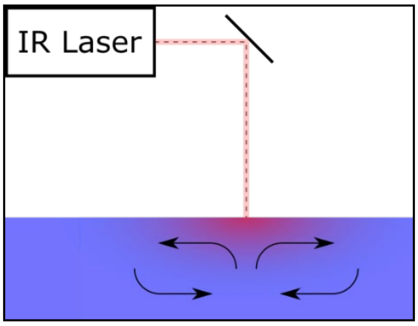
Tasks:

- Literature review / state of the art on triboelectric sensors / understanding of the project
- Characterization
  - Fabrication of the samples (moulding, 3D printing)
  - Characterization tests (design of experiment, building test benches, mechanical and electrical characterization, …)
  - Model / study of the results (analytical model, statistic study, ...)
- Proof of concept
  - Design and optimization of a prototype

[1] S. Niu et al., Theoretical systems of triboelectric nanogenerators, Nano Energy. 14 (2015).
[2] R. Ccorahua et al., Nano Energy Enhanced-performance bio-triboelectric nanogenerator based on starch polymer electrolyte obtained by a cleanroom-free processing method, Nano Energy. 59 (2019).

12. Fluid selection to enhance a laser-induced thermocapillary flow (may be coupled to an internship in France, FEMTO-ST)

Promotor: Pierre LAMBERT **Supervisor:** Franco PINAN BASUALDO – fpinanba@ulb.ac.be



Context: A temperature gradient is created in a water-air interface using an infrared (IR) laser. This creates a surface tension gradient, due to its temperature dependence, which in turn generates a flow due to the Marangoni effect. We have seen that since water is a polar fluid and has a high surface tension, this interface is very susceptible to surfactant contamination. Such surfactants weaken the thermocapillary flow to the point where after a couple minutes of exposition to air, the flow completely disappears.

Goals: The main goal to this project is to find a suitable fluid (normally some oil) to replace the water to reduce the surfactants effect. According to the student profile, we can consider different objectives:

- Selection and characterization of some fluids. Some properties might need to be measured: mainly the dependence of surface tension on temperature and the absorption coefficient for a given wavelength.
- Numerical simulation. We have developed a finite elements simulation using COMSOL, but the development of a new code can be considered.
- Characterize flow and compare the results with the simulations. PTV measurements have been performed in the past, but the implementation of new techniques can be considered.
- Selection of the best fluids according to different criteria: Maximum flow velocity, resistance to surfactant contamination, etc.
- The use of multiple fluid layers can be analyzed.

During this project, the student will develop the following skills: surface rheology and characterization of a fluid interface, finite elements simulations and flow velocity measurement using image analysis.

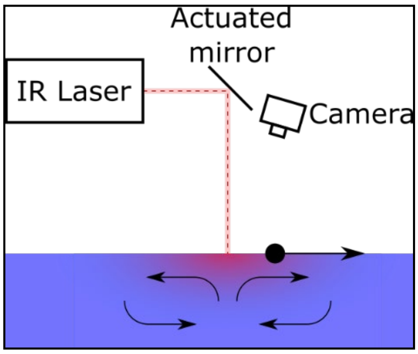
Internship: This project is part of a collaboration between the ULB and the FEMTO-ST Institute (Besançon, France). Therefore, it is possible to link this master thesis proposal with an internship in France in micromanufacturing or microrobotics.

References:

[1] Terrazas-Mallea, R.T., Bolopion, A., Beugnot, J.-C., Lambert, P., Gauthier, M., 1D manipulation of a micrometer size particle actuated via thermocapillary convective flows, (2017) IEEE International Conference on Intelligent Robots and Systems, 2017-September, art. no. 8202187, pp. 408-413.
[2] Muñoz, E., Quispe, J., Lambert, P., Bolopion, A., Terrazas, R., Régnier, S., Vela, E. Optimizing the speed of single infrared-laser-induced thermocapillary flows micromanipulation by using design of experiments (2017) Journal of Micro-Bio Robotics, 12 (1-4), pp. 65-72.
[3] Terrazas-Mallea, R.T., Bolopion, A., Beugnot, J.-C., Lambert, P., Gauthier, M. Laser-Induced thermocapillary convective flows: A new approach for noncontact actuation at microscale at the fluid/gas interface (2017) IEEE/ASME Transactions on Mechatronics, 22 (2), art. no. 7782755, pp. 693-704.

13. Geometry optimization for thermocapillary micromanipulation of 3D printed particles using Nanoscribe or FEMTOprint (may be coupled to an internship in France, FEMTO-ST)

Promotor: Pierre LAMBERT **Supervisor:** Franco PINAN BASUALDO – fpinanba@ulb.ac.be



Context: A temperature gradient is created in a water-air interface using an infrared (IR) laser. This creates a surface tension gradient, due to its temperature dependence, which in turn generates a flow due to the Marangoni effect. We use the resulting flow to control particles floating in the free surface. With this setup, we were able to control spherical particles (100µm to 1mm diameter) in position and simple 3D printed particles both in position and orientation.

Goals: So far, the previously described setup has been used to manipulate simple particles. According to the student profile, we can consider different objectives:

- Develop control strategies for complex geometries. Multiple laser spots or light patterns might be needed to manipulate complex and big particles.
- The second objective is to design particles to facilitate their manipulation with the setup:
  - Optimize the shape of the particle to attain the maximum speed.
  - Design particles to simplify the simultaneous control of position and orientation.
  - Analyze if with the right geometry, we could obtain a stable configuration (pulling instead of pushing).

During this project, the student will develop the following skills: computer vision and image processing, design of a controller based on an empirical model, development of quantitative parameters to compare different control techniques and use of advanced 3D microprinting techniques like Nanoscribe and FEMTOprint. Additionally, other fields are involved: fluid mechanics and wetting phenomena.

Internship: This project is part of a collaboration between the ULB and the FEMTO-ST Institute (Besançon, France). Therefore, it is possible to link this master thesis proposal with an internship in France in micromanufacturing or microrobotics.

References:

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[2] Muñoz, E., Quispe, J., Lambert, P., Bolopion, A., Terrazas, R., Régnier, S., Vela, E. Optimizing the speed of single infrared-laser-induced thermocapillary flows micromanipulation by using design of experiments (2017) Journal of Micro-Bio Robotics, 12 (1-4), pp. 65-72.

[3] Terrazas-Mallea, R.T., Bolopion, A., Beugnot, J.-C., Lambert, P., Gauthier, M. Laser-Induced thermocapillary convective flows: A new approach for noncontact actuation at microscale at the fluid/gas interface (2017) IEEE/ASME Transactions on Mechatronics, 22 (2), art. no. 7782755, pp. 693-704.

14. Modélisation de la mécanique des “muscular thin films”.

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Co-promotor: Dr Thomas LESSINES (thomas.lessinnes@epfl.ch)

Contexte

Ces 15 dernières années ont vu l’éclosion de divers matériaux bio-hybrides. Parmi ceux-ci, les “muscular thin films” (MTF) [1,2] ont reçu un intérêt particulier car les expériences ont rapidement montré une grande versatilité. Elles ont commencé par une démonstration de principe [1]: en assemblant une couche fine en polymère synthétique (PDMS) et une couche de cardiomyocytes ventriculaires (cellules de muscles) on obtient un fin film que l’on peut activer en déclenchant la contraction des myocytes. Ensuite, les mêmes expérimentateurs ont montré [2] que leurs techniques pouvaient être utilisées pour construire un nageur qui se déplace en imitant la nage d’une méduse.

Différents groupes se sont intéressés à la modélisation numérique de ce système (par exemple [3,4]). Une des difficultés rencontrées est que ce système nécessite des lois constitutives non linéaires car le tissus musculaire subit des grandes déformations. Ainsi les théories de coques standard échouent et c’est pourquoi une description analytique simple du système manque toujours. Un tel modèle simplifié serait cependant fort utile pour permettre la construction de systèmes de plus en plus complexes dont différentes parties seraient constituées de ces matériaux bio-hybrides.

Objectifs

L’objectif du mémoire sera d’abord de faire l’état de l’art de la question et ensuite d’implémenter une nouvelle théorie de coque [5,6] pour obtenir un modèle efficace simple du système. Pratiquement, l’étudiant renforcera ses connaissances en biomécanique, en mécanique des solides sous grandes déformations, en méthodes variationelles et en géométrie différentielle.

Références

[1] A. Feinberg, *et al.*, "Muscular Thin Films for Building Actuators and Powering Devices”, *Science*, vol. 317, (2007)

[2] J. C. Nawroth, *et al.*, "A tissue-engineered jellyfish with biomimetic propulsion”, *Nature Biotech. Letters*, vol. 30 (2012).

[3] M. Böl, *et al.*, "Computational modeling of muscular thin films for cardiac repair”, *Comp. Mech.*, 43, (2009).

[4] J. Shim, *et al.*, "Modeling of cardiac muscle thin films: Pre-stretch, passive and active behavior”, *J. Biomech.*, 45, (2012).

[5] A. Yavari, “A geometric Theory of Growth Mechanics”, *J Nonlinear Sci.,* 20, (2010).

[6] T. Lessinnes, *et al.*, “An effective model for self-healing bilayers", *In prep.*, (2019).

15. A définir

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Context

Goals

References

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LAMBERT Pierre
Master thesis and/or internships proposals for the summer 2019 and the academic year 2019-2020