Prof. Dr. Ulrich Mescheder
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Semester project master SMA and MZ, Summer semester 2019

Project: (5 + 1 ECTS= 150 + 30 h)

MED: project with medical background (also for MTZ students)

1) Application of a micromechanical laser scanning system

Within a cooperative project (Prof. Kallmann, Prof Mescheder) a laser projection system is developed which is based on a micromechanical, electrostatically actuated cylinder lens which allows to adjust the beam width of a laser beam within laser projection systems (e.g. in a profilometer). An experimental set-up and the micromechanical component have been developed and are available for testing.
Within the project, the system should be evaluated experimentally (validation of the concept). The developed models (COMSOL, FEM) should be adjusted in respect to the experimental results.

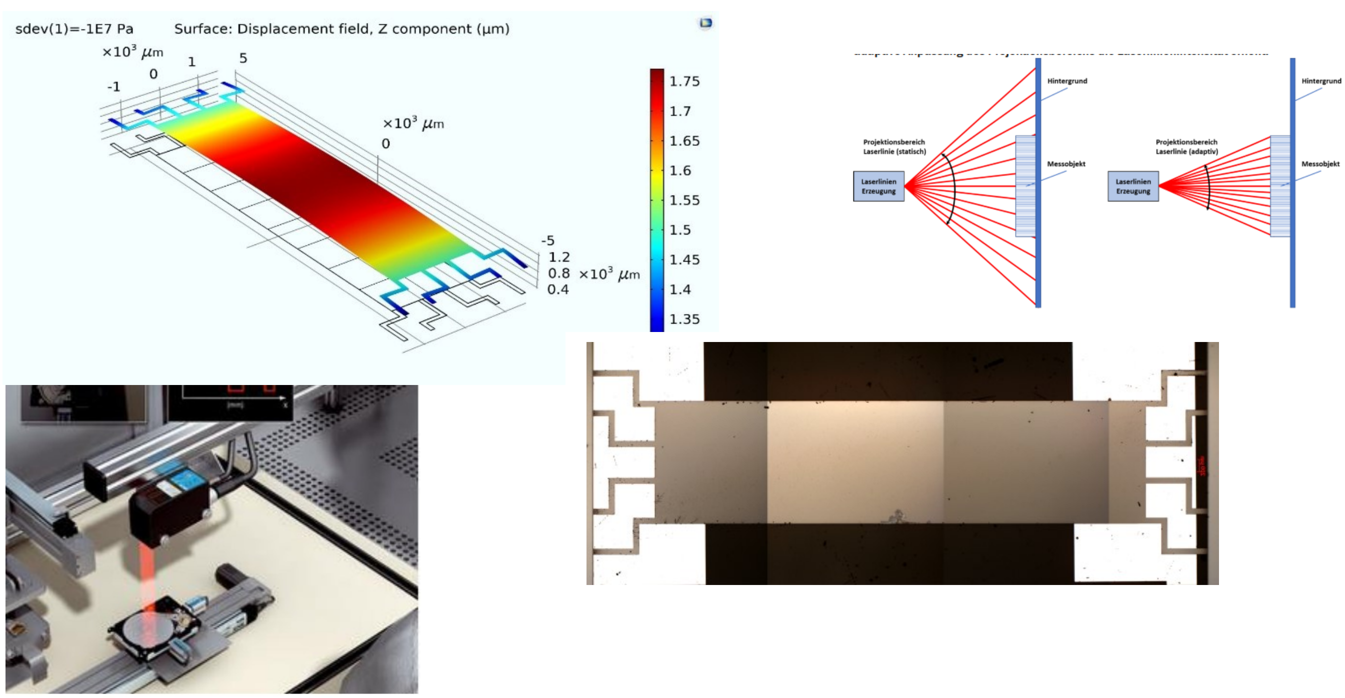

Fig.: Top left: simulated bending of the micromechanical, cylinder shaped membrane , top right: principle of laser beam adjustment, bottom left: Profilometer, Sick AG, tor right: microscopic picture of fabricated micromechanical device

Tasks:

- Literature Study
- Experimental characterization (mechanical, optical and dynamical properties)
- analysis of the data and evaluation of different membrane suspensions regarding buckling and parabolic deformation
- Optimisation of FEM-models
- Documentation

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2) Characterization and optimization of a fluid initiation device for biological system with Blood-Brain-Barrier application

Context The understanding of cell to cell interactions is of high interest for many biomedical applications. Examples are therapeutic interventions resulting from analyzing tumor-stroma interactions or permeability studies of new central nervous system pharmaceuticals with the help of *in-vitro* models of the Blood-Brain-Barrier (BBB). To enable analysis of various cell behaviours, advanced 3D cell cultivation systems in combination with different qualitative and quantitative analysis methods are needed and are subject of many research activities. To provide the needed 3D environment for cell cultivation, often chambers separated by permeable membrane structures are used.

Aim of the research The candidate will start with an already established microfluidic platform for mimicking the BBB system. This project follows a Master thesis during which a fully operational prototype of automatic fluid initiation device for the BBB microfluidic chip was developed. The Si-based microfluidic design consists of two parallel channels separated by a middle channel representing the BBB. The “walls” of the middle channel are composed of regularly spaced circular Si-pillars allowing a certain permeability between the lateral channels. To enable the utilization of this system as cell cultivation platform the filling and flow parameters of the coexisting aqueous fluid phases must be controlled precisely during the initial filling phase as well as during the whole cultivation sequence.
The preliminary project consisting in establishing a fluid initiation device for the BBB microfluidic platform was already conducted during a Master thesis and the present candidate will have for main task to put the device in service and to characterize it in order to optimize the prototype. The work will also focus on the software part of the control system in order to optimize the close-loop feature, i.e. does the device reacts appropriately and automatically to the flow system? Furthermore, in order to reach a step further towards bio-mimicking, the candidate will adapt the fluid initiation device in such a way that the device proposes a pulsatile mode of the fluid flow in the BBB-chip, as in reality the fluids undergo such behaviour in arterial blood flow. The device will be upgraded with this pulsatile mode as well as other preset configurations (e.g. simultaneous 2 or 3 channel filling…). Finally, the candidate will explore other fluid systems than just water, such as “hydrogel” (or similar fluids) in order to test the device in operating situation close to the cell cultivation mode.

Requirements Clean room experience and basic knowledge of Si-technology processes, fluid mechanics, sensor technology and electrical engineering, design and construction abilities, good knowledge in microcontroller programming especially in Arduino programming, basic knowledge in medical technology and the area of cell cultivation, **ability to work independently and high level of self-motivation**

Tasks:

- Literature research (focus on microfluidic liquid handling and fluid dynamics, pressure sensors and electrical engineering for fluidic systems (e.g. “automated/controlled syringe pumps”))
- Put in service of an existing experimental device
- Characterization and optimization of the prototype (especially concerning the close-loop system)
- Improvement of the existing device toward bio-mimicking (pulsatile mode, preset modes, test with other fluid systems than just water)
- Documentation and presentation

Literature:

- R. Booth und H. Kim, Lab Chip 12, p.1784, 2012
- L. Griep et al., Biomed Microdevices 15, p.145, 2013
- B. Prabhakarpandian et al., Lab Chip 13, p.1093, 2013
- D. S. Kim et al., J. Micromech. and Microeng. 12, pp.236-246, 2002
- B. Sittkus, A. Kovacs & U. M. Mescheder, MikroSystemTechnik 2019 - Congress (pp. 1-4), 2019.
- B. Hagmeyer, F. Zechnall & M. Stelzle, Biomicrofluidics 8, 2014.

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3) Finger position sensing within Braille reader systems (MED)

Braille displays (fig. 1 [1]) are important tools to help blind or visually handicapped people to read and write data. In this project a new concept for sensing the finger position, to identify the “reading finger” (to control “cursor” setting during reading) has to be developed.
In a first stage different contact- and forceless methods such as PCAP or PCT [2] have to investigated theoretically and compared in respect to the specific needs in a Braille display. PCAP is widely used for touch displays in mobile phones or pads and are based on capacitance change due to a finger tip nearby (fig.2)
For a “test kit” [3] hardware on flexible substrate should be developed.
This project is part of a cooperation with the company Helptech, Horb (Germany)..

Tasks:

- Literature research about touch displays (principles, set-ups, materials, pros/cons
- Design of PCAP for Braille display (concept for realization below polymer surface)
- Microfabrication of test set-up (shadow mask)
- Characterization
- Documentation and presentation

Literature:
[1] https://helptech.de/en/products/braille-displays-and-note-takers/braille-keyboards
[2] https://www.hy-line.de/infothek/veroeffentlichungen/whitepapers-fachartikel/hcc-fachartikel/ein-klassiker-erfindet-sich-neu/
[3] Narjes Pourjafarian , Anusha Withana , Joseph A. Paradiso , Jürgen Steimle, Multi-Touch Kit: A Do-It-Yourself Technique for Capacitive Multi-Touch Sensing Using a Commodity Microcontroller, UIST ’19, October 20-23, 2019, New Orleans, LA, USA. Copyright is held by the author/owner(s). ACM ISBN 978-1-4503-6816-2/19/10. http://dx.doi.org/10.1145/3332165.3347895

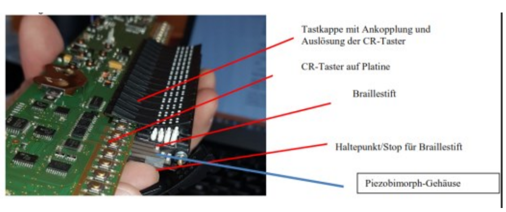

Fig.1 Inside view of Braille display, courtesy S. Kipke Helptech

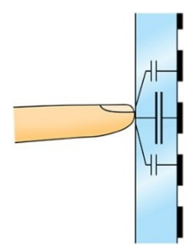

Fig. 2: principle set-up of PCAP [https://www.adm-electronic.de/blog/technologien/pcap-touch-sensor/]

Advisor: mes

Analysis of oxygen plasma parameters on the surface energy of Polydimethylsiloxane (PDMS)
The activation of PDMS surfaces with O_2-Plasma is a well-known process to alter the surface energy of the pristine elastomer surface. The plasma treated PDMS surface changes its properties due to the interaction with the reactive plasma species (ions, radicals, electrons), whereby unreactive methyl groups are replaced with reactive O-H groups. Further, ions with a high kinetic energy result also in an etching effect leading to an overall roughening of the surface. Lastly, the higher energy state of the treated surface exhibits a transient behaviour, leading to a reduction of the surface energy over time. The resulting surface energy state is a crucial parameter determining the interaction with subsequent materials. Therefore, it is of special interest to study the gradual change of the surface energy with varying plasma-treatment parameters. Even there are numerous publications available, studying the influence of specific parameters on the surface energy of PDMS, these parameters are only partially transferable to other plasma devices. Further, a dedicated analysis of the gradual increasing and subsequently decreasing surface energy state is of special interest for specific subsequent adatom surface interactions.
Therefore, the goal of this research project is, to evaluate the changing surface energy state as well as the surface roughness in dependence of selected plasma parameters. Consequently, an extensive set of experiments must be conducted and analysed adequately. The plasma parameters which must be varied are plasma power, gas pressure and treatment time. For the evaluation of surface energy, a modern contact angle measurement device (OCA200 DataPhysics) at the laboratory in Rottweil will be used. Also, the existing oxygen plasma device (PlasmaFlecto30 plasmatechnology) will be used to ensure a constant time offset between activation and measurements. The samples will be pristine spin coated PDMS membranes. For roughness analysis an Atomic Force Microscope is used.
Summary of Tasks:

- Literature research and extension of own knowledgebase about oxygen plasma treatment of PDMS
- Analysing the change in surface energy and surface roughness of PDMS membranes with varying oxygen plasma treatment (in dependence on plasma power, gas pressure and treatment time)
- Analysing the transient behaviour of increased surface energy level
- Adequately summarizing the results in report or scientific paper form with a subsequent discussion of the observed interplays

Requirements:

- since the experiments (main part of the project) are conducted in Rottweil, a car and driver license are advantageous
- high level of self-motivation and ability to work standalone
- basic knowledge about surface modifications with plasma treatments
- ability to work independently with complex devices after instruction
- ability to familiarize with complex theoretical models

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DEAP Actuation
So-called dielectric electro-active polymers (DEAP) are a relatively new material class for actuators. In this semester project a “tool-kit” of a DEAP actuator should be tested, evaluated and used to a lab-experiment later used in an undergraduate lab about actuators. Additionally to such commercial DEAP acutators on research at the HFU and according devices can be integrated into the lab work.

Tasks:
-literature research: understanding of DEAP actuation (priniciples, properties)
-selection of a toolkit (e.g. from Sateco or Danfoss)
- Design and set-up of lab experiment
- documentation

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Simulation and verification of influence of thin film stress on membrane like MEMS-structures
Stress in thin films can cause severe problems in flexible MEMS structures such as micromachined beams or membranes. E.g. in membranes used for active focusing and made out of almost stress-free silicon thin reflective

coatings might introduce stress which will lead to distortion of the membrane and therefore reduce the optical quality of such a device by introducing so-called wavefront errors.
Based on previous work, in this project a COMSOL model should be adjusted to model the influence of Aluminum coated on one or two sides of such MEMS structures as measure to reduce the distortion.
The model should be validated experimentally by PVD deposition on suitable test structures such as freestanding membranes. Here, also high resolution microscopy will be used to measure the change of membrane deflection by coating (white light interferometer, Zygo).
Tasks

- literature research on thin film stress (basics)
- learning of COMSOL multiphysics simulation software
- modelling of single or double side coated stress AL on membranes
- design of (simple) test structures for validation
- processing of test structure in the technology lab for micro- and nanosystems
- comparision simulation results and experiments
- adjusting model
- documentation
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