1. Objective of the project

The aim of the project is to **passively** produce perfectly identical **double emulsion droplets** – they will consist of a water droplet inside oil droplet that is dispersed in aqueous phase (see Figure 1). They will be produced in a microfluidic device, which is a network of microscopic channels in the plastic plate the size of the business card. Due to very small dimensions (>1 mm), the fluids flowing through the device can be very precisely controlled. The design of the network of channels (i.e. a 'geometry') is crucial, as it dictates the fluids where and how they flow. Geometry can make the stream of fluid to split into a number of smaller portions – droplets. One of the techniques relying on microchannels geometry to produce uniform droplets is **step-emulsification** (see Figure 1), named after a sharp increase of the channels depth (a 'step'). This technique relies on the surface forces acting on the stream of fluid when it crosses the step to enter a reservoir filled with another, immiscible fluid. There is a need to control flow of only one fluid (the droplet phase) to generate identical droplets one after another. Not requiring the control of the outer phase is the reason for calling this technique a **passive** one.

2. The research to be carried out

During the project a method for producing stable double emulsions with very thin shells will be introduced. An initial collection of water-in-oil droplets will be pushed through the microfluidic chip, where they will be split in water into a number of identical compartments – double emulsions. A number of fluid properties will be tested if they influence the formation of a double emulsion droplet in a step-emulsification geometry. The mechanism of double droplet formation will be investigated and a model explaining the process mechanism may be proposed. The usefulness of the presented concept will be tested by producing stable double emulsion droplets that contain inside an artificial phospholipid bilayer. Tests on stability of such systems in relation to the lipid composition of the bilayer will be conducted.

3. Reasons for choosing the research topic

Droplets are very important to a number of fields of science, as they can play a role of test tube that is thousands of times smaller than conventionally used glass or plastic tubes. Double emulsion droplets are especially important as they have additional shell between inner droplet and the environment that shields the core droplet content. What is more, the shell can be played with, e.g. it can be solidified while core droplet remains liquid.

No work has been ever done before on double emulsion production in step-emulsification geometry. It is surprising, as the method yields very good results in production of single emulsions (e.g. water-in-oil droplets). What is more, the preliminary results show that it is possible to produce double emulsions with thin shells in the step-emulsification geometry. The project will lead to deepening our knowledge of physical chemistry, but will also produce a novel technology of producing high quality double emulsions. They can be used in a number of biomedical applications.

The formed droplets will have thin shells, making them more stable than double emulsions with thick shells in which the core droplet can swim around freely. This will be important for investigation of the **droplet interface bilayer**s (DIBs, see Figure 1), very useful model for studying e.g. cellular membrane proteins activity. Providing the research community with an easy to use tool for production of such systems will benefit the research community as well as medical diagnostic methods. New screening methods can be developed as well as modern multi-stage drug carriers using presented double emulsions. Lastly, the step-emulsification microfluidic chips are the robust and easy to operate means of droplet production that can be operated with use of simple laboratory equipment such as electronic pipettes. This shows promise to be applicable in a number of Point-of-Care applications.

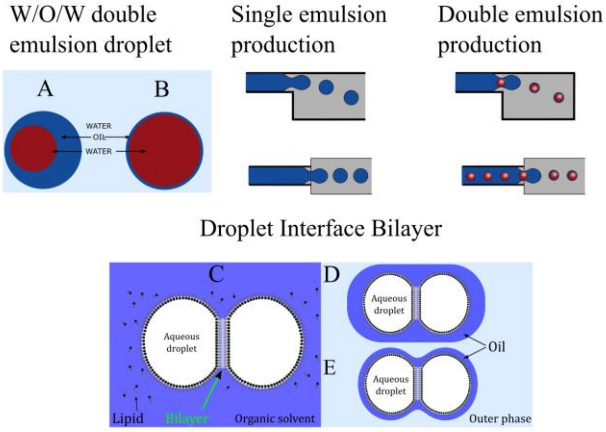

Figure 1 Left top: Schemes of water-in-oil-in-water double emulsion droplets with an oil shell (A) and a thin oil shell (B). Right top: schematics of step-emulsification of both a single and a double emulsion. Bottom: scheme of Droplet Interface Bilayers: formed by lipids on water-oil interface (C), formed within double emulsion (D) and formed within thin-shelled double emulsion (E).