French Polytech network form for PhD Research Grants from the China Scholarship Council

This document describes one of the PhD subjects proposed by the French Polytech network. The network is composed of 15 engineering schools/universities. The document also provides information about the supervisor. Please contact the PhD supervisor by email for further information regarding your application.

Supervisor information	
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PhD information	
Title	Towards an acoustic wave driven PCR in a lab-on-a-chip platform
Main topics regards to CSC list (3 topics at maximum)	Acoustic, Biotechnology, Microtechnology

Required skills in science and engineering	For this multidisciplinary project a candidate with a Master degree or Engineering degree in one or more of the following fields is required : Physics, Acoustics, Materials Science, Mechanical Engineering, Micro and Nanotechnologies or similar. Knowledge in Biomedical and/or Biotechnology Engineering would be a plus. The candidate should be familiar with numerical tools (FEM simulations bases knowledge) and have interest for experimental work. Finally a good level in English (written and spoken) is required.

Subject description (two pages maximum including biblio)

Lab-on-a-chip (LOC) platforms are one of the most promising approaches to address the important societal challenge of providing quality healthcare at an affordable cost. The scale reduction can lead to lower reagent volume consumption, massive parallelization of experiments, far more rapid outcomes, and better process control [1]. On the other hand, in disease diagnostics, the current method generally relies on mass duplication of the virus' genetic material via Polymerase Chain Reaction (PCR), a slow heating process that limits the throughput of diagnostic efforts. Indeed, the reaction is based on 3 keys steps, namely denaturation (94-98°C), annealing (50-68°C), and elongation (72°C). LOC with included PCR systems have already been studied [2] and are a growing trend. However, they use microvalves, micropumps or thermocyclers which are difficult to manufacture on a small scale and which require a continuous source of energy. In this context, the surface acoustic wave (SAW) technology is particularly relevant as it has the advantage of being simple, battery-less and has the ability to offer extremely large accelerations (>108 m/s2) in a microscale fluid. Indeed, the Rayleigh-SAW (R-SAW) transmits its energy in the form of longitudinal compression waves in the liquid which lead to rapid fluid flow, called acoustic streaming. Depending on the operating frequency and the power supply, the dynamics may exhibit control and rapid mixing, heating or motion [3]. In this project we aim to develop a new LOC platform based on surface acoustic waves devices to perform a PCR. This challenge perfectly fits the field of space medicine since the results could, in the longer term, be invested in the International Space Station (ISS) laboratory and have a direct impact on the general public. We know that many common medical devices have their origin in space research. For example, dialysis machines are derived from water purification systems in missions and ventricular pump are inspired from injection pump of space shuttle. We also know that astronauts undergo numerous medical tests before, during and after their trip. The interest in developing a SAW based LOC-PCR could thus be twofold: 1) to perform simple, rapid, and early detections of viral diseases in people aboard the ISS. Indeed, immune cells become less efficient during flights [4]. 2) to advance laboratory research at the ISS in order to better understand virus mutations and thus predict their evolution on earth. Indeed, due to the particular environmental conditions (microgravity, high oxygen level, radiation) bacteria and viruses mutate faster [5]. Project and tasks: This multidisciplinary project, will include state-of-the-art studies, design, fabrication, integration and extensive characterization work that can be divided in 3 ambitious steps, namely: 1) Prototyping and dedicated Rayleigh-SAW development According to our specification, a 40MHz device will be designed, followed by a standard clean room process. This step will include the development of a multi-physics model to study the wave/fluid interaction and thus optimize the design. In our team, we have already shown that biological species are not affected by Rayleigh SAW [6]. 2) PCR cycle optimization This step will include the realization of a complete PCR cycle using Rayleigh-SAW, first with a non-biological fluid (water-glycerol mix with appropriate viscosity) and then with harmless viral strains (such has Human Coronavirus 229E). The verification of the DNA amplification will also be conducted thanks to fluorescence or migration. 3) Assembling in a demonstrator In this step we will design and build the LOC platform by 3D printing to achieve the "ready to use" PCR test that include the Rayleigh-SAW device. Indeed, the different parts that were separately tested (the SAW device, the heating cycle, the DNA duplication, etc.) will here be assemble in a single platform to run a test from a biological sample to the genetic duplication.

References:

[1] Y.C. Lim, et al., "Lab-on-a-chip: a component view," Microsystem Technologies, vol. 16, no 12, p. 1995-2015, 2010.

[2] Y. Wang, et al., "A rapid and controllable acoustothermal microheater using thin film surface acoustic waves," Sensors and Actuators A: Physical, 2021, vol. 318, p. 112508.

[3] W. Connacher, et al., "Micro/nano acoustofluidics: materials, phenomena, design, devices, and applications," Lab on a Chip, 2018.

[4] B.V. Rooney, et. al., "Herpes virus reactivation in astronauts during spaceflight and its application on earth," Frontiers in microbiology, p. 16, 2019.

[5] M.L. Weng, et al., "The mutation induced by space conditions in Escherichia coli," World Journal of Gastroenterology, vol. 5, no 5, p. 445, 1999.

[6] T. Roux-Marchand, et al., "Rayleigh surface acoustic wave compatibility with microdroplet polymerase chain reaction," International Journal of Microscale and Nanoscale Thermal and Fluid Transport Phenomena, 2013.