µFLU-NEGF2018/106

‘‘DESIGN OF A TEMPERATURE MICRO-SENSOR WITH A GASEOUS FLUID FLOW’’

Nataša Djordjević*[1], Gian Luca Morini[2], Juergen Brandner[1]
[1]Karlsruhe Institute of Technology, Campus North, Eggenstein-Leopoldshafen, Germany
natasa.djordjevic@kit.edu,juergen.brandner@kit.edu
[2]DIN, Alma Mater Studiorum Università di Bologna, Bologna, Italy
gianluca.morini3@unibo.it

KEY WORDS

Liquid Crystal Thermography (LCT), micro-channel, micro-sensor design, temperature gradient, thermo-chromic liquid crystals (TLC)

SHORT SUMMARY

Non-intrusive Liquid Crystal Thermography technique (LCT) has been proven as a powerful tool for low-temperature application in micro-scale systems. It provides high-spatial resolution temperature maps dependent on colour response of heated thermo-chromic liquid crystal material (TLC). Different types of TLCs have been widely used in form of coated paints or water-based droplets in aqueous carrier fluid. Up to now, suitable designs of micro-devices with specific features optimized for their use in the presence of gas micro-flows has still not being proposed. Therefore, the study of a design of single channel micro-device for liquid-gas mixing is presented here. Research work has been performed experimentally and/or numerically to investigate the effect of various geometric designs of micro-devices to provide uniformly distributed TLC particles along a gas flow and to avoid their sedimentation. Beside the geometric design, material and heating systems are of high importance in order to achieve desirable observation of temperature gradients along the channel. Moreover, the flow rate and shear stress inside the channel were set to be minimal due to suspected high sensitivity of TLCs.
This paper is intended to bring new insights and fresh perspectives to the development of temperature micro-scale sensors for practical implementation in the future.

EXTENDED ABSTRACT

There is currently much interest in developing complex microfluidic devices such as micro-heat exchangers, micro-sensors and micro-reactors for various lab-on-a-chip, micro-chemical and micro-biological applications [1, 2]. These devices can either be integrated into conventional processes in entirely new industrial applications or incorporated into modified designs of already existing applications. To permit such integration, however, it has to be possible to obtain precise and accurate process parameters in micro structured reaction systems.

It is well known that differences between published experimental data on the dynamic and thermal behaviour of micro-flows and values predicted via classical theories stem partly from the experimental methods used for micro-flow investigation. Here, the local values of the main physical parameters - pressure, temperature, and velocity - are particularly affected. Although many measuring techniques for these parameters have been tested in micro-devices, the need for new approaches remains, since a deeper understanding of the transport phenomena of heat and fluid flows in micro-scale systems is necessary. However, building a reliable and effective system for temperature measurements in microfluidic devices is still a challenging task due to complex fluid behaviour and fluid-structure interaction, micro-device's material, optical access, etc.

To remove these obstacles and provide more functionality of micro-devices, the research in this study has been focused on a new design of a single channel micro-device with uniformly distributed thermo-chromic liquid crystals (TLC) as tracer particles along a fluid flow. A schematic of the design is shown in Figure 1.

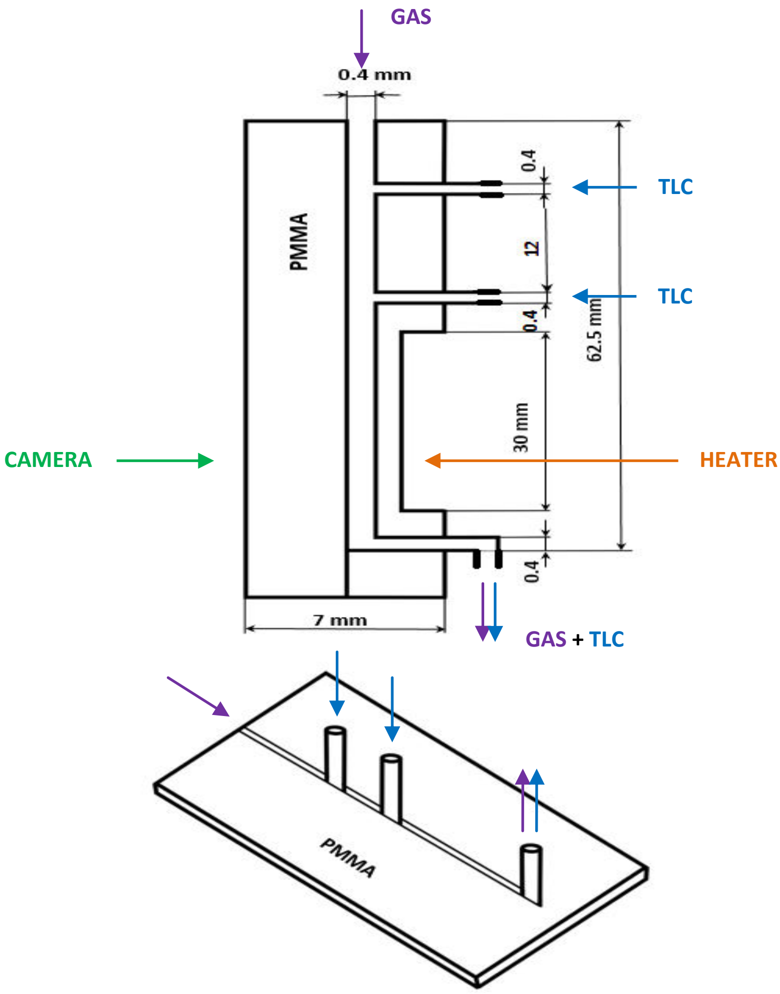

Fig. 1: Design of a single channel micro-device with multiple inlets

Temperature measurement, with a relatively narrow temperature range (25–35˚C), can be carried out by using non-intrusive Liquid Crystal Thermography technique (LCT) [1, 3] as it provides high-spatial resolution temperature maps dependent on colour response of heated TLCs.
In recent years, many different types of TLCs have been widely used in form of coated paints or water-based droplets in aqueous carrier fluid [4–6], but up to now their use in the presence of gas micro-flows has still not being proposed. In effort to improve measurement accuracy, TLC particles image quality and to provide uniformly distributed particles, the study of a design of a micro-device for liquid-gas mixing is presented here. The straight rectangular micro-channel, formed from a 400 x 400 µm cross-section, was milled into a micro-device with multiple inlets. The micro-device consisted of two separate plates made of PMMA and glued together. The transparency and low thermal conductivity of PMMA (λ=0.167−0.25 W/mK) allowed observation of a temperature gradient of TLC particles along the channel. Heating of the micro-channel was carried out by squared electrical flexible heater made in a polyimide substrate and placed in a flat-surface pocket on the opposite side of a camera. The micro-device was placed vertically in order to avoid TLCs

sedimentation and blockage of the channel, as well as to easily reach better TLCs distribution along the fluid flow. The direction of flow can be changed from upside-down to downside-up. A combined experimental and numerical investigation will consider different fluid flow rates, as well as the influence of pressure and shear stress increase on a TLC particles behaviour in a laminar flow.

Acknowledgements

This work, under the framework of 'MIGRATE' project, has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 643095.

References and Citations

[1] Dabiri D. (2009). Digital particle image thermometry/velocimetry: a review. *Exp Fluids*, **46**, 191-241.
[2] Naqiuddin N. H., Saw L. H., Yew M. Ch., Yusof F. & Ng T. Ch. (2018). Overview of micro-channel design for high heat flux application. *Renew. Sust. Energ. Rev.*, **82**, 901-914.
[3] Abdullah N., Abu Talib A. R., Jaafar A. A., Mohd Salleh M. A. & Chong W. T. (2010). The basics and issues of thermochromic liquid crystal calibrations. *Exp Thermal Fluid Sci*, **34**, 1088-1121.
[4] Behle M., Schulz K., Leiner W. & Fiebig M. (1996). Color-based image processing to measure local temperature distributions by wide-band liquid crystal thermography. *Applied Scientific Research*, **56**, 113-143.
[5] Segura R., Cierpka C., Rossi M., Joseph S., Bunjes H. & Kähler C. J. (2013). Non-encapsulated thermo-liquid crystals for digital particle tracking thermography/velocimetry in microfluidics. *Microfluid. Nanofluid.*, **14**, 445-456.
[6] Basson M. & Pottebaum T. S. (2012). Measuring the temperature of fluid in a micro-channel using thermochromic liquid crystals. *Exp Fluids*, **53**, 803-814.