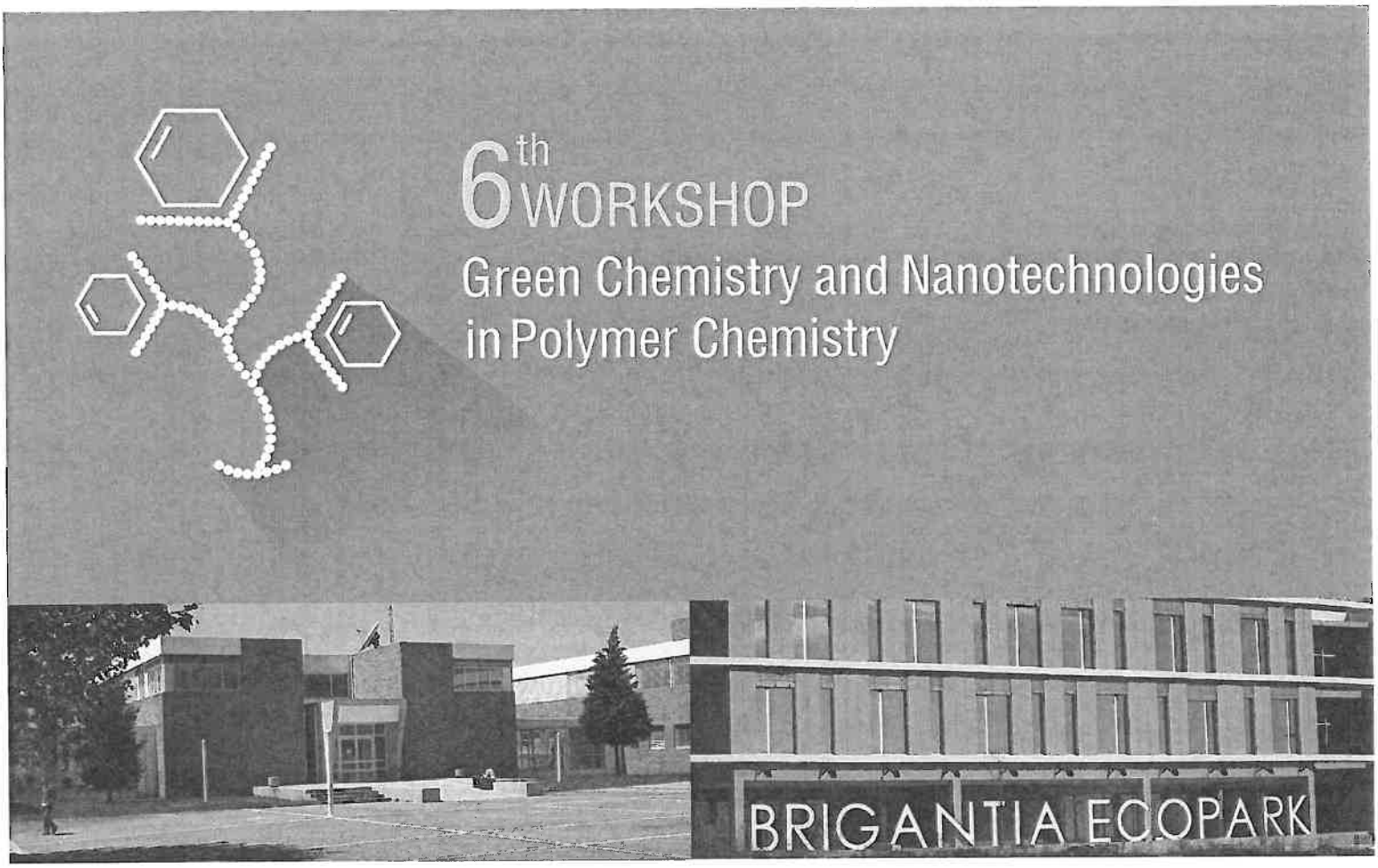


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# WORKSHOP PROCEEDINGS

Eds. - M. F. Barreiro, O. Ferreira, A.I. Pereira

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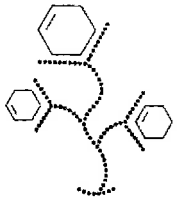

6th WORKSHOP
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# P17. FLOW FOCUSING TECHNIQUE TO PRODUCE PDMS MICROPARTICLES FOR BLOOD ANALOGUE FLUIDS

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## Introduction

The study of the blood flow behaviour through microchannels is crucial to improve our understanding about blood flow phenomena happening in the human microcirculatory system. However, the difficulties associated with the use of *in vitro* blood, such as coagulation and sample storage, have promoted the increasing interest to develop fluids with rheological properties similar to real blood [1].

Polydimethysiloxane (PDMS), due its remarkable properties such as good optical transparency, biocompatibility and permeability to gases, is widely used to fabricate microfluidic devices for *in vitro* blood experiments [2]. Recently, this inert elastomer has been used to produce monodisperse PDMS microbeads through a microfluidic approach [3]. Jiang et. al. have proposed a flow-focusing technique where a PDMS precursor was dispersed into microdroplets within an aqueous continuous phase [3]. By using this method they were able to produce PDMS microbeads with an average dimension of 80 microns. However, to develop blood analogue fluids it is essential to have PDMS microparticles with dimensions more close to the blood cells, i. e., the microparticles should have dimensions smaller than 20 microns. Hence, in this study a novel flow focusing technique was used to produce PDMS microparticles with dimensions more close to real blood cells. This technique was recently proposed to produce jets, droplets, and emulsions with sizes ranging from tens of microns down to the submicrometer scale [4]. This procedure is also based on the flow focusing principle which the above mentioned method relies on. Nevertheless, our technique makes use of the breakage of a steady jet to form the microparticles, which can lead to much higher production rates.

In our technique, liquid is injected at a constant flow rate through a hypodermic needle to form a film over the needle's outer surface. This film flows toward the needle tip until a liquid ligament is steadily ejected. Both the film motion and the liquid ejection are driven by the viscous and pressure forces exerted by a coflowing fluid stream. The outcome is a capillary jet which breaks up into droplets.

## Experimental

We used a hypodermic needle with an inner (outer) diameter of about 160 (300) μm, and with an outer hydraulic radius of a few microns in the tip. The needle used in this study was not subjected to any kind of treatment. The needle was located inside a converging–diverging nozzle with a neck about 150 μm in diameter by using high-precision orientation–translation systems. The nozzle was formed at one of the ends of a borosilicate capillary, and its shape was characterized with the procedure described elsewhere [5]. We used a common PDMS elastomer kit consisting of two parts: a base of vinyl-terminated siloxane oligomers (Part A) and a curing agent of siloxane oligomers and catalyst (Part B). The proportion Part A:Part B of the mixture was 6:4, whose viscosity was around 827 cSt [3]. The mixture was injected through the needle at a constant flow rate by means of a syringe pump connected to a stepping motor. The needle and the nozzle were immersed in a bath of a mixture of glycerine and surfactant Brij 30 (to avoid the coalescence of the droplets), which is immiscible with the PDMS precursor. The outer bath was suctioned across the nozzle at a constant flow rate with another syringe pump to produce the focusing effect (see figure 1).

Digital images of the fluid configuration were acquired using a digital camera which allowed us to acquire images with an exposure time of 25 μs. The camera was equipped with a set of optical lenses. The optical lenses were selected depending on the size of the imaged object, with a magnification ranging from 0.076 to 0.52 μm/pixel. The camera could be displaced both horizontally and vertically using a triaxial translation stage to focus the jet. The fluid configuration was illuminated from the back side by

cool white light provided by an optical fiber connected to a light source. We also acquired images of the needle by using an auxiliary camera with an optical axis perpendicular to that of the main camera. The use of the two cameras allowed us to check that the needle was correctly positioned. All these elements were mounted on an optical table with a pneumatic anti-vibration isolation system to damp the vibrations coming from the building.

## Results and discussion

Our preliminary results indicate that the technique described in this work allows us to produce particles of PDMS ranging 1-100 microns in diameter. We checked that the collections of drops had a high degree of monodispersity and we can reach high production rates (see figure 1).

**Fig. 1.** (Left) Precursor jet of PDMS particles. (Right) Stream of droplets, about 5 microns in diameter, behind the nozzle.

Once the droplets are accumulated in the syringe, the emulsion can be transferred to an oven at 70 °C to thermally cure the droplets into solid particles. After that, these PDMS microparticles can be either stored in the same glycerine solution or centrifuged, rinsed and dried under vacuum to a powder. Dried particles can be re-dispersed in various media depending on the application.

## Conclusions

In this work, we have applied a novel flow focusing technique to produce microparticles of PDMS with diameters down to the micrometer scale, and high degree of monodispersity and production rates. The results are very promising and we believe that the produced PDMS microparticles can be used to develop a blood analogue fluid with rheological properties similar to real blood.

One of the features of the present technique is the fact that the variation of the needle position in the nozzle enables one to select the size of the resulting droplets, which confers the method on both flexibility and robustness. The droplet size will be measured systematically to determine its dependence not only on the needle position but also on the rest of the control parameters of the problem.

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