Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME-CFDSC-CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

In-situ microplastic pre-treatment and sorting using an inertial microfluidic device.

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ABSTRACT

Microplastics (MPs) contamination is a growing concern due to their abundance and intrinsic negative impact on the environment and the hazardous consequences for living organisms and ecosystems. Recent studies have demonstrated the viability of creating monomers, fuels, and crucial chemicals from MP waste. However, capturing MPs to recycle is inherently challenging due to the different types and sizes of MPs in natural environments. Inertial microfluidics is a passive, practical, and high-throughput lab-on-chip technology used in various applications. It is based on the interaction of suspended microparticles and microchannels in the Stokes flow regime. In spiral-like inertial chips the Dean drag force (F_D), associated with a secondary flow (Dean flow); and the inertial lift force (F_L), caused by the interaction of particles with the channel walls, are the main forces that allow the mixing of reactants and microparticles sorting by size. In this work, we present the design and optimization of a Polydimethylsiloxane (PDMS) spiral microfluidic chip (SMC) for sorting and collecting of Polystyrene microbeads of 20 and 10 µm. This device was fabricated by established soft lithography and placed on a 75 mm x 50 mm glass slide, features rectangular channels (400 µm width and 250 µm height) and was characterized at different Reynolds numbers. Its design allows adaptation to different microplastic sizes by adjusting the input velocity or geometrical parameters. In addition, the Dean flow present on SMC facilitates the reagent mixing for on-chip pre-treatment applications on MPs.

Despite PDMS's wide adoption in microfluidics due to its optical transmission, low cost, and rapid manufacturing, it degrades in the presence of solvents commonly used on pre-treatments of MPs. To address this limitation, we proposed the use of borosilicate glass as a material for the SMC, offering great potential for in-situ deployment and portable MP pre-treatment and sorting in real environments. Glass has multiple advantages, including durability and chemical inertness. However, it is notoriously difficult to manufacture cost-efficiently in small batches.

Spark-Assisted Chemical Engraving (SACE) is a thermochemical micromachining process for difficult-to-machine materials such as glass and ceramics. It is a contactless process with the potential for creating near-defect-free surfaces that can be directly bonded due to the absence of redeposition. Recent advances in SACE have allowed the low-cost rapid prototyping of the SMC in glass, being the first SACE-machining of an inertial microfluidic device to our knowledge. This device was benchmarked against the PDMS model, comparing various performance indicators.