Optimized cross-slot microdevices for extensional rheometry

Microfluidic cross-slot devices can generate wide regions of vorticity-free extensional flow near the stagnation point, resulting in large extensional deformation and orientation of the microstructure of complex fluids, with possible applications in extensional rheology. However, standard cross-slot devices, with abrupt or rounded corners, generate a flow field with a non-homogeneous extension rate that peaks at the stagnation point, but decays rapidly with distance from the stagnation point. To circumvent this limitation, an optimized shape cross-slot extensional rheometer (OSCER) was designed numerically and shown to generate a constant extension rate over a wide region of the in- and out-flowing symmetry planes [1]. Since the OSCER device was based on a 2D flow approximation, the practical implementation requires a large aspect ratio (depth/width=10.5 was used in [1]), which cannot be easily reproduced by soft-lithography techniques. In the present work, we use the numerical method developed by Alves [2] to obtain new designs for optimized cross-slot geometries, considering aspect ratios of order 1. A set of experiments have been carried out in order to validate the kinematics by means of micro-particle image velocimetry, and the results are found to be in close quantitative agreement with the numerical predictions, thus validating the proposed devices as suitable micro-extensional rheometers.

References: