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PARTICLE IMAGE VELOCIMETRY AND NUMERIC SIMULATIONS FOR AN IMPROVED UNDERSTANDING OF THE STAGGERED HERRINGBONE MIXER STRUCTURE

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1. Introduction

Mixing of fluid flowing through microchannels is important in many microTAS applications. However, the laminar flow conditions allow only mixing by diffusion, a process too slow for many applications. A large number of passive and active micromixers have been developed. Many of these mixers are however, complicated to fabricate or require moving parts. There is therefore a great interest for the passive staggered herringbone mixer (SHM) structure presented recently by Stroock et al. [1]. The SHM is comparatively simple to fabricate and in this mixing structure 3D flow patterns are generated by herringbone-shaped trenches on the floor of the channel.

2. Experimental

We have fabricated a SHM structure with the same geometry as in Ref. [1] but by deep reactive ion etching in silicon and sealed the structure with an anodically bonded glass lid (Fig 1). We present the first particle image velocimetry (PIV) measurements of the velocity field in a SHM structure. For these measurements the fluid (glycerol) was seeded with fluorescence microspheres (1 µm diameter). Two pictures are taken in quick succession, the displacements of the microspheres are calculated using a standard PIV algorithm, and from this the velocity vector for each point is extracted.

3. Results and discussion

While the velocity along the channel is dominant, the flow also has a smaller transversal component. In a plot of this transversal velocity component (Fig 1C) the herringbone trenches can clearly be recognized. The transversal velocity is greatest in the valleys of the trenches, whereas it is close to zero or reversed at the peaks. At a line connecting the tips of the herringbone trenches there is no transversal flow, and on each side of this division line the transversal flows are in opposite directions.

The velocity profile was determined at various depths in the channel by changing the focal plane of the microscope. From these measurements the transversal and the longitudinal velocity as a function of the channel depth (Figs. 2) is extracted for various positions (*a-j*, indicated in Fig. 1A). From the middle of the herringbone structure (point *a-e*) to further downstream (point *f-j*) the transversal flow increases. At points *a-b* and *f-h* in Fig 2A&B a characteristic S-shaped curved is observed where the transversal flow changes direction between channel bottom and top. This indicates a helical flow in agreement with Stroock et al. [1]. The longitudinal flow component is parabolic (Fig 2C&D), but with a slight asymmetry due to the effective velocity slip condition at the trenches [2]. These experimental findings compare favorably to numerical simulations (data not shown).

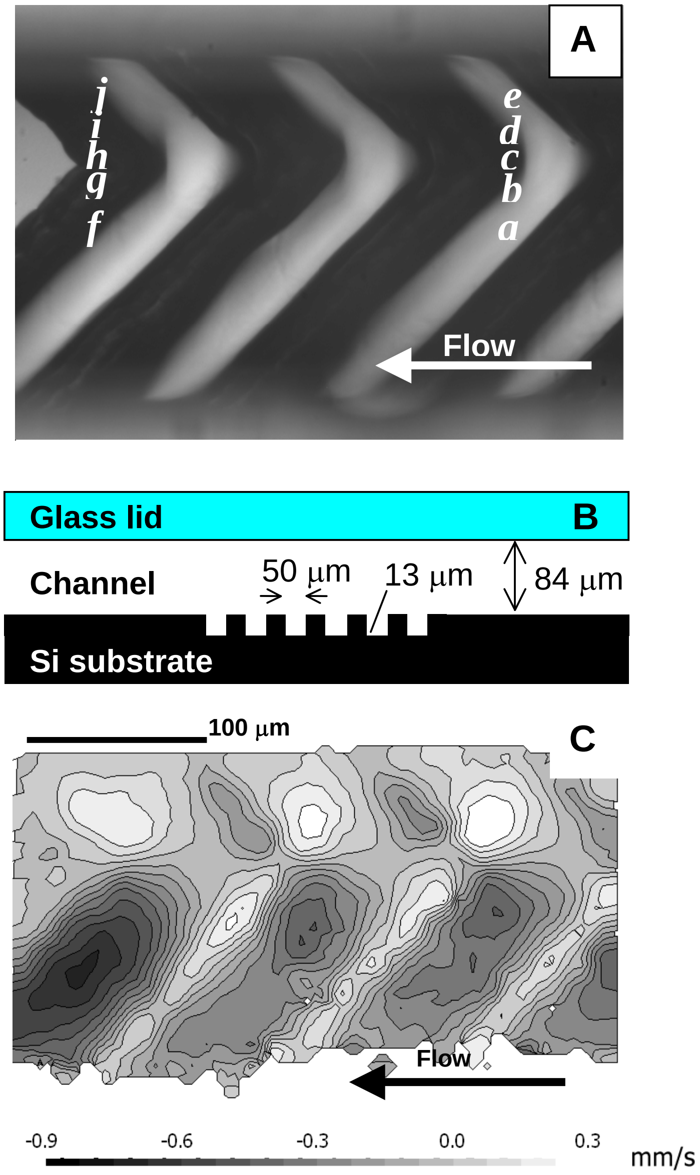

Fig 1. A: Microscope image of the herringbone trenches in the microfluidic channel. **B:** Schematic cross-sectional sideview of the channel with the herringbone trenches. **C:** Contour plot of the transversal flow component.

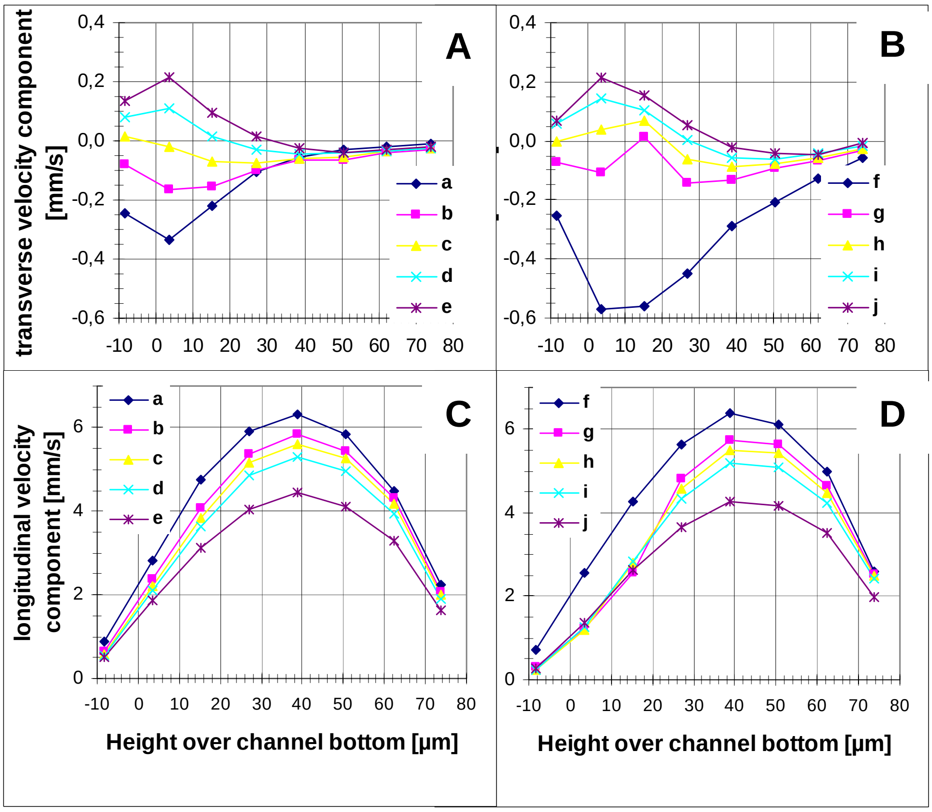

Figure 2 The transversal flow component **(A, B)** and the longitudinal flow component **(C, D)** as a function of height over the channel bottom. The height is set to zero at the channel bottom and is therefore negative in the herringbone trenches. (see Fig 1A for locations of points *a-j*).

4. Conclusions

Using PIV measurements it is possible to measure the flow in much greater detail than possible with the methods used by Stroock et al. [1]. Such detailed measurements as presented here are an important contribution to a better understanding of the staggered herringbone mixer structure, improved simulation tools, and for optimization of the design of the structure.

References

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