(Invited) Active control of shear and mass transport in microfluidic devices

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The production of particles and crystals is an key activity for the pharmaceutical and chemical industry. In the production process of particles, the flow conditions that a particle experiences during its formation play a critical role on the structural properties of particles. In the present contribution we use active actuation to control the flow and to handle particles under formation.

By oscillating a piezoceramic element coupled to a channel with a frequency (2 MHz) that is matched with the width of the channel (375 µm) to achieve resonance, we induce acoustic streaming, giving rise to an oscillating pressure profile. As a result, vortices are produced, allowing for a rapid long-range transport of particles. It is demonstrated that an increase in transport rate of 1 µm particles by 4 orders of magnitude is achieved compared to pure diffusive transport. When particles reach a critical size (around 2 µm), acoustic radiation forces dominate and hard particles rapidly focus at the pressure node in the middle of the channel. The dynamics of this process is experimentally characterized using a recently developed 3D particle image velocimetry methodology and interpreted by comparing with computational fluid dynamics simulations. Experiments were performed with fluorescent polystyrene particles as well as with miconazole (API) crystals.

Next to migration speed, also the shear rate that particles (under formation) experience is of importance during the formation, especially for crystals. In common (Poisseuille) flow conditions, the local shear rate value changes linearly in the lateral direction, making it difficult to assess the influence of shear rate. To allow for a systematic assessment of the impact on specific shear values, we developed a device wherein the cover is mechanically translated, resulting in a linear flow profile. In the resulting constant shear situation in the channel (excluding the zones near the walls) crystallization experiments were performed with the protein Lysozyme (se Fig. 1). Striking changes solubility line were observed.

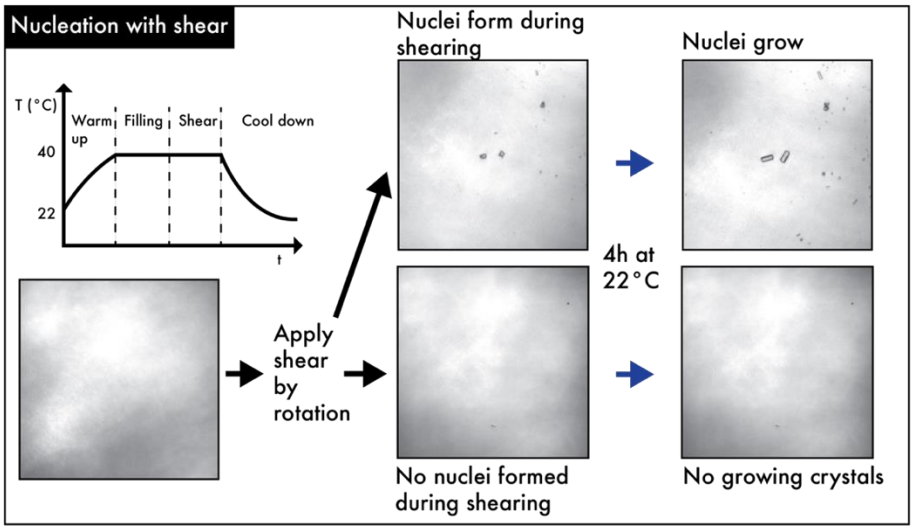

Figure 1: Experimental procedure to study nucleation with constant shear. First the microfluidic chip is filled at elevated temperature. Next, the solution is subjected to constant shear by rotating the cover lid of the channel. The chip is subsequently cooled down to room T to allow crystals to grow.