Designing microfluidic hourglasses to study flows of dense colloidal suspensions under gravity

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We study dense colloidal suspensions, made of particles that are heavy enough to sediment in their surrounding fluid and form a well-defined pile, but small enough to be sensitive to thermal agitation (typically between 1 and 5 µm). Those colloidal suspensions are similar in appearance to granular materials, but show peculiar flowing properties. For example, when a pile is inclined in a microfluidic drum, two distinct regimes are observed. Above a critical angle θ_c a fast avalanche occurs, similar to what is expected for classical athermal granular media. However, below this angle, the flow never stops, and the pile slowly creeps under thermal agitation until it becomes completely flat. [1]

Therefore, one could wonder how such a suspension behaves when it flows through an orifice, as in a silo discharge experiment: would the flow rate be constant, as for a macroscopic granular material in an hourglass, or would it depend on the height of the pile, as for a clepsydra filled with a fluid?

To try to answer to this simple question, we have used microfluidic fabrication techniques to build microscopic hourglasses that are filled with suspensions of silica micro-particles (Figure 1). We have encountered different problems with classical soft-lithography set-up in polydimethylsiloxane (PDMS), and have instead used rigid closed cells made in SU-8 photoresists. Finally, we measured the flow rate of the suspensions as a function of the ratio between the particles diameters and the necks widths. The results are compared with the classical Berverloo law that predicts the rates of macroscopic granular materials flowing through an orifice [2].

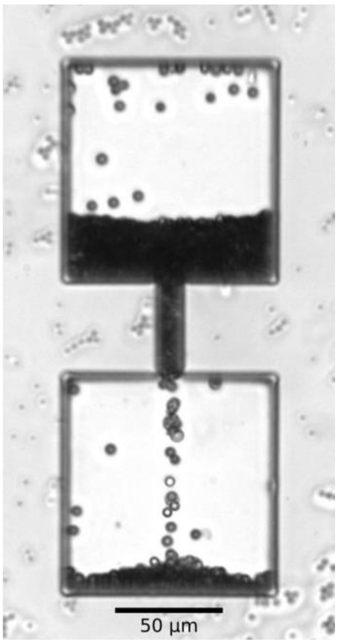

Figure 1: Microfluidic container, made with a deposit of SU-8 photoresist on a glass wafer (neck width = 11 µm), filled with a suspension of silica micro-particles (diameter = 3.97 µm) dispersed in bidistilled water.

References

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[2] Beverloo W. A., Leniger H. A. and Van de Velde J., "*The flow of granular solids through orifices*" J. Chem. Eng. Sci. **15**, 260-296 (1961).