CLOGGING OF MODEL PORES WITH BROWNIAN PARTICLES

Olivier Liot, Patrice Bacchin, Paul Duru, Pierre Joseph, Jeffrey F Morris

▶ **To cite this version:**

Olivier Liot, Patrice Bacchin, Paul Duru, Pierre Joseph, Jeffrey F Morris. CLOGGING OF MODEL PORES WITH BROWNIAN PARTICLES. The 21st International Conference on Miniaturized Systems for Chemistry and Life Sciences (MicroTAS 2017), Oct 2017, Savannah, United States. 2p. hal-01644282

HAL Id: hal-01644282

https://laas.hal.science/hal-01644282

Submitted on 22 Nov 2017

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

CLOGGING OF MODEL PORES WITH BROWNIAN PARTICLES

Olivier Liot[1,2,*], Patrice Bacchin[3], Paul Duru[4], Pierre Joseph[1] and Jeffrey Morris[5]
[1]LAAS-CNRS, Univ Toulouse, Toulouse, France, [2]Fédération Fermat, Toulouse, France, [3]LGC, Toulouse, France, [4]IMFT, Toulouse, France, and [5]Levich Institute, City College of CUNY, New-York, USA

ABSTRACT

Pore clogging with Brownian particles is of wide interest in filtration processes. We perform experiments where model sub-micrometric pores are clogged using a Brownian suspension. We study the influence of the ionic strength on the clog formation dynamics. The erosion/drag force competition is also studied using a crossflow in the inlet channel. The way the clogs disintegrate after the clogging process provides some information about their structure, which can be composed of two or three "layers" – labile or not.

KEYWORDS: Brownian suspension, clogging, model pores.

INTRODUCTION

This paper reports new results about model pores clogging with strongly Brownian particles. The accumulation of particles in a porous media is a complex process which involves DLVO, steric and hydrodynamic interactions. The clogging phenomenon may occur in inkjet printers or numerous other applications such as water filtration through a membrane. While the fouling of a membrane at the macroscopic scale is well understood, the investigations at the pore scale are still at their beginning [1]. Very recent works have used model microchannels to study the effect of different parameters, such as ionic strength or Péclet number (advection/diffusion competition) on the clogging of pores at the micrometer scale [2-4]. The sub-micron dimensions are still unexplored in spite of strong specificities (Brownian motion, system size comparable to scales of interaction), and relevance (0.2 µm being a typical industrial pore size). In this context, we study the clogging/unclogging of silicon-glass channels with Brownian particles. We focus particularly on the influence of ionic strength and the building/erosion processes using a crossflow imposed in the inlet microchannel.

EXPERIMENTAL

We use silicon-etched micro-fabricated channels, covered with a borosilicate wafer. The design (see figure 1) consists of two microchannels connected by ten smaller "nanochannels" 10µm wide, 50µm long and 860nm deep. We inject a suspension of latex fluorescent beads of diameter 250nm with a volume fraction $\Phi=4.10^{-5}$. The ionic strength (I) is fixed using a buffer (phosphate buffered saline). A pressure drop ΔP is imposed between the two microchannels to allow particles to cross the nanochannels. The clog formation and disintegration processes are captured by fluorescence microscopy. Figure 2 shows clogs built at the entrance of the nanochannels.

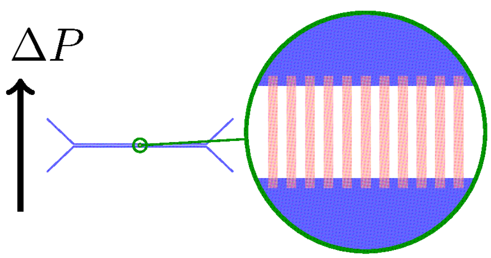

Figure 1: Chip design with a zoom on the nanochannels (red). Microchannels are blue-colored.

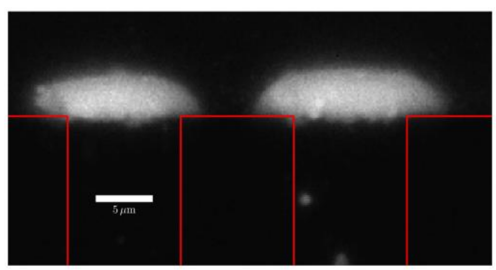

Figure 2: Picture of clogs at the entrance of 860nm deep nanochannels delimited by red lines.

RESULTS AND DISCUSSION

The time evolution of clogs at different pressure drops is presented in figure 3 for an ionic strength $I = 0$mM (no asses salts). For the lower pressure drops ($\Delta P = 10$ and 15 mbar) we observe a regular growth of the clog then a saturation, whereas for higher ΔP (20 mbar) the saturation is replaced by a slow growth. The kink point appears when the drag forces become lower than the high repulsive ones – due to surface charge effects at low ionic strength. The difference between saturation and slow growth could result from the competition between drag forces and Brownian diffusion. Study of the clog breakdown when the pressure drop returns to zero shows that the external part of the clog is labile: the hydrodynamic forces are not enough compared to electrostatic repulsions to stick all the particles to the walls or to other particles. The absence of saturation of the clog size when the pressure drop is large enough is the consequence of the appearance of a third "layer" of the clog with a particle concentration rise as visible on the insets figure 3.

Figure 4 compares size of the clog region with and without crossflow in the inlet microchannel for the same pressure drop through the nanochannels and for I = 3mM. No saturation is visible without crossflow because of the ionic strength: repulsive interactions are screened. The saturation visible when a crossflow is imposed is due to the competition between drag forces and erosion.

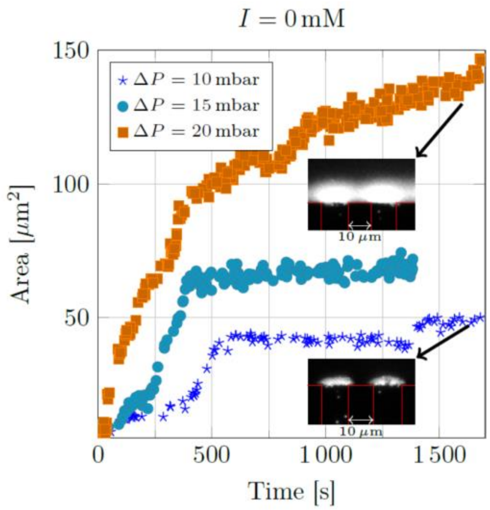

Figure 3: Clog size time evolution at I=0mM. The insets represent a picture of two clogs.

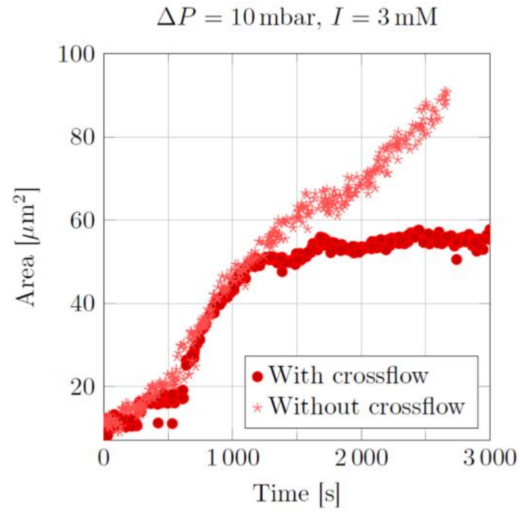

Figure 4: Clog size time evolution with and without crossflow.

CONCLUSION

Using these microfluidic devices we can understand better the clogging at the pore scale with Brownian particles within the filtration context. Various parameters are involved in the clogging dynamics, such as pressure drop, ionic strength or crossflow. The more the pressure drop, the faster the clog grows. Due to surface charge screening, the clog does not seem to saturate when ionic strength is increased. Saturation of the clog size appears when the repulsive forces are high (I = 0mM) or if there is a crossflow in the inlet microchannel. This is related to Brownian motion/drag forces and erosion/drag forces competitions respectively. Clogs are organized with a lower layer of stuck particles and another layer of repulsive glass. In certain conditions a polarization layer consisting of a high-concentration suspension can appear.

ACKNOWLEDGEMENTS

We acknowledge the Fédération Fermat and University of Toulouse (Project *NEMESIS*) for funding these researches. O. Liot warmly acknowledge M. Socol for his chip microfabrication and experimental help.

REFERENCES

[1] E. Dressaire, and A. Sauret, "Clogging of microfluidics systems," *Soft Matter*, 13, 37, 2017.

[2] H. M. Wyss, D. L. Blair, J. F. Morris, H. A. Stone, and D. A. Weitz, "Mechanism for clogging of microchannels," *Physical Review E*, 74, 061402, 2006.

[3] B. Dersoir, M. Robert de Saint Vincent, M. Abkarian and H. Tabuteau, "Clogging of single pore by colloidal particles," *Microfluid Nanofluid*, 19, 4, 2015.

[4] M. Robert de Saint Vincent, M. Abkarian and H. Tabuteau, "Dynamics of colloid accumulation under flow over porous obstacles," *Soft Matter*, 12, 1041, 2016.

CONTACT

* O. Liot; phone: +33561337810; oliot@laas.fr