Special issue on transport in narrow channels

Paolo Malgaretti, Gleb Oshanin, Julian Talbot

► To cite this version:

Paolo Malgaretti, Gleb Oshanin, Julian Talbot. Special issue on transport in narrow channels. *Journal of Physics: Condensed Matter*, 2019, 31 (27), pp.270201. 10.1088/1361-648X/ab1548 . hal-03087152

HAL Id: hal-03087152

<https://hal.science/hal-03087152>

Submitted on 30 Dec 2020

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Special Issue on Transport in Narrow Channels

The transport of molecules, colloids and particulate matter in narrow channels is ubiquitous in natural, industrial and technological processes. While there is a long history of research relevant to the topic (Stokes/Poiseuille flow, Hele-Shaw cells, ion channels and pumps, etc.) the field has grown rapidly in the last few years attracting contributions from researchers with a variety of backgrounds. The 22 articles appearing in this special edition showcase a variety of approaches and applications of transport in narrow channels. We can identify a number of general topics including polymers, active particles, currents and current fluctuations. One common theme found in several articles is the problem of optimizing the transport efficiency.

Polymers

Synthetic or bio-polymers in channels have many important applications including, for example, protein and DNA sequencing. Chinappi and Cecconi [3] discuss nanopore-based devices for protein sequencing. They focus on the physical modelling of the transport process, emphasizing its multiscale nature. Sakaue [9] analyses the behavior of a semiflexible polymer confined in nanochannel under compression in the axial direction. Sarabadani and Ala-Nissila [15] review recent developments in the theory of polymer translocation dynamics through a nanopore using their own iso-flux tension propagation theory. Tagliazucchi et al. [16] study translocation routes of nanoparticles through polymer-brush modified nanopores, including those that do not coincide with the axis of the pore. They show that there is an optimum particle size that maximizes translocation. Nomidis et al. [19] review existing models of the reaction limited capture process of biomolecules by a nanopore.

Active Particles

Active particles, which consume energy in order to move, have been the focus of intense interest in recent years. In this special issue, they are featured in several contributions: Bet et al. [5], motivated by design principles for self-steering particles, derive analytical solutions to the equation of motion of general particles that undergo strongly confined quasi-2D motion in Hele-Shaw cells. They study both symmetric and asymmetric particle shapes and they find excellent agreement with numerical simulations of the particle trajectories. The contribution of Daddi-Moussa-Ider et al. [11] explores the state diagram of a three-sphere microswimmer in a channel. They consider neutral, puller and pusher type swimmers. The latter always end up trapped at the channel walls, while the first two may also perform a gliding motion. Certain aspects may be captured analytically using the method of images. Cecconi et al. [13] examine the anomalous mobility of a driven active particle in a steady laminar flow. Yang et al. [14] study colloidal transport through an array of traps controlled by microswimmers and observe that the active micro-swimmers control the diffusion of passive particles.

Current and Current Fluctuations

The Fick-Jacobs equation provides an approximate, one-dimensional description of diffusion in channels (2D) and tubes (3D). This approach is used in two of the present contributions: Chávez et al. [2] develop a theory for the position-dependent effective diffusivity for two-dimensional asymmetric varying-width channels, and for three-dimensional curved midline tubes, formed by straight walls. Kalinay and Slanina [8] present a formalism reducing the general 2D advection-diffusion equation onto the longitudinal coordinate, also valid for nonconservative forces. The result is a generalized Fick-Jacobs equation.

Zorkot and Golestanian [1] present a linearised theory of frequency dependent fluctuations of current through nano channels. The predictions are compared with brownian dynamics simulations.

Carusela and Rubi [7] study the current rectification of particles moving in a pulsating channel under the influence of an applied force. Berezhkovskii and Bezrukov [12] examine the effect of stochastic gating on the flux of solute molecules through a membrane channel. The spontaneous transitions of channel-forming proteins between their open and closed states is well known. Coalson and Jasnow [18] present discrete state models of single-file ion permeation through a narrow ion channel pore and use them to analyze the ratio of forward to backward tracer current.

Colloidal and Other Topics

Fang et al. [4] present a molecular dynamics study of the invasion of gas into mica nanopores. Liot et al. [6] present an experimental study of the influence of diffusion, confinement and particle nature on the transport of nano-objects in narrow channels. Two contributions are concerned with clogging phenomena: Reichhardt and Reichhardt [10] examine the flow and clogging of particles driven through asymmetric funnel arrays using brownian dynamics simulation. The clogged states remain robust at finite temperatures but develop intermittent bursts of flow in which a clog temporarily breaks apart but quickly reforms. Barré et al. [20] propose analytically soluble stochastic models of blockage in channel bundles and show that, in the case of reversible blockage, the exiting flux can be maximized. Bacchin [17] provides a general, unifying description of colloidal dispersion flow in confined systems. Ooshida and Otsuki [21] present a theoretical framework that allows analytical calculation of two-tag correlations of interacting brownian particles confined to a narrow channel. Bénichou et al. [22] present a review of tracer diffusion in crowded, narrow channels.

We thank the authors for their contributions and the editors of the Journal of Physics : Condensed Matter for the opportunity to serve as guest editors of this special issue.

Paolo Malgaretti, Gleb Oshanin, Julian Talbot

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