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The Translocation Time through a Nanopore with an Internal Cavity is Minimal for Polymers of Intermediate Length

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Nanopores are of great interest in the study of biological systems and in the development of new scientific and industrial tools.
Synthetic nanopores, constructed from silicon wafers or similar materials, show great potential for detecting, sorting, and manipulating polymers rapidly and efficienctly.
Traditional nanopores are short cylindrical holes in a membrane, whose radii and lengths are comparable.
The average translocation time of polymer electrically forced to pass through such pores is a monotonic function of polymer length.
In the present work, we conceive of a novel nanopore design, in which a relatively large hollow cavity is included between two traditional nanopores.
Using numerical simulations of a model system, the average polymer translocation time through this new geometry is found to be a complicated function of length and driving force.
For moderate driving forces, translocation time is minimal for some critical polymer length, with shorter chains slowed by entropic trapping, and longer chains slowed by virtue of their length.
For larger driving forces, the effects of entropic trapping are suppressed as the chain is forced against the far side of the cavity.
As such, translocation time is almost constant below the critical polymer length.
Furthermore, the rich dynamics of this system can be explained by a simple free energy description.
This model accurately predicts the relationship between the critical polymer length of the system and the strength of the driving force with no free parameters.
These results suggest that the new pore geometry could be used as a highly selective filter for extracting polymers from a solution, behaving as a band-pass filter for moderate driving forces and a low-pass filter for strong driving forces.
Further, the filter threshold can be tuned dynamically using the relation predicted by the free energy model.
Thus, this device opens up new applications for nanopores within nanofluidic devices.

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