

A sensor to measure flow rate in individual nanopore

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Nanopore based applications have benefited from significant instrumental development in order to measure physical quantities associated to flow and transport at the nanoscale. Electrical current, for instance, can now be measured through a single nanochannel with commercial apparatus. Flow rate, on the other hand, is a quantity that is both central when dealing with flows and still notoriously difficult to be measured experimentally at the scale of an individual nanometric confinement. The best commercial flow rate sensor gives the ability to measure flow rates of the order of 10 nL/min that remain three decades larger than those typically expected in a single nanopore. A few approaches exist though to probe such small flow rates but indirectly and in specific configurations only [1]. We show in this communication that minute flow rate can be directly measured accumulating liquid over time within a compliant membrane whose deflection is precisely measured by means of strain gages [2]. A demonstrative sensor based on this approach covers three decades of flow rates ranging from 1 pL.min⁻¹ to 1 nL.min⁻¹. Such a versatile sensor works independently of the nature of the liquid, the origin of the flow, and the geometry of the confinement. The capabilities of the sensor are illustrated with the measurement of flow rate through benchmark micro capillaries and through a single conical nanopore within a 1 micron thick silica membrane that opens new possibilities for the study of electro-osmosis in strong confinement.

[1] E. Secchi, S. Marbach, A. Nigués, D. Stein, A. Siria, and L. Bocquet, Massive radius-dependent flow slippage in carbon nanotubes, *Nature*, **537**, 7619, 210-213, (2016).

[2] C. Picard, E. Charlaix, P. Sharma, Dispositif et procédé de mesure de débit d'un liquide, demande de brevet d'invention N° 1851804 (2017).

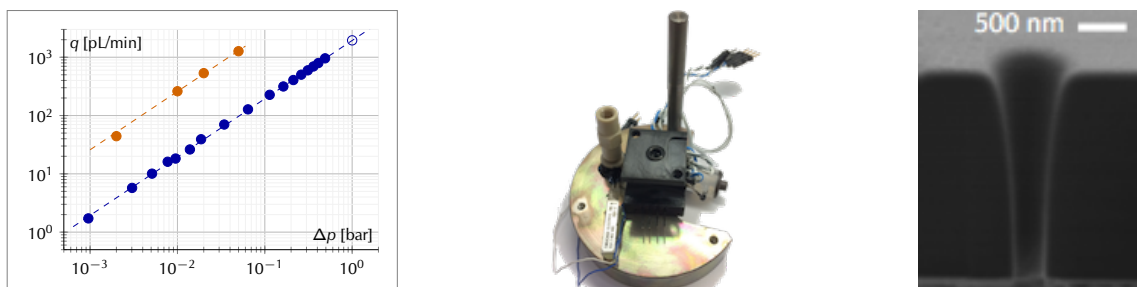


Figure 1: Measured flow rate through calibrated capillaries (left), picture of the flow rate sensor (center) and a transmembrane nanopore studied with the sensor (right).