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Single Ion Transport with a Single-Layer Graphene Nanopore

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Abstract : Graphene material has found tremendous applications in water desalination, DNA sequencing and energy storage. Multiple nanopores are etched to create opening for water desalination and energy storage applications. The nanopores created are of the order of 3-5 nm allowing multiple ions to transport through the pore. In this paper, we present for the first time, molecular dynamics study of single ion transport, where only one ion passes through the graphene nanopore. The diameter of the graphene nanopore is of the same order as the hydration layers formed around each ion. Analogous to single electron transport resulting from ionic transport is observed for the first time. The current-voltage characteristics of such a device are similar to single electron transport in quantum dots. The current is blocked until a critical voltage, as the ions are trapped inside a hydration shell. The trapped ions have a high energy barrier compared to the applied input electrical voltage, preventing the ion to break free from the hydration shell. This region is called “Coulomb blockade region”. In this region, we observe zero transport of ions inside the nanopore. However, when the electrical voltage is beyond the critical voltage, the ion has sufficient energy to break free from the energy barrier created by the hydration shell to enter into the pore. Thus, the input voltage can control the transport of the ion inside the nanopore. The device therefore acts as a binary storage unit, storing 0 when no ion passes through the pore and storing 1 when a single ion passes through the pore. We therefore postulate that the device can be used for fluidic computing applications in chemistry and biology, mimicking a computer. Furthermore, the trapped ion stores a finite charge in the Coulomb blockade region; hence the device also acts a super capacitor.

Keywords : graphene nanomembrane, single ion transport, Coulomb blockade, nanofluidics
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