Ionic memory in two-dimensional nanochannels

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Abstract

Memristor, or memory resistor, is a device whose resistance depends on its previous history of applied voltage. In 2008, Hewlett-Packard (HP®) group announced the discovery of the memristor and they experimentally demonstrated its properties which opened the way to the emergence of several memristive systems [1]. The vast majority of these memristors are solid state with quite a few ionic-liquid based memristors which require high voltage application and complex experimental conditions. It was demonstrated that the loop style (crossing or touching at the origin of current-voltage curve) depends on the mechanism behind the memristive effect [2]. Herein, we use 2D slit shaped angstrom-scale channels with pristine MoS_2 walls or activated carbon walls to study the memristor effects in two-dimensional channels [3, 4]. The confinement in the 2D (height of the channel <10 nm) was necessary to observe the memristive effects. The surface charge and the composition of the electrolyte played an important role in the determination of the style of the memristive IV loop. The main advantage of this new memristor is the use of simple electrolyte salts (HCl, KCl, NaCl, $CaCl_2$, $AlCl_3$, etc.) rather than complex ionic liquids and the application of up to hundred times smaller voltages (within the water oxidation window) which can potentially reduce the energy consumption [5]. Indeed, the MoS_2 2D channel devices showed interesting versatility, with different memristor loop styles and even we can observe them reversibly in the same device, by simple modification of the salt type, concentration, pH, frequency, the channel height etc. The existence of memristor effects was confirmed by the dependence of the IV loop area on the alternative voltage frequency. Finally the memristor showed interesting synapse-like dynamics and long/short memory effects. This discovery can pave the path toward the real life application in digital logic circuits, random access memory, signal processing, random number generator, artificial intelligence and neuromorphic computing.

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FIGURES

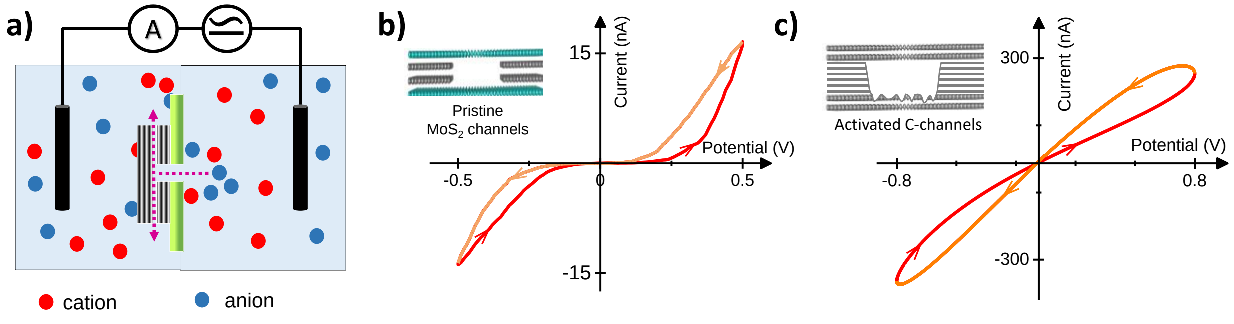

Figure 1: a) Schematic view of the set-up used for memristor device based on the application of alternating voltage using two Ag/AgCl electrodes dipped in electrolyte solution. Typical memristor current-voltage graph observed in b) pristine MoS_2 channels (height = 1 nm, salt concentration = 3 M) showing touching style loop c) activated carbon channels (height = 5 nm, salt concentration =1 M) showing crossing style loop.