Research Highlights

DOI: 10.1039/b904003j

Nanofluidic diode consisting of heterogeneous oxide materials

In a recent study, Li-Jing Cheng and L. Jay Guo from The University of Michigan investigated the ion transport behaviour in nanochannels consisting of heterogeneous oxide materials with opposite polarity of surface charges (Fig. 1).[1] Such nanofluidic devices could serve as a nanofluidic diode and may be integrated on a microfluidic chip to perform pH control and to provide key function in bio-/chemical separation processes in integrated micro- and nanosized systems. However, to achieve this, methods are required to create robust and tuneable surface charges along a channel. In particular, one of the key challenges is the creation of asymmetric surface charge along the channel. While in previous approaches surface chemical treatment was used, the authors utilised solid-state oxide materials of different isoelectric points, *i.e.*, a negatively charged silicon dioxide and a positively charged Al_2O_3 nanochannel connected in series. The properties of the created nanochannels rely on the arrangement of these oxide materials by means of photolithography. The fabricated nanofluidic diodes exhibit high rectification of ion current in forward bias configuration. In a double junction diode, breakdown effect is observed and investigated, while the regulation of ionic current and ionic switching is demonstrated in a three-terminal nanofluidic triode. The method provides the basis for the fabrication of nanofluidic networks to precisely control the transport of ions and hence, systems with more sophisticated functionalities can be built.

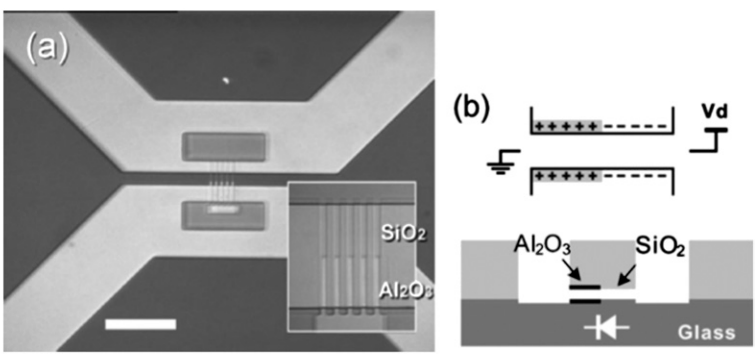

Fig. 1 A nanofluidic diode. The micrograph (a) and the scheme (b) show nanofluidic channels, fabricated between microfluidic channels. The nanochannels consist of two different oxide surfaces with different surface charges providing the requirements to serve as a fluidic diode. (Reprinted from ref. 1 with permission. Copyright 2009 American Chemical Society).

Nanointerstices to generate predictable capillary flow

Capillary-driven flow is widely employed for filling of single-use microdevices. It is very convenient due to its simplicity, and no external power sources are required. Naturally, capillary-driven flow is strongly dependent on the surface properties of the capillaries. However, the commonly used materials for disposable microdevices, *i.e.* different kind of plastics, are either hydrophobic and hence, inhibit capillary-driven flow, or they provide non-stable surface properties. To prevent aging of surfaces and to enhance hydrophilicity, surface modifications based on chemical coatings and plasma treatment has been suggested. Roger D. Kamm and researchers from MIT suggest in a recent article a simple alternative for the creation of long-term predictable flow.[2] They produced nanointerstices adjacent to a much larger microchannel by uncomplete bonding of a PMMA substrate, containing the microchannels, to a bottom PMMA cover. Briefly, the bonding is performed by addition of acetone at several points around the channel wall, while substrate and cover plates are pressed together. In this way, the outside of the channel wall is melted, while the inner sides are not reached by acetone. By removing the pressure on the plates, the nanointerstices are formed. The microflow in the device is compared to PMMA channels treated by a plasma, over a time interval of one year, and show indeed the improved properties of the novel nanointerstices-bordered microchannels. The authors believe that the technique is particularly useful for commercialized products, to generate predictable microflows in devices regardless of surface properties and device storage time.

Toward nanofluidic FET devices

An advance in the fabrication of hollow nanotubes with uniform and well-defined molecular-size inner diameters, controllable geometry, and chemical and electrical composition of the nanotube shell has been reported by Moshit Ben Ishai and Fernando Patolsky from Tel Aviv University (Israel).[3] The formation process of the single-crystalline silicon nanotubes involves (i) the formation of vertical single-crystalline Ge nanowires as template in an ultrahigh-vacuum chemical vapour deposition, (ii) the epitaxial growth of high-quality silicon nanotubes, and (iii) the etching of the core templates by wet etching with H_2O_2 after removal of the nanotubes from the substrates by sonication. The use of Ge templates has several advantages. As the germanium core shell and the silicon shell both have diamond crystal structures with similar lattice constants, silicon can grow epitaxially on the Ge nanowires. Furthermore, the diameter of the core can be controlled over a broad range from as small as 1.5 up to 500 nm by altering the growth conditions, or by employing postgrowth thermal oxidation or enlargement. Finally, the selective etching of germanium does not affect the integrity or crystallinity of the silicon shell. An important advantage of this approach is the possibility to precisely change the chemical composition, *i.e.* the introduction of dopants or reactants. The authors show, for example, the formation of Si_xGe_{1-x} alloy nanotubes and p-type silicon nanotubes. To increase the solubility, the nanotubes were chemically modified by covalent binding of silane molecules containing different functional groups. In order to demonstrate the use of the nanotubes, the researchers fabricated a FET device from p-doped silicon nanotubes and evaluated the performance. In future work, they want to focus on biological and chemical applications.

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References

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