



Technology Focus: Nano Materials & Manufacturing

Filtering Water by Use of Ultrasonically Vibrated Nanotubes

Water molecules could flow through; larger molecules and other particles could not.

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Devices that could be characterized as acoustically driven molecular sieves have been proposed for filtering water to remove all biological contaminants and all molecules larger than water molecules. Originally intended for purifying wastewater for reuse aboard spacecraft, these devices could also be attractive for use on Earth in numerous settings in which there are requirements to obtain potable, medical-grade, or otherwise pure water from contaminated water supplies. These devices could also serve as efficient means of removing some or all water from chemical products — for example, they might be useful as adjuncts or substitutes for stills in the removal of water from alcohols and alcoholic beverages. These devices may be constructed using various materials, such as ceramics, metallics, or polymers,

depending on end-use requirements.

A representative device of this type (see figure) would include a polymeric disk, about 1 mm in diameter and between 1 and 40 μm thick, within which would be embedded single-wall carbon nanotubes aligned along the thickness axis. The polymeric disk would be part of a unitary polymeric ring assembly. An acoustic transducer in the form of a piezoelectric-film-and-electrode sub-assembly — typically 9 μm thick and made of poly(vinylidene fluoride) coated with copper 150 nm thick — would be affixed to the outside of the outer polymeric ring by means of an electrically nonconductive epoxy.

The nanotubes would be chosen to have diameters between about 8 and about 13.5 \AA because water molecules could fit into the nanotubes, but larger

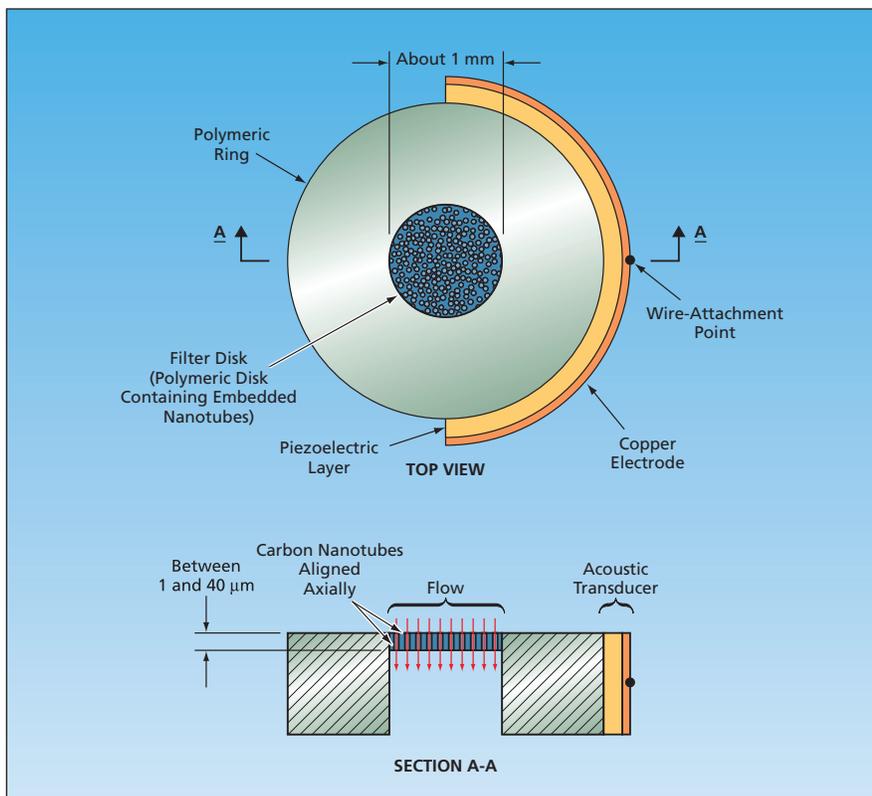
molecules could not. Water to be purified would be placed in contact with one face (typically, the upper face) of the filter disk. The surface tension of water is low enough that water molecules should enter and travel along the nanotubes, and computational simulations of molecular dynamics and experimental measurements have shown that the water molecules inside the nanotubes in this size range can be expected to become aligned into helical columns that exhibit properties of both hexagonal ice crystals and liquid water.

The acoustic transducer would be excited by means of an oscillator operating in the frequency range from 50 to 200 MHz. The assembly can feasibly be operated in the gigahertz range with a choice of a different oscillator. The frequency could be varied automatically over this range. The resulting acoustic waves would be coupled via the polymeric ring and disk to the nanotubes and water molecules. The acoustic energy transferred to the water molecules by the acoustic waves would, conservatively, equal or exceed the specific heat of fusion of ice — sufficient to cause the water molecules to become detached from each other, collectively behaving more like liquid water. Thus, the acoustic excitation would enable water to flow more freely along the nanotubes and to leave the filter disk on the lower face.

Devices of this type would be scalable to larger diameters and power levels and to multiple-filter assemblies. Although a quantitative estimate of power consumption was not available at the time of writing this article, it was reported that a single-filter device having the dimensions described above could be powered by a 9-volt battery. Larger assemblies could be powered from household and industrial power lines.

This work was done by Lillian Susan Gavalas of Johnson Space Center.

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Aligned Carbon Nanotubes having diameters within a critical range would be embedded in a polymeric disk. The acoustic transducer would be used to excite vibrations at or near a resonance frequency of water molecules inside the nanotubes, thereby hastening the movement of the water molecules from the inlet to the outlet face of the disk.