FLUID EXPERIMENTS IN SINGLE MULTIWALL CARBON NANOTUBES: A NOVEL PLATFORM TO STUDY FLUID TRANSPORT AND PHASE CHANGE AT THE NANOSCALE

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The dynamic transport of fluids in nanochannels is currently receiving increased attention not only because of its relevance to fundamental questions regarding fluid behavior near the continuum limit, but also because of its implications in technological applications of the future. A hydrothermal method of catalytic nanotube synthesis has been shown [1] to produce high-aspect-ratio, multiwall, capped carbon nanotubes, which are hollow and contain a high-pressure encapsulated aqueous multicomponent fluid displaying clearly segregated liquid and gas by means of well-defined interfaces (see Fig. 1). Thermal experiments are presented using electron irradiation as a means of heating the contents of individual nanotubes in the high vacuum of a transmission electron microscope (TEM). The experiments clearly demonstrate [2] that TEM can be used to resolve fluid interface motion at these ultrafine length scales. Fully reversible interface dynamic phenomena are visualized, and an attempt is made to explain the origin of this fine-scale motion. Experimental evidence is presented of nanometer-scale liquid films rapidly moving fluid along the nanochannel walls with velocities 0.5μm/s or higher. Video sequences of controlled fluid transport in individual nanotubes are presented, thus demonstrating the capability to transfer fluid along the carbon nanotube interior. The research illustrates that carbon nanotubes offer a promising platform for studying the behavior of multicomponent, multiphase fluids in nanosize channels at high-pressure conditions.

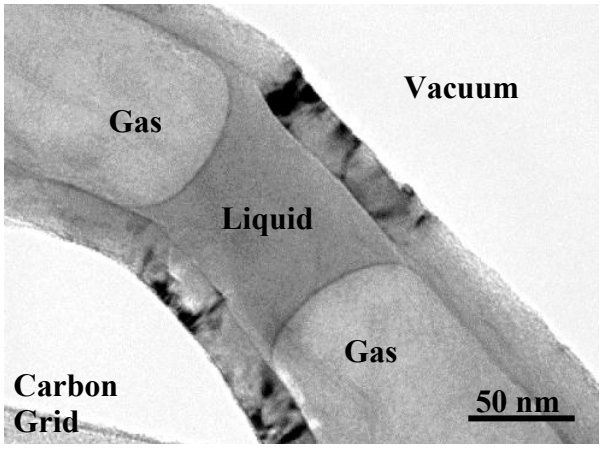

Fig. 1 Transmission electron photomicrograph showing an elbow portion of a carbon nanotube made hydrothermally. This tube is capped at both ends and contains a liquid inclusion constrained between two menisci separating the aqueous liquid from the adjoining gas. The nanotube rests on a holey carbon grid, a segment of which is visible in the lower left corner of the micrograph. The environment outside the nanotube is the high vacuum of the TEM column [2].

References

[1] Y. Gogotsi, J. A. Libera, A. G. Yazicioglu, and C. M. Megaridis, "In-situ Multiphase Fluid Experiments in Hydrothermal Carbon Nanotubes," *Applied Physics Letters,* v. 79, p. 1021-1023, 2001.

[2] C. M. Megaridis, A. G. Yazicioglu, J. A. Libera, and Y. Gogotsi, "Attoliter Fluid Experiments in Individual Closed-End Carbon Nanotubes: Liquid Film and Fluid Interface Dynamics," *Physics of Fluids,* v. 14, p. L5-L8, 2002.