System Description

- Cylindrical geometry, closed ends
- Internal pressure: up to 30 MPa (leak-tight)
- Fluid components: H₂O (~85%), CH₄, CO₂
- Contact angles: 0-25 degrees (wetting)
- Liquid volumes: ~10⁻¹⁸ [atto] liters
- Excellent definition of gas/liquid interfaces
- No significant defects on the inner wall surface; ideal system for contact line or wetting studies

The Experiment

(a) and (f) were created by interlacing several images of the same nanotube to retain high resolution.

EVAPORATIVE TRANSPORT OF AQUEOUS LIQUID IN A CLOSED CARBON NANOTUBE: A NANO HEAT PIPE?

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Evaporative transport of liquid from one end of a carbon nanotube compartment, about 1 μm long, to the other end was achieved using a hydrothermally-produced multiwall nanotube and the beam of a transmission electron microscope (TEM, JEOL JEM-3010, 300 keV) as the heat source. The inner diameter of the tube shown above is 70 nm. Initially, the liquid inclusion (marked by the white dashed outline) was constrained between an internal closure and a long gas bubble (frame a). The field of view of the TEM was moved to the top area of the shown nanotube (b), where the liquid was initially located, and this area was heated slowly by focusing the electron beam. As the beam was contracted, the liquid gradually evaporated due to the induced heating (c-d). When the heating was ceased, approximately 65% of the liquid had evaporated from this area (e). The TEM field of view was subsequently moved to the other (lower) end of the nanotube, which was relatively cool during the heating of the top area, to reveal that the liquid had condensed there (f). The entire sequence (a-f) lasted for about 20 seconds.

This sequence demonstrates the ability to transfer energy between the two ends of the nanotube. Assuming the liquid is pure water, the energy transported in this process is approximately 2 nJ. This energy, if delivered in its entirety, could raise the temperature of a 5 μm biological cell by ~0.01 K. Supported by NSF NIRT grant CTS-0210579.

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