

# Physicists Investigate Controversy over Room-Temperature Ice

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(PhysOrg.com) -- By confining water in nano-sized spaces, physicists from Leiden University in the Netherlands have turned water into ice at room temperature. While it's not the first time scientists have created room-temperature ice, Dutch physicists K. B. Jinesh and Joost Frenken hope that their findings will put the controversial subject of water under nanoscale confinement in a new light.

Compared with other liquids, water behaves in strange ways. When under extreme confinement – such as when squeezed between two surfaces in an area of less than 10 molecular diameters (or 1 nm) – most liquid molecules become highly ordered, acquiring a solid-like structure.

But in the case of water, several factors theoretically oppose the molecular ordering under confinement. For one thing, water is the only liquid that expands when it freezes, making it difficult for water to turn into ice when confined to a small space. Some physicists have proposed that water's unique characteristics cause it to remain a liquid under confinement, while others argue that water solidifies under confinement, with each water molecule sharing hydrogen bonds with its neighbors.

“Some simulations and even experiments have shown that water retains its liquid state and bulk viscosity even under extreme confinement, down to 0.1 nm,” Jinesh told *PhysOrg.com*. “At the same time, some other experiments have shown that the viscosity of water changes under confinement. This experimental controversy is the difficulty existing in literature to explain how water would behave as a lubricant under various

situations.”

In their recent study published in *Physical Review Letters*, Jinesh and Frenken have demonstrated direct experimental evidence for water transforming into ice at room temperature when confined between two objects. By scanning the tungsten tip of a high-res friction force microscope over a graphite surface, the physicists showed that the water trapped in between due to capillary condensation rapidly transforms into ice due to confinement. The current study builds on the team’s initial demonstration of ice formation under confinement in 2006, but with more solid information about the structure of the ice formed.

“Our experiment undoubtedly demonstrates that water crystallizes at room temperature, under confinement,” Jinesh said. “This is a strong step towards resolving the existing controversy of whether or not water would change its bulk property due to confinement.”

Here, the physicists investigated how scanning speeds and changes in relative humidity affected the tungsten tip’s scanning motion, as measured by a friction-sensitive Tribolover cantilever on the tip. At low scanning speeds and modest humidity, the tungsten tip exhibited stick-slip motion, alternately stopping and sliding. The physicists explained that this motion occurs because of the subsequent breaking and resolidification of the ice that is firmly attached to the tip and to the graphite. Only the molecules between the tip and graphite are solid ice, while everywhere else the molecules remain in a liquid water state.

“The ice that forms in the confinement is normal ice; most probably, ice with a hexagonal lattice, which is the form of the most common crystalline ice seen in nature,” Jinesh said.

The physicists also observed a few other ice formation traits. They found that, at higher humidities, ice appeared only to form under lower tip-

scanning speeds compared to at lower humidities. This difference may be because high humidity causes the water film to be thicker, so that the molecules require more time for ordering, and need to be confined under the tip for a longer time.

The researchers also observed evidence for static friction between the tip and the substrate, due to the ice formation. When the tip briefly paused, the ice had more time to become completely ordered, which made the tip “stick” more at that point in its stick-slip motion.

“It is difficult to foresee an application at this level of invention,” Jinesh said. “The foreseeable difficulty is that in MEMS and NEMS, where the contact areas are shrinking in dimensions, ice formation could be a big problem that causes immediate failure of the devices. On the other hand, to increase friction wherever necessary, this technique could be employed, but it is so far a fiction, I would say!”

More information: Jinesh, K.B. and Frenken, J.W.M. “Experimental Evidence for Ice Formation at Room Temperature.” *Physical Review Letters* 101, 036101 (2008).

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