Freezing point of supercooled water varies with electric charge

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'Feather' ice. Image: Craig Thom, via Wikipedia

(PhysOrg.com) -- Just as water can be superheated and remain liquid above the boiling point if there is no nucleating surface (such as a surface defect or a speck of dust), it can also become supercooled and remain liquid well below its freezing point of 0°C. Now scientists have found that supercooled water freezes at different temperatures in the presence of a surface with a positive or negative charge.

In the absence of a charged surface supercooled water can freeze at temperatures as low as -40°C, and it has been known for over 150 years that the presence of an electrical field can affect the freezing point (a phenomenon known as electrofreezing). The dominant hypothesis for the effect is that because water molecules are polar, with a small negative charge at one end and a positive charge at the other, an electric field would align them according to their charge. It has been difficult to study this phenomenon because charged surfaces (such as metals) act as nucleating agents, and therefore trigger freezing.

Igor Lubomirsky and colleagues from the Weizmann Institute of Science in Rehovot, Israel, have solved the dilemma by creating a charge on a non-nucleating pyroelectric material surface, to allow the electrical effects alone to be examined.

The scientists used lithium tantalate ($LiTaO_3$) crystals and thin films of strontium titanate ($SrTiO_3$) as the non-nucleating surfaces, and placed them in a humid room. They then cooled the room until water droplets formed on the surfaces and then lowered the temperature even further until the droplets froze.

The results showed that in the absence of an electric field the water droplets froze at an average of -12.5°C. If the surface was negatively charged the freezing point was -18°C, while if the surface was positively charged the droplets froze at -7°C. Lubomirsky said the difference in freezing temperatures was surprising. The exact mechanism is unclear, and the team are investigating.

They also found they could freeze liquid supercooled water by heating it. With the surface of an $LiTaO_3$ crystal negatively charged, the water was kept liquid at -11ºC for around 10 minutes, but after the charge dissipated the temperature was increased to induce a positive charge on the surface, and the water froze at -8 ºC. Powder x-ray diffraction studies showed that freezing on the positive surface began at the solid/water interface, while on the negative surface freezing began at the air/water interface.

The experiments demonstrated that if the surface charge is controlled ice formation can be either enhanced or suppressed, and this could possibly have an application in the cryogenic freezing of tissues and blood, or in cloud seeding.

The study was published on February 5 in the journal *Science*.

More information: David Ehre, Etay Lavert, Meir Lahav and Igor Lubomirsky, *Science*, 2010, DOI:10.1126/science.1178085

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