

## **Surface porosity and wettability are key factors in boiling heat transfer**

EurekaAlert!

### ***Understanding the properties that control surface dissipation of heat could lead to improved power plants and electronics with high heat-transfer rates***

CAMBRIDGE, Mass- A team of MIT researchers has succeeded in carrying out the first systematic investigation of the factors that control boiling heat transfer from a surface to a liquid. This process is crucial to the efficiency of power plants and the cooling of high-power electronics, and could even lead to improvements in how vehicles travel through water.

The research deals with a key transition point known as the critical heat flux, or CHF, a value of heat transfer, per unit time and area, where a surface's heat-transfer characteristics suddenly change: For example, when the cooling panels of an electronics system become covered with a layer of vapor that blocks heat transfer, the resulting rise in temperature can damage or destroy the equipment. The new findings could raise the value of CHF, providing extra safety margins or operating ranges for such equipment.

The research was carried out by seven MIT researchers and published in the journal *Applied Physics Letters*. Co-author Jacopo Buongiorno, an associate professor of nuclear science and engineering, says it could lead to safer nuclear reactors, more efficient heat exchangers, and better thermal management of high-power electronics.

Until now, there has been no agreement on the relative importance of three surface attributes that could affect the onset of CHF: roughness, wettability (the ability of water to spread across a surface) and porosity. Now, after a detailed investigation, the team has found that the presence of a porous layer on a material's surface is by far the most important factor.

While other researchers have studied these surface effects, Buongiorno explains, those earlier analyses often changed multiple surface parameters at the same time, making it difficult to identify which was most important. Buongiorno's team was able to independently vary each of the three parameters, and obtained "some surprising results," he says.

The new work grew out of the team's earlier studies of nanofluids — nanoparticles suspended in water — for possible use in nuclear-plant cooling systems. They found that the nanoparticles, which tended to deposit on surfaces, raised the CHF, potentially boosting safety in the plant.

But it was unclear exactly why this worked. Co-author Michael Rubner, the TDK Professor of Polymer Materials Science and Engineering at MIT, says that when Buongiorno "indicated that enhancements in CHF appear to be related to the deposition of nanoparticles onto surfaces, we got excited since we had developed methodologies for systematically depositing nanoparticles onto surfaces with nanoscale control over thickness, wettability and porosity. Using these methodologies, we were able to produce well-defined surface characteristics and structures that made it possible to sort out the important factors at play in the process."

Based on the new tests, the team determined that the nanoparticles form a hydrophilic porous coating on the surface, accounting for the improvement. The earlier "common wisdom" among researchers, Buongiorno says, had been that wettability alone, not porosity, was the main property accounting for increases in CHF.

Co-author Tom McKrell, an MIT research scientist, says, "It was the multidisciplinary team that allowed for this finding." Without the team's expertise in surface nanoengineering, surface characterization and thermal hydraulics, he adds, the relative contributions of these attributes to CHF "would have remained a mystery."

For most applications — such as fuel rods in nuclear power plants or liquid cooling systems in high-power electronics — it is desirable for CHF to be as high as possible. But for some applications — such as drag-reduction on the surface of objects moving underwater — a low CHF is desirable; the new analysis shows how to reduce the CHF by applying a hydrophobic, porous coating to the surface.

The new work builds on earlier research by Buongiorno and his colleagues that looked at the flip side of CHF, a process called quenching. This is what happens when a hot material is put in contact with a cold liquid — such as when water is injected into an overheated fuel assembly in a nuclear plant, or a glowing-hot piece of metal is submerged in cold oil to engineer its microstructure.

In such cases, the liquid's contact with the hot metal can create a vapor barrier that effectively insulates the surface. Buongiorno says the metal could be "so hot that when you put water on it, it wouldn't touch it" — a problem that can be overcome by coating the surface with a porous hydrophilic layer that accelerates rewetting of the surface, enhancing heat transfer. Conversely, if rewetting is undesirable, a porous hydrophobic layer would be applied.

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