Better droplet condensation could boost power efficiency

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Researchers at MIT have developed an innovative approach to improving heat transfer in power plants and cooling systems. The new system could provide a 100 percent improvement in the efficiency of heat transfer over conventional systems, the researchers say.

Heat transfer by condensation is key to the operation of today's power plants, where fossil fuels are used to boil water and the resulting steam drives turbines to generate electricity. The steam must then condense back to water, which is collected and sent back to the boiler to start the cycle again.

The new system is an improvement of the condensers used to turn steam back into water. The same principle might also be used to improve condensers in desalination plants and in thermal-management systems.

Three key qualities contribute to the efficiency of heat transfer in such systems: Droplets must form easily and abundantly on a condenser surface; the area of contact between the droplet and the surface must be large enough to easily conduct heat; and the droplets must quickly fall away from that surface to allow new droplets to start condensing.

While most previous research on improving condensers has focused on the third part, the new work improves all three aspects at once, says associate professor of mechanical engineering Evelyn Wang, senior author of a paper just published in the journal *Scientific Reports*. The report was co-authored by Rong Xiao and Nenad Miljkovic, both of whom just completed their PhDs at MIT, and former postdoc Ryan Enright, now at Bell Labs in Dublin.

The innovation combines three properties: First, a nanopatterned surface, etched with tiny pillars, reduces contact between droplets and the surface. Second, a chemically varied coating, with scattered hydrophilic spots on a hydrophobic background, provides "seeds" for nucleation. Finally, a layer of oil coats the surface, helping droplets to form abundantly on the surface and also making it easy for them to slide off.

"We know it's a combination of these qualities that is optimal," Wang says. "We believe the big contribution of this work is to drastically enhance [droplet] densities. … We see [droplets] form on every single one of those pillar tops."

Condensers' contradictory need to enhance both droplet formation (requiring a hydrophilic surface) and droplet release (requiring a hydrophobic surface) is satisfied by the combination of nanostructures, varied coatings and an oily surface. The local hydrophilicity makes it easier to form droplets on the tops of the tiny pillars—while still being hydrophobic overall, causing droplets to fall away quickly as they grow in size. The new system produces much greater density of droplets than has been achieved on most other nanopatterned surfaces, Wang says.

Because the droplets condense right through the thin coating of oil, and end up being immersed in oil, the researchers coined the term "immersion condensation" to describe their new system. The new approach can be applied to ordinary copper plates or tubes, typically used in today's condensers, so it should be relatively easy to incorporate into existing plants, Wang says.

The group initially did computer modeling of the system, then carried out experiments to verify the models' predictions. The experiments confirmed a 100 percent enhancement of heat-transfer efficiency, compared to copper surfaces treated with a hydrophobic coating alone.

Further research, using different kinds of oil and different texture patterns, could yield even greater improvements, Wang says. "There's lots of opportunity for optimization of the structures to get better performance," she says.

The paper is titled "Immersion Condensation on Oil-Infused Heterogeneous Surfaces for Enhanced Heat Transfer."

More information: www.nature.com/srep/2013/13061 … /full/srep01988.html

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