Engineers use liquid drops to make solids stiffer

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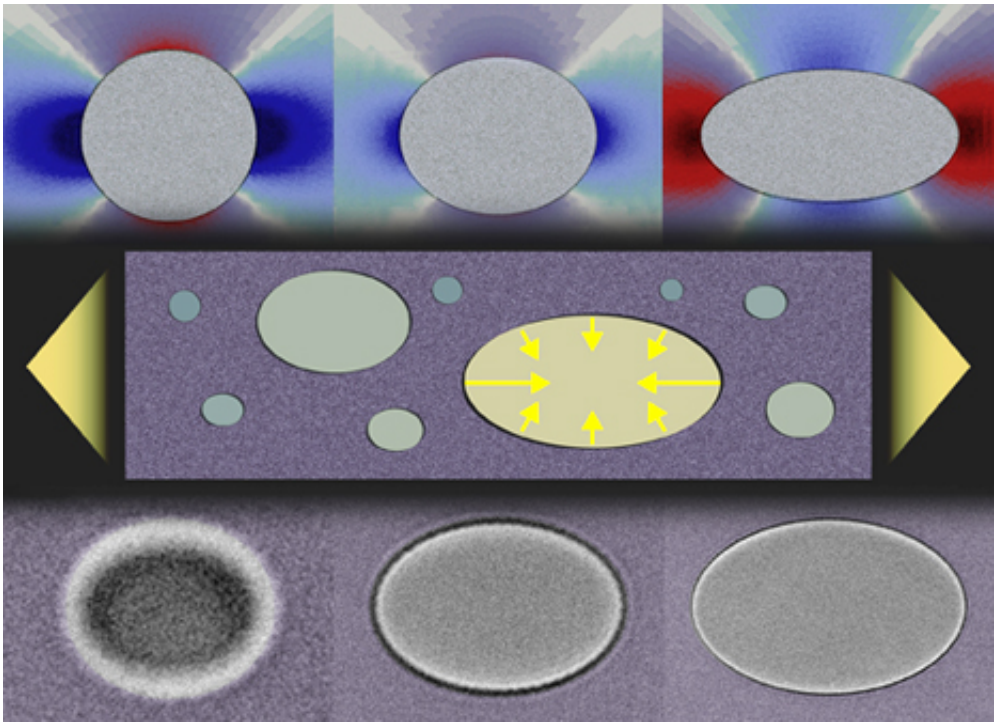

Yale engineers are strengthening soft materials with surface tension.

(Phys.org)—Engineers at Yale University have discovered that the stiffness of liquid drops embedded in solids has something in common with Goldilocks: While large drops of liquids are softer than the solid that surrounds them, extremely tiny drops of liquid can actually be stiffer than certain solids. But when they're "just right," the liquid drops have the exact same stiffness as the surrounding solid.

The key is a liquid's tendency to have as small a surface as possible—a contractile force known as "surface tension" that, for example, allows a cup of water to be filled slightly above the brim without spilling.

"Usually, replacing parts of a solid with liquid only makes a material weaker," said associate professor of mechanical engineering and materials science Eric Dufresne, principle investigator of the research appearing Dec. 15 in *Nature Physics*. "But when the embedded liquid droplets are very small, surface tension makes them so stiff that they can actually make a solid stronger."

Dufresne's team demonstrated this counterintuitive effect by embedding liquid drops as small as a micron in diameter into silicone. The researchers then stretched the silicone, causing the liquid to stretch as well.

When the liquid drops in the silicone were large enough, they deformed easily and weakened the material. However, very small droplets resisted deformation and strengthened the surrounding material. When many tiny liquid drops were embedded in the silicone, the resulting material was as much as 30% stronger than the pure silicone, according to the researchers.

"It turns out that the importance of surface tension is inversely proportional to the size," said Dufresne, who is also the director of Yale's Center for Engineering Innovation & Design. "So what's just a negligible force for big things becomes a strong force for very small things—which in turn can strongly affect the material as a whole."

Dufresne suggested that these results provide engineers with "a new knob to turn" to control the properties of composite materials. For example, droplets of just the right size can mimic the mechanical properties of the surrounding solid; these "cloaked" droplets could

provide additional optical or electrical functionality, without sacrificing mechanical performance.

More information: Stiffening solids with liquid inclusions, DOI: 10.1038/nphys3181

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