A New Take on Microbrewing

April 10 2008

Since Babylonian times, a still has provided the means to turn grain, fruit, or vegetables into an intoxicating drink. Today, a still may provide a solution to the more complex problem of how to detect diseases.

California Institute of Technology researchers have crafted the world's tiniest still to concentrate scant amounts of micromolecules for easier detection. This device may help to overcome difficulties in tracking extremely low-abundance molecular biomarkers, which can indicate disease.

"Distillation has been around for millennia, and it's a well-established technology. There weren't many new avenues to develop because it's so well studied," comments David Boyd, a lecturer in mechanical engineering at Caltech and lead author of a paper describing the new approach to distillation in this month's issue of *Analytical Chemistry*. "But we've created a new space for distillation because you don't need to boil the fluid anymore."

Stills can separate components of a mixture as well as concentrate materials dissolved in liquid, and are used, among other things, to purify seawater, to separate crude oil, and to amplify alcohol content. Now, with nanoparticles of gold and a microbubble, Boyd and his colleagues have created a microscale still that operates at room temperature and pressure, making it potentially useful in biomedical devices.

The still is a microfluidic chip, with a microns-wide channel, thinner than a hair, etched into silicone rubber and serving as the microplumbing for tiny volumes of fluid. But unlike typical microfluidic chips, the channel is sealed by a glass slide studded with gold nanoparticles. Into the channel is introduced a microbubble wide enough to form an air gap in the fluid. Energy from a laser no more powerful than an average laser pointer heats the gold particles, which quickly transfer the heat to the liquid on one side of the bubble, turning it to vapor.

The vaporized liquid passes from the warmer to the cooler side of the bubble, where it condenses. "Only the most volatile molecules cross over the bubble, but everything else is left behind," Boyd describes. In conventional distillation, the same type of separation is achieved either by heating the entire volume of fluid to boil off individual components, or by reducing the gas pressure above the liquid to allow components to more easily escape, he explains.

With the new setup, the team discovered the same process takes place with a very slight change in fluid temperature and without reducing air pressure. They demonstrated the method with dye in ethanol and water, creating a distilled solution of concentrated dye on one side of the bubble and clear liquid on the other.

This microscopic still overturns some major obstacles in microscience. First, it allows distillation of delicate molecules and organisms that can't survive high temperatures and a lack of dissolved gasses. Second, while nanoparticles have often been useful floating freely in fluid, this can bring unwanted side effects, remarks coauthor David Goodwin, professor of mechanical engineering and applied physics at Caltech. "It's difficult to control the concentrations of nanoparticles, they can interact with organisms or other particles in a way you don't want, and they're hard to get out once they're there," he says.

Instead, the team anchored the particles to the base of the chip, and took advantage of unique heating properties of gold in its nanoform. Just as gold particles in stained glass windows absorb green light strongly, making the windows appear red, in the still they absorb the green frequency of a cheap laser and, as Goodwin describes, "act like antennas for visible light." But a laser is only one option for powering the still; Goodwin notes that any low-power heat source, like a wire or resistor, would work.

The bubble, which is key to the novel distillation method, was also once a dreaded entity. "Typically air bubbles are a real annoyance in microfluidics. They pin the flow in fluid and are hard to get rid of," comments Boyd. "We've learned to love them." The team even managed to use bubbles to pump fluid around corners in the microchannels.

Ultimately, the scientists hope that this tiny still can serve in the detection or monitoring of biological processes. They envision a sensor, perhaps even worn as a patch, that will concentrate larger molecules to detect what they are. Patients with diabetes, for example, could wear one to constantly monitor blood sugar level. As Goodwin describes, "Distillation is hard to do on a chip, but when you put it on a chip, it becomes a biomedical monitor."

Source: Caltech