Tiny Bubbles

Stephen W. Carmichael[1]
Mayo Clinic
carmichael.stephen@mayo.edu

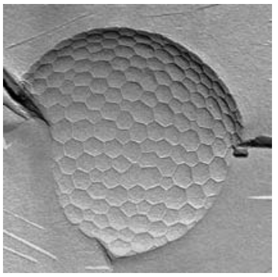
This is not an article about the song made famous by the late (great) Don Ho. This is about a breakthrough in the understanding of how micrometer-sized bubbles can be stabilized for long periods of time. This can influence the taste, smell, and consistency of consumer products including food and cosmetics.

In two-phase systems, which can include air (as bubbles) suspended within a liquid, the structures of the dispersed (bubbles) and continuous (liquid) phases play a critical role in determining the properties of the material. There is also the function of time in that the microstructure of the dispersed phase continuously evolves toward a state of lower energy by minimizing the surface area between the two phases (referred to as the interfacial area). In the long term, this time evolution diminishes the usefulness of two-phase systems. Emilie Dressaire, Rodney Bee, David Bell, Alex Lips, and Howard Stone have devised a way to stabilize a two-phase system for time periods of a year or longer.[2]

In gas-liquid two-phase systems, the air/liquid surface tension produces a pressure that drives the dissolution of gas into the liquid that leads to larger bubbles growing at the expense of smaller ones (a phenomenon known as Ostwald ripening). An important aspect of this is that it is the product of the surface tension and the curvature of the interface that produces the pressure difference between the bubble and the continuous phase. The time scale of this dissolution can be less than a second for micrometer-sized bubbles in pure water. The separation can be delayed by a few orders of magnitude by the addition of surfactants and other "tricks" that decrease the surface tension, but it is still difficult to keep small bubbles suspended in a liquid for more than a few months.

Dressaire et al. reported creating very stable gas dispersions obtained using a standard multiphase mixing technique to trap air into surfactant shells within a viscous liquid. The surfactant solution was very viscous glucose syrup (approximattely 3 parts sugar to 1 part water) with sucrose stearate as the surfactant (2% by weight; mainly a mixture of mono- and diesters). The solution was aerated by vigorous mechanical mixing for 2 hours that "sheared" trapped bubbles within the viscous liquid to reduce the size of the bubbles.

The resulting foam was examined using several techniques and microscopes. These included freeze-fracture transmission electron microscopy (TEM), cryogenic scanning electron microscopy (cyro-SEM), and cryo-TEM. Using these techniques, Dressaire et al. showed microbubbles (about 1 micron in diameter) and that every microbubble had a nearly hexagonal surface pattern on a nanometer scale (see cryo-SEM, right). They thought that using several different imaging methods was essential to convince themselves that what they were seeing was real rather than artifacts.



Dressaire et al. have demonstrated that it is possible to achieve stabilization of microbubbles in a viscous solution and that this system can be stabilized for more than a year. The regular surface patterning they found on the microbubbles is the thermodynamic signature of the formation of an elastic, condensed surfactant phase that also correlates with the extended stability of the system. The features of this system can be tuned on a nanometer scale by modifying the chemical composition of the interface. It will be interesting to see how this new system will be incorporated into consumer products in the future!

1. The author gratefully acknowledges Dr. Howard Stone for reviewing this article.

2. Dressaire, E., R. Bee, D.C.Bell, A. Lips, and H.A. Stone, Interfacial polygonal nanopatterning of stable microbubbles, Science 320:1198-1201, 2008.

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This image is a thin (30 micrometer) section of a lunar breccia recovered by Edwin Aldrin and Neil Armstrong in the Sea of Tranquility. The image was recorded in polarized light on a Nikon OptiPhot-Pol microscope and has a magnification of ~400x. Cover courtesy of Molecular Expressions, (microscopy.fsu.edu).

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Charles E. Lyman, Editor-in-Chief
charles.lyman@lehigh.edu

Ron Anderson, Technical Editor
microscopytoday@tampabay.rr.com

Phil Oshel, Technical Editor
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Dale Anderson, Art Director
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Regular Mail to:
Microscopy Today, P.O. Box 247, Largo, FL 33779

Telephones:
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