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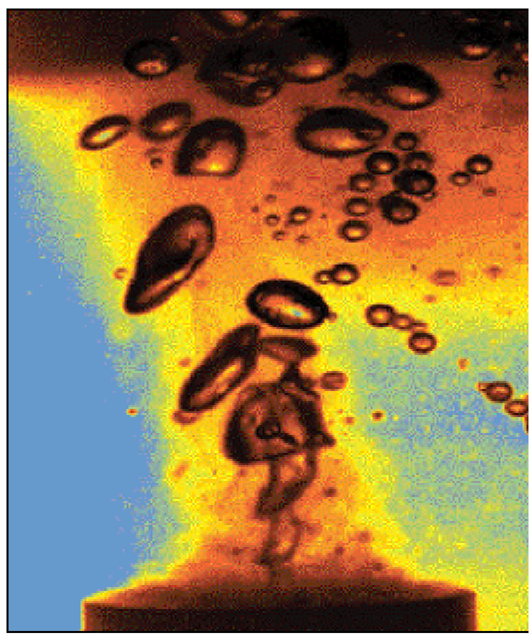
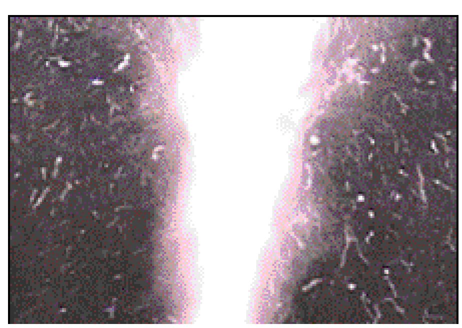
Researchers Probe Chemistry of Bubbles

Since luminescence in single cavitating bubbles was described more than a decade ago, the phenomenon has attracted much attention from scientists. Earlier this year, interest was piqued all the more, when a team at Oak Ridge National Laboratory in Tennessee claimed to have observed neutron emissions from the bubbles that indicated fusion processes. Now researchers at the University of Illinois at Urbana-Champaign have analyzed the chemistry of single bubbles, opening the door to a better understanding of the event and calling into question the claims of fusion.



Researchers have performed a quantitative analysis of the chemistry of cavitating bubbles. They produced the bubbles by vibrating a titanium rod in water. Spectral data indicate that far more energy is consumed in the formation of ions and radicals than is released as photons. Courtesy of Kenneth S. Suslick.

Sonoluminescence occurs in the bubbles in an acoustic wave in a liquid. In a low-pressure region of the wave, a bubble expands a thousandfold, trapping gases that were dissolved in the liquid. When exposed to a high-pressure region, the bubble collapses violently, producing temperatures that may be as high as 20,000 K and ionizing the gases within.



At this stage, it emits a 50- to 500-ps pulse of broadband radiation, and the products of the reaction dissolve back into the liquid. The process begins again as the bubble is exposed once more to a low-pressure region of the wave.

The university researchers created their 60-µm-diameter bubbles in a 15-ml glass cell that contained water at 3 or 22 °C. A titanium rod vibrating at 28 or 52 kHz

induced the acoustic waves, and a Jobin
Yvon monochromator and a 1024 X 256-pixel CCD detector collected the spectra from individual cavitating bubbles. The team employed a long-pass filter at wavelengths longer than 400 nm to minimize second-order radiation.

Energy conversion

The scientists monitored the production of ions, radicals and photons in a given collapse event. Together with measurements of the size of the bubbles, these counts enabled them to estimate the efficiency with which a bubble converts its potential energy into mechanical energy, heat, chemical reactions and light.

They discovered that about 1/10,000 of the energy in a collapsing bubble was used to form nitrite ions and hydroxyl radicals from the nitrogen that diffused into it in the expansion phase. The energy of the photons released in luminescence was two orders of magnitude smaller. The results indirectly challenge the claim of fusion in perdeuterated acetone, noted Kenneth S. Suslick, who conducted the study with Yuri T. Didenko. The volatility of acetone should lead to strongly endothermic chemical reactions of polyatomic molecules in the bubbles that would readily consume the available energy and thereby limit the maximum temperature on collapse.

The researchers note, however, that the possibility of fusion by cavitation cannot be rejected in substances with extremely low volatility, such as polar organic liquids, liquid metals and molten salts.

Daniel S. Burgess

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Internet: www.Photonics.com
E-mail: photonics@laurin.com
Phone: (413) 499-0514, Fax: (413) 442-3180