Activity of micron-sized gas bodies trapped in a solid surface.

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A microscopic gas body is stabilized against diffusion if it exists in a hole at the surface of a solid. Certain membranes sold commercially for filters (e.g., polycarbonate membranes prepared by Nuclepore Corp., Pleasonton, California) provide holes of micron dimensions, and under suitable conditions air remains trapped in these holes when they are immersed in water. The gaseous microbodies so formed are set into volume oscillations when subjected to an ultrasonic field. We have made studies of the dynamics of these oscillations; investigations have also been made of activities which occur near the holes as a result of these volume oscillations.[1-3] These activities include (i) migration of suspended particles toward the holes as a result of radiation force, (ii) circulation or "microstreaming" of the fluid near the holes and (iii) damage to small biological cells in suspension near the holes.

Theory for the volume oscillations has been developed using an approach similar to that used for free spherical bubbles. Taking the gaseous body to be a cylinder of radius a and length ℓ the resonant frequency is found to be

$$f_0 = \frac{1}{2\pi} \left[\frac{2\gamma P_0}{\rho a \ell}\right]^{\frac{1}{2}}$$

Where γ is the polytropic exponent for the gas, P_0 is the ambient pressure and ρ is the density of the water.

When the holes are fairly closely spaced (e.g., 10^5 holes/cm^2) their interactions must be taken into account. For this purpose we have made use of theory developed by Weston[4] for scatterers in a plane array. Experimental tests of the dynamical theory have been made by making measurements of the reflection coefficient as a function of frequency. Reasonably good agreement is found. A characteristic effect of the interaction is to reduce the pressure amplitude in the vicinity of each hole below the value which would apply if the holes were widely separated. For closely spaced holes this reduction can be very great, and is important in connection with biological and other applications.

We expect to discuss details of theory for oscillations of the gaseous microbodies, and of experimental findings, in a later publication.

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DISCUSSION

A limiting excitation level exists beyond which the bubbles disintegrate, but this limit has not yet been accurately assessed. The resonant amplitude of the bubble surface is given by:

$$\xi_o = \ell P_A / 2\gamma\delta P_o(1 + R)$$

where P_A is the acoustic pressure, δ the loss angle and R the reflection coefficient.