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Single bubble oscillations in viscoelastic media

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We report a new ultrasonic technique for determining the viscoelasticity of soft materials based on the oscillations of single bubbles injected into the material of interest. It is known that bubbles in a liquid act as strong acoustic scatterers that exhibit a low frequency resonance known as the Minnaert resonance. In the case of viscoelastic media, the complex frequency-dependent shear modulus causes the Minnaert frequency to be shifted to a higher value and leads to additional ultrasonic absorption. Therefore, both storage and loss shear moduli can be determined from the resonance frequency and the damping rate of the acoustic oscillations of a single bubble that has been injected into the sample. Experiments were performed on optically transparent commercial hair gel, agar gel, and PDMS rubber, allowing independent measurements of the bubble sizes to be made by an optical imaging technique. The acoustical properties of the samples were measured by sweeping the frequency of a continuous sinusoidal signal from 4 to 50 kHz. Because the Minnaert frequency is inversely proportional to the radius of the bubble, experiments on bubbles of different sizes enabled the frequency dependence of the complex shear moduli of the materials to be determined.