Bubble Architectures for Locally Resonant Acoustic Metamaterials

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Soft acoustic metamaterials that embed soft materials in a host media have promising applications in aqueous environments. However, the preparation of soft metamaterials under water and realization of lowfrequency soft acoustic metamaterials remains a challenge. By combining 3D printing technology and surface hydrophobic properties, this work presents a general approach to construct 3D soft acoustic metamaterials using bubbles as resonator units. Low-frequency broadband locally resonant metamaterials can be realized using patterned bubbles with bandgaps that are orders of magnitude wider than other locally resonant metamaterials. In addition, a water-to-air ultratransmission metasurface is prepared by patterning a layer of bubbles beneath the water surface, which allows for the ultratransmission of sound across an air–water interface. This strategy opens up promising avenues for many applications based on locally resonant metamaterials such as deep subwavelength acoustic superlenses or negative-refraction metamaterials.

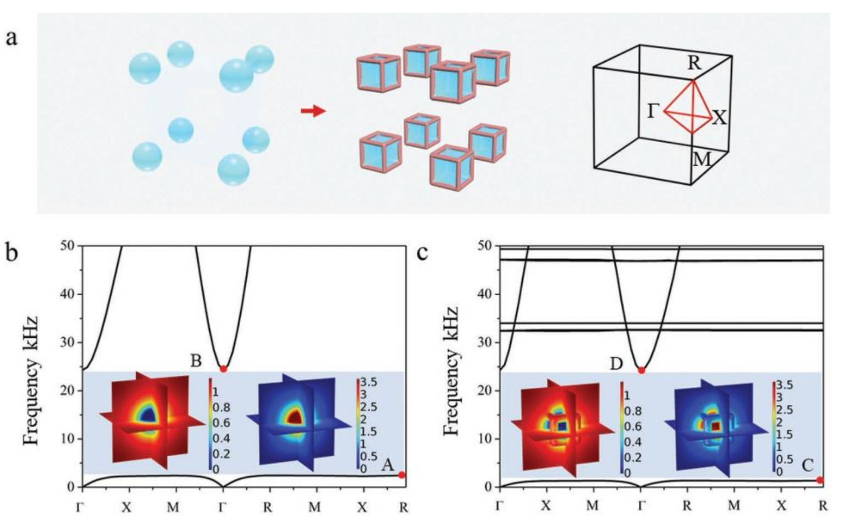

Figure 1. Dispersion relations for bubble arrays. a) Schematic diagram of a simple cubic array of spherical bubbles and bubbles with solid frames.Right side shows the reciprocal lattice and symmetry points in the Brillouin zone. The dispersion curves for the b) spherical bubbles and c) bubbles with solid frames. Inserts show the corresponding modes for the point labeled in the curves.

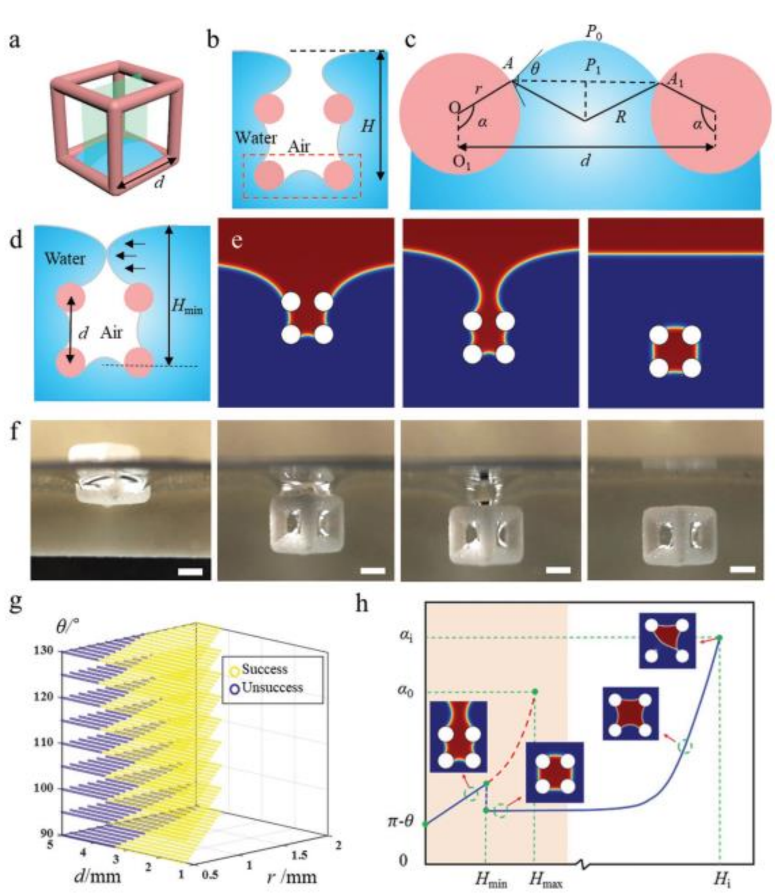

Figure 2. Design principles for bubble architectures and geometrical analysis of the air–water interface.

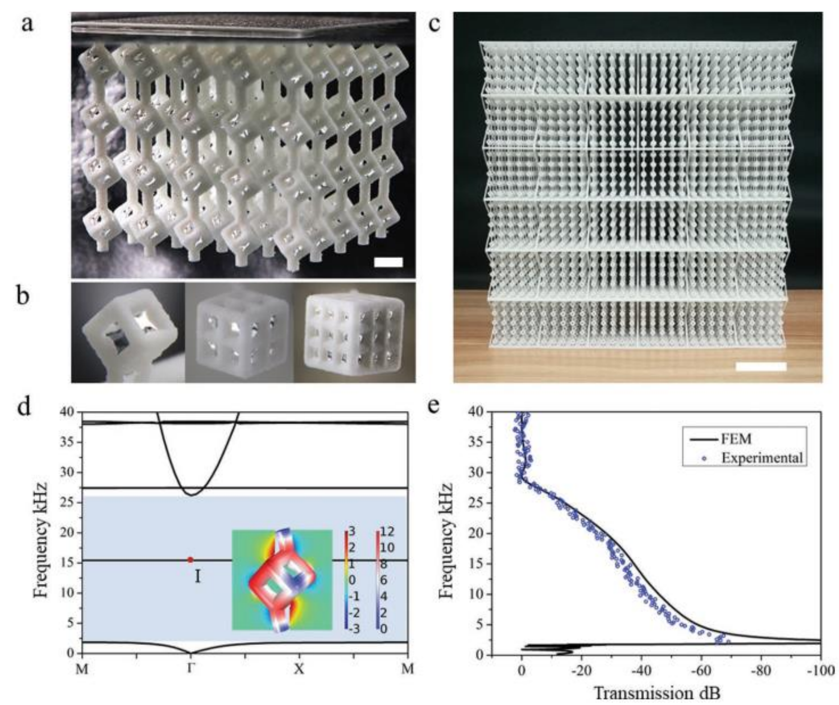

Figure 3. (a,b,c) The 3D printed bubble metamaterials. d) The dispersion curves for the sample shown in (a) and (c). e) Transmission spectra for the sample obtained by experiment (blue circle) and FEM (black line).

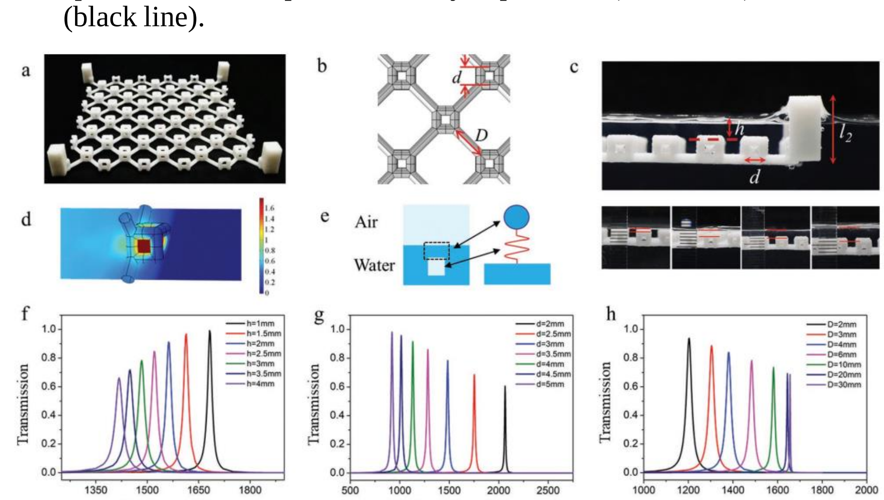

Figure 4. Impedance-matched ultratransmission metasurface based on bubble architectures. a) The 3D printed hydrophobic frame structure. b) Scheme of the geometry parameters. c) The bubble architecture floating on water. d) The sound pressure distribution for the metasurface determined by the FEM at maximum transmission frequency. e) Scheme for the mass-spring model. Transmission spectra for different parameters of *h* (f), *d* (g), and *D* (h). The maximum transmission coefficient and half peak width change with these parameters.

References

[1] *Adv. Funct. Mater.* 2019, 29, 1906984.