

Merging the Ultrasonic and Microacoustic Sensor Principle

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Ultrasonic sensors and acoustic (resonant) microsensors are well accepted devices in many application fields. Both principles are based on acoustic wave propagation in a way that the value of interest perturbs wave propagation in a distinct manner. The sensing capabilities of ultrasonic sensors rely on time of flight measurement of an ultrasonic burst traveling through the object of interest. This value can be determined with high accuracy. Similarly, the impressive sensing capabilities of resonant microsensors result from the high Q-factor of the resonator and precise determination of the resonant frequency. Both principles face however, severe limitation in size and integration into microsystems.

Acoustic band gap materials, so-called phononic crystals, provide a new platform for sensing material properties in small cavities. Phononic crystals are periodic composite materials with spatial modulation of acoustically relevant parameters like elasticity, mass density and longitudinal and transverse velocities of elastic waves. Their most exiting feature is the existence of acoustic band gaps, i.e. a frequency range where (ultra)sound cannot propagate through the structure. The sensor concept just recently introduced employs specific transmission windows within the band gap. In this application it is most reasonable that the material of interest constitutes one component of the phononic crystal, e.g., a fluid in the holes of a solid plate. If the value of interest, e.g. the concentration of a contaminant in a liquid mixture, changes its acoustic properties, the acoustic properties of the phononic crystal will change as well.

Transmission or reflection coefficients are appropriate parameters for measurement and used to find a characteristic feature of the phononic crystal. For a sensor application, a transmission peak within the band gap or a transmission dip outside the band gap is the most favorable feature since the respective frequency of maximum/minimum transmission is easy to determine. The sensor scheme therefore relies on the determination of the frequency dependence of maximum/minimum transmission on the physical or chemical value of interest. The transmission peaks can be considered as being based on resonance-like effects, their examination therefore merges basic features of ultrasonic and acoustic microsensors.

Three realizations of the phononic crystal sensor will be introduced. The simplest version is the parallel arrangement of several layers of metal plates and a liquid in between. The transmission properties can be analytically calculated; the results can serve as proof-of-principle. The sensitivity related to those peaks is in the order of macroscopic sensors. Sensors utilizing 2D phononic crystal have been studied in two basic arrangements, with in-plane excitation and detection of waves and an incidence direction perpendicular to the plate. In both realizations a liquid fills all holes of the phononic crystal plate; in the latter case it also covers both surfaces. In the in-plane arrangement specific peaks could be identified which represent changes in liquid properties. When using normal incidence of waves, the extraordinary transmission peak has been found

to be strongly dependent on liquid sound velocity. The effect is more robust and the insertion loss of the device is much lower, an important issue from a practical point of view.