New Ultrasonic Torsional Waves for Sensing Applications

Background, Motivation and Objective

Your text explaining what has been done previously and why this work is of importance.

We are currently witnessing a fascinating development of the theory of surface and bulk acoustic waves. New extraordinary properties in the domain of acoustic waves appeared with the invention of new materials, e.g., metamaterials. The use of elastic metamaterials for the construction of ultrasonic waveguides has created a fertile ground for the discovery of a series of new ultrasonic waves. In this paper, the author applied metamaterials to develop new cylindrical liquid viscosity sensors. Classical ultrasonic cylindrical liquid viscosity sensors are made of conventional elastic materials. These sensors are usually used to determine the viscosity of liquids in biosensors and chemosensors. However, sensors of this type are not free from disadvantages. Namely, the ultrasonic field of this classical torsional wave is distributed in a large volume of the waveguide, which results in a moderate mass sensitivity of the cylindrical sensor. Therefore, the need to solve this problem arose. The aim of the author's work was to overcome this drawbacks. To solve this problem, the author used the extraordinary properties of elastic metamaterials. The waveguide proposed by the author consists of a metamaterial core immersed in a three-dimensional (3D) elastic external medium (see figure below). The mechanical susceptibility of the metamaterial cylindrical core can take negative and positive values. In this work, the author presented the theory of a new torsional ultrasonic wave propagating in metamaterial cylindrical waveguide structures. The new discovered cylindrical surface waves have only one axial mechanical displacement component (see figure below). The key property of the newly discovered torsional ultrasonic waves is that their mechanical displacement is concentrated close to the surface of the cylinder, which greatly increases the mass sensitivity of the sensor.

Statement of Contribution/Methods

Description of equipment, methods used.

Using the equations of motion (written in a cylindrical coordinate system), constitutive equations and the appropriate boundary conditions on the cylinder surface, we developed analytical formulas for the dispersion relation of the wave, phase and group velocities and the distribution of the mechanical displacement of the torsional wave as a function of the radius r.

/Discussion

Presentation of the results obtained and discussion of the results.

Phase and group velocity dispersion curves and the distribution of the mechanical displacement of the new torsional waves as a function of the radius r was determined. A very high concentration of energy was found near the surface of the cylinder for r=a which results in a large mass sensitivity of the new torsional waves. These new ultrasonic torsional waves have several times higher mass sensitivity than the conventional torsional bulk waves. It is worth noting that there is an electromagnetic (optical) analogue of the new ultrasonic torsional wave. The coefficient of mass sensitivity S_{σ}^{v} was evaluated numerically for torsional surface waves propagating in cylindrical waveguides composed of a PMMA metamaterial core embedded in ST-Quartz surrounding space, in the frequency range from 10 KHz to 10 MHz. The radius of the inner PMMA core was 0.5 1.0 and 2.0 millimeters, respectively. Consequently, the result presented in this work can be employed in design and optimization of torsional wave biosensors, chemosensors and sensors of physical quantities with large mass sensitivity.