Optopneumatic medium for precise indication of pressure over time inside the fluid flow

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The artificial periodic structures like layered photonic crystals may serve as a means of measurement for time-varying processes in fluids and that peculiar to living organisms like so called Mayer waves of pressure in arteries caused by oscillations in human receptor control systems. The fine structure of pressure and local temperature time dependencies would make clear the nature of complicated processes in fluids.

In this work, a gas-filled 1D elastic pneumatic photonic crystal (EPhCr) is proposed as an optical indicator of pressure which can unite several pressure scales of magnitude. The indicator includes layered elastic platform, optical fibers and switching valves, all enclosed into a chamber. We have investigated the pneumatic photonic crystal bandgap structure and light reflection changes under external pressure. At the chosen parameters the device may cover the pressure interval (0, 10) bar with extremely high accuracy (1 μbar) for actual pressures existing inside the biofluid systems of biological organisms. The size of the indicator is close to 1 mm and may be decreased. The miniaturized optical devices considered may offer an opportunity to organize simultaneous and total scanning monitoring of biofluid pressure in different parts of the circulatory systems.

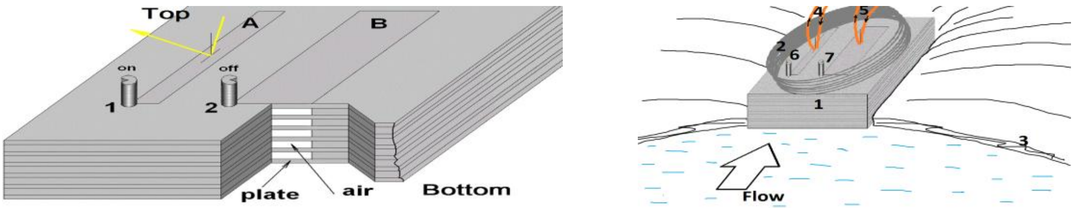

***Fig. 1. (a)** A layered EPhCr as a multiscale pressure indicator schematically. A stack of plates contains two strip pneumatic photonic crystals A and B. 1, 2 are switches of access to upper gaseous medium (chamber) atmosphere. Geometry of light beam incidence is shown for strip A. **(b)** A sketch to the one-sided measurement of pressure in a pipe. 1, PhCr body, 2, upper chamber wall, 3, pipe membrane 4, 5, input-output fibers (light beams), 6, 7, switching elements of pressure access.*

The pneumatic photonic crystals can exhibit significant optical sensitivity to variations of the external pressure and/or temperature. There exist two schemes of pressure indication in a fluid-filled pipe, one-sided kind scheme is shown in Fig. 1 where the EPhCr body 1 is placed into the closed chamber 2 penetrating through the pipe membrane in fluid. The strip A device represents a scale of first level embracing interval (10, 10^4) mbar, whereas the scale B serves to measure more fine-tuned dynamical changes. We have calculated reflection measured by device B at chosen photon energy ω=1.17 eV for pressure interval (1000 – 1002) mbar where the reflection coefficient decreases from 0.83 to zero. The isothermal regflection sensitivity to pressure $\eta=(d\rho/dP)_T$ changed from zero at P=1001.86 mbar to the maximal magnitude 0.698 mbar^{-1} at P=1001.18 mbar. The size of the indicator was close to 1 mm and may be decreased.

The miniaturized optical devices considered here may offer an opportunity to organize simultaneous and total scanning monitoring of fluids in technical systems and biofluids pressure in different parts of the circulatory system.