Wide-band laser-acoustic spectroscopy of proteins

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Abstract: The absorption of acoustic waves in proteins in the frequency range 2-50 MHz was investigated using wide-band acoustic spectroscopy set-up with laser excitation of ultrasound. The ultrasound absorption coefficient in fresh chicken proteins is proportional to the squared frequency. Transformation of the spectrum of ultrasonic absorption to the first power of frequency dependence takes place after the denaturation of proteins. The ultrasound absorption coefficient for denaturated protein is higher than in the fresh one over the whole investigated frequency range. The possibility of laser ultrasonic diagnostics of proteins is discussed.

INTRODUCTION

Ultrasound waves are widely used in biomedical diagnostics. Therefore, biological tissue ultrasonic parameters, such as ultrasound attenuation and velocity, can be clinically significant. It is well known that ultrasound absorption in tissue is proportional to some power of the frequency in a wide spectral range and this frequency dependence changes when the tissue is deceased. So, the frequency dependence of ultrasound absorption coefficient can be used for tissue diagnostics. Laser excitation of ultrasound (1) allows one to get sources of short powerful acoustic pulses in a frequency range up to hundreds of MHz - opto-acoustic (OA) sources (1,2). Wide-band acoustic spectroscopy set-up with laser OA source is proposed to measure absolute value of ultrasound absorption coefficient in proteins in the frequency range 2-50 MHz in real time.

EXPERIMENTAL SET-UP

Experimental set-up is shown in Fig. 1. Pulsed Q-switched Nd:YAG laser is used to excite acoustic pulses in OA source - blue-green glass optical filter with free boundary. Frequency range of excited ultrasonic pulses is 1-50 MHz. These pulses (reference pulses) propagate through etalon medium (distilled water) or investigated medium and are registered by wide-band piezoelectric receiving transducer. Temporal resolution of transient digital acquisition system is 3.5 ns, signal-to-noise ratio of received electric pulses is 30-40 dB. Spectra of acoustic pulses are calculated by standard FFT procedure.

FIGURE 1. Wide-band acoustic spectrometer with laser excitation of ultrasound: 1 - OA source, 2 - etalon or investigated medium, 3 - piezoelectric receiving transducer.
The frequency dependence of ultrasound absorption coefficient in investigated medium is

\[ \alpha(f) = -\frac{1}{L} \ln \frac{|S(f)|}{|S_0(f)|}, \]  

(1)

where \( L \) is thickness of the medium, \( S_0(f) \) is the frequency spectrum of reference acoustic pulse, passed through distilled water, \( S(f) \) is the frequency spectrum of the same pulse, but passed through investigated medium and changed because of absorption of ultrasound in them. The dependence \( \alpha(f) \) is calculated in the whole frequency range of reference pulse in real time (i.e. for each acoustic pulse) because of high signal-to-noise ratio and high stability of temporal profiles (and spectra) of laser and acoustic pulses. The influence of diffraction in this frequency range was negligible because of acoustic wave velocities in etalon and investigated medium were close to one another. The difference in reflection coefficients for etalon and investigated media was taken into account before using formula (1).

**EXPERIMENTAL RESULTS AND DISCUSSION**

The experimental results shown in Fig. 2 confirm that ultrasonic absorption both in liquid (fresh) chicken albumin and fresh chicken yolk follow the power dependence on frequency with \( n=2 \). This corresponds to the ultrasonic absorption in classical viscous liquid. After heat denaturation (at temperature 94 \( ^\circ \)C) of these proteins the ultrasonic absorption have become linear function of frequency. This is of common thing for polymers, such dependence indicates the presence of a number of relaxation processes with the relaxation times varied over a wide range.

**FIGURE 2.** Ultrasound absorption coefficient vs frequency for chicken albumin: (1)-fresh, (2)-heat denaturated, and chicken yolk: (3)-fresh, (4)-heat denaturated.

Linear dependence ultrasound absorption on frequency in denatured proteins confirms the polymerisation of proteins during the heating. Moreover, the ultrasonic absorption in denatured proteins is higher than that in fresh one. This can be used for the diagnostics of proteins state in vivo.

**REFERENCES**