Elastic, Adsorption Properties of Nanocomposites of Multiwalled Carbon Nanotubes and Polyethylene, Polyvinyl Chloride, Expanded Polystyrene

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INTRODUCTION

The influence of ultrasound (US) deformation ε_{US} studed on inelastic internal friction (IF) Q^{-1} and elastic modulus E characteristics of multiwalled carbon nanotubes (MWCNT) nanocomposites. The increase of the nanocomposite crystallinity degree at growth of multiwalled carbon nanotubes concentration filling with the nanotubes of matrix results in the decline of content of organized phase.

Total deformation consists of elastic and anelastic constituents $\varepsilon_{\Sigma} = \varepsilon_E + \varepsilon_{AE}$ [1]. Elastic deformation ε_E takes a place "instantly". Anelastic deformation ε_{AE} is conditioned motion of dislocations [2,3].

Effects of acoustic emission (AE) under laser thermal-mechanical strains in $SiO_2/TiO_2/ZrO_2$ films are investigated. Elastic waves pulses are discovered from micro fractures that of probably connected with elastic balance films.

MATERIALS AND METHODS

Anelastic IF Q^{-1} and elastic E characteristics are essentially depended on morphology of surface layer. 3D atomic-force microscopy (AFM) of the microstructure image of SiO_2 on Si (100) is represented in fig. 1.

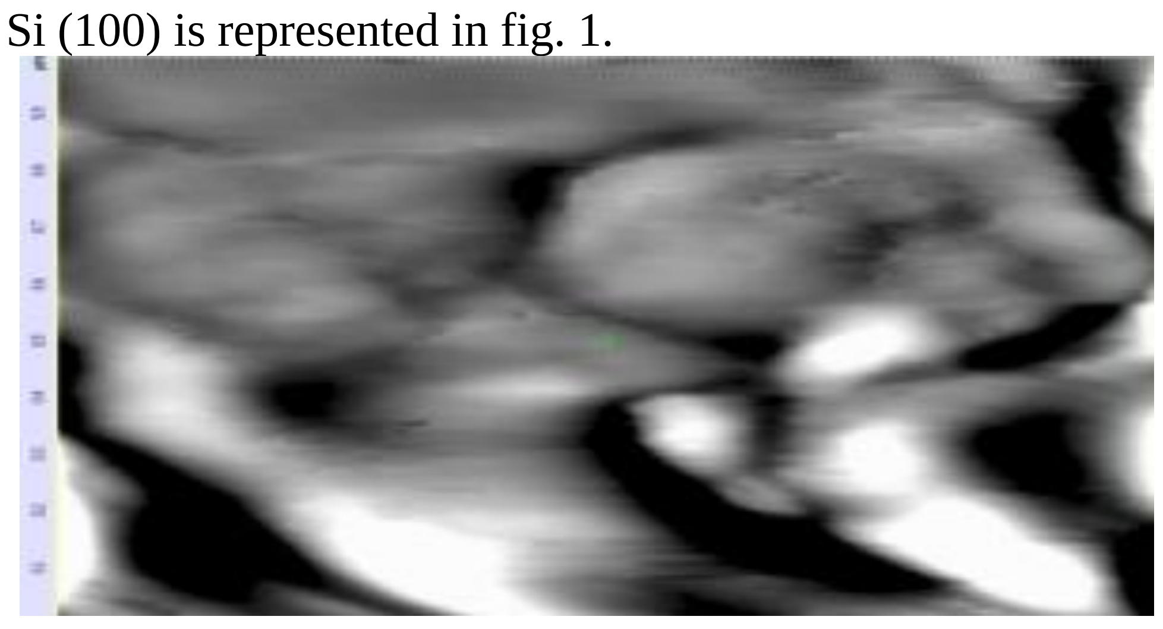

Fig. 1. 3D atomic-force microscopy image of SiO_2 on Si (100) microstructure (1x1x10^3 nm)

The SiO_2 surface after laser irradiation is shown in fig. 2. This process in a set of time phases mimics the "volcanic eruption".

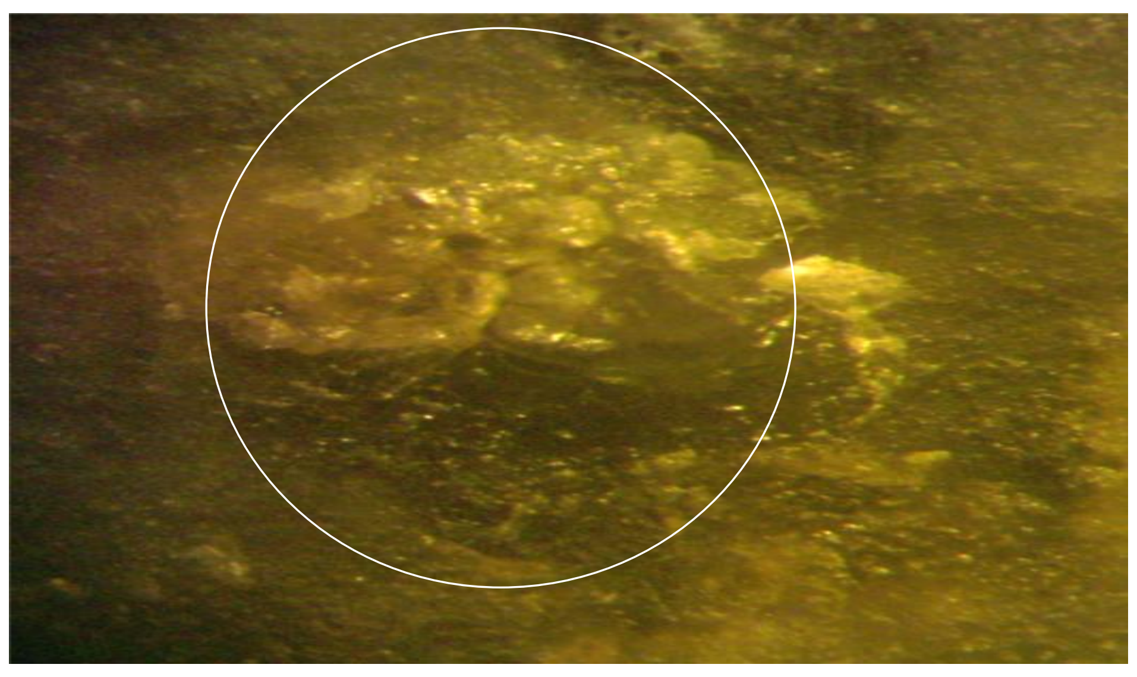

Fig. 2. SiO_2 surface after the nanosecond laser irradiation by the ruby laser with the intensity of I ≈ 300 Mw/cm^2 with the dose D = 4xI the duration of the ruby laser pulse $\tau \approx 20$ ns with the wavelength $\lambda = 694$ nm. The circle indicates the area of the laser irradiation (x56)

Ultrasound (US) pulse-phase method for determining the velocities of elastic waves using USMV-LETI, modernized USMV-KNU and computerized "KERN-4" in fig. 3 with frequencies $f_{\parallel} \approx 1$ MHz and $f_{\perp} \approx 0{,}7$ MHz [4,5] .

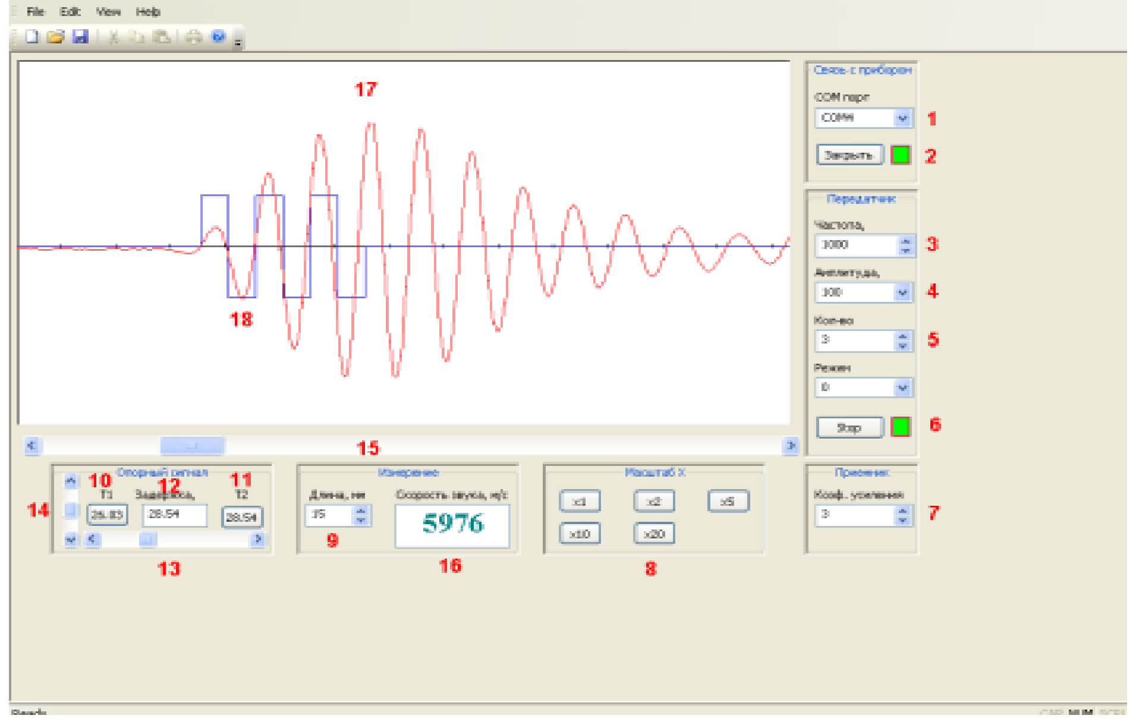

Fig. 3. Illustration of the window for processing data of elastic waves velocity $V_{\parallel}$ measurements in SiO_2/Si plate by echo-impulse method at frequency $f_{\parallel} \approx 1$ MHz and the presence of computer device KERN-4

RESULTS AND DISCUSSION

The quasitransversal US velocity $V_{\perp} = 759 \pm 10$ m/sec, shear module $G = \rho V_{\perp}^2 = 578$ Mpa, the quasilongitudinal US velocity $V_{\parallel} = 2485 \pm 10$ m/sec, dynamical elastic module $E = \rho V_{\parallel}^2 = 6{,}057$ GPa, Puasson coefficient $\mu = 0{,}442$ nanocomposite polyethylene with low density high pressure $(C_2H_4)_n$ + 3% MCNT + 0,5% dye DBSQ were determined from the oscillogram [1] in fig. 4.

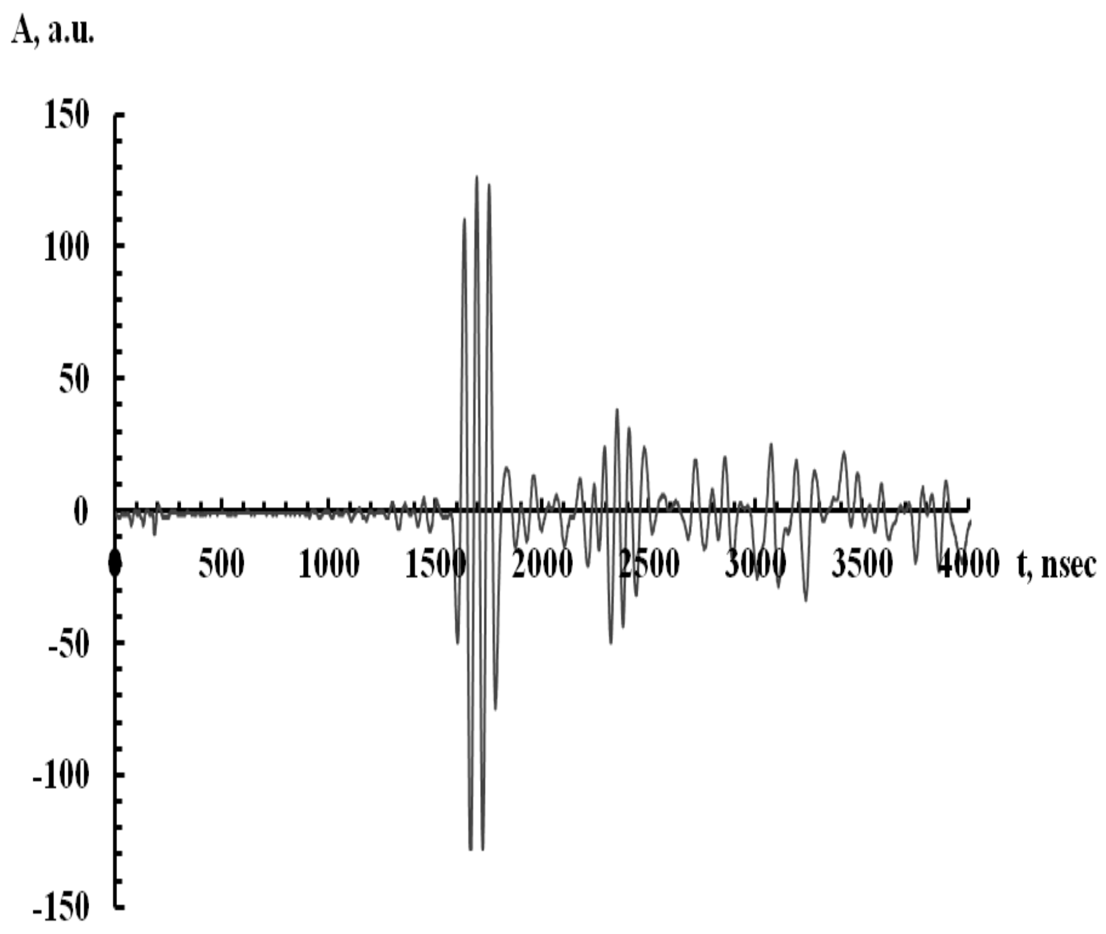

Fig. 4. The data plot illustration of the quasitransverse elastic waves velocity $V_{\perp} = 759$ m/s in nanocomposite of low-density high pressure polyethylene $(C_2H_4)n$ + 3% MWCNT + 0,5% dye DBSQ by impulse-phase ultrasonic method at frequency $f_{\perp} = 0{,}7$ MHz. Logarithmic decrement ultrasound attenuation

$$\delta = \ln\left(\frac{A_{n+1}}{A_n}\right) = \ln\left(\frac{123}{121}\right) \approx (1{,}64 \pm 0{,}1) \times 10^{-2}$$

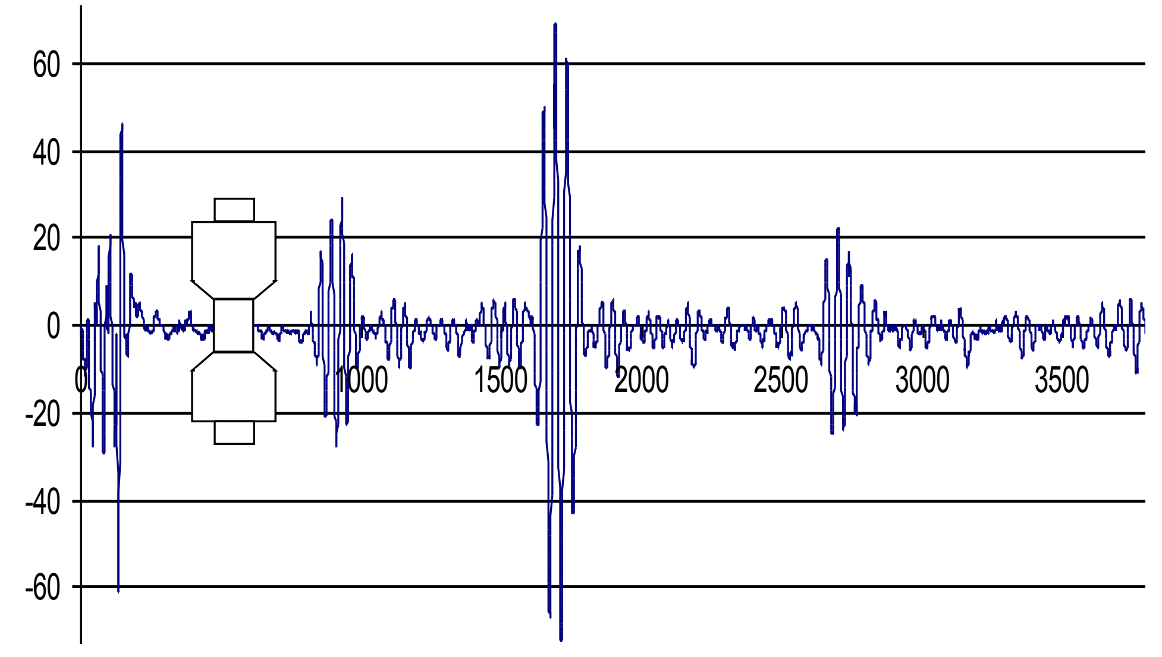

Fig. 5. Source of disturbances and the receiver - piezoquartz (ultrasonic sensor)

The modified polymer real network has the large number of the different defects, those do not participate in the transfer of the strains σ in the network, and, therefore, do not contribute to its elastic modulus G, E. It's showed, that anelastic Q^{-1} and elastic E characteristics are essentially depended from morphology of surface layer. The determination method of the distributing function of microcracks orientation is developed from data of the azimuthal measurings of elastic waves velocities. With the purpose of determination of temperature position of relaxation of the elastic modulus $\Delta G/G_o$ simultaneously with the internal friction $Q^{-1} = \delta/\pi$, where δ - the logarithmic decrement ultrasound attenuation, measuring temperature dependence of $G = \rho V_{\perp}^2$ was measured. The large absolute value of the shear modulus G(C), the elastic modulus E(C) of nanocomposite polyvinyl chloride $(C_2H_3Cl)_n$ + and methylene dark blue colouring agent (CH_{2-}) indicate about the significant interaction with maximum at $C_0 \approx 5\%$.

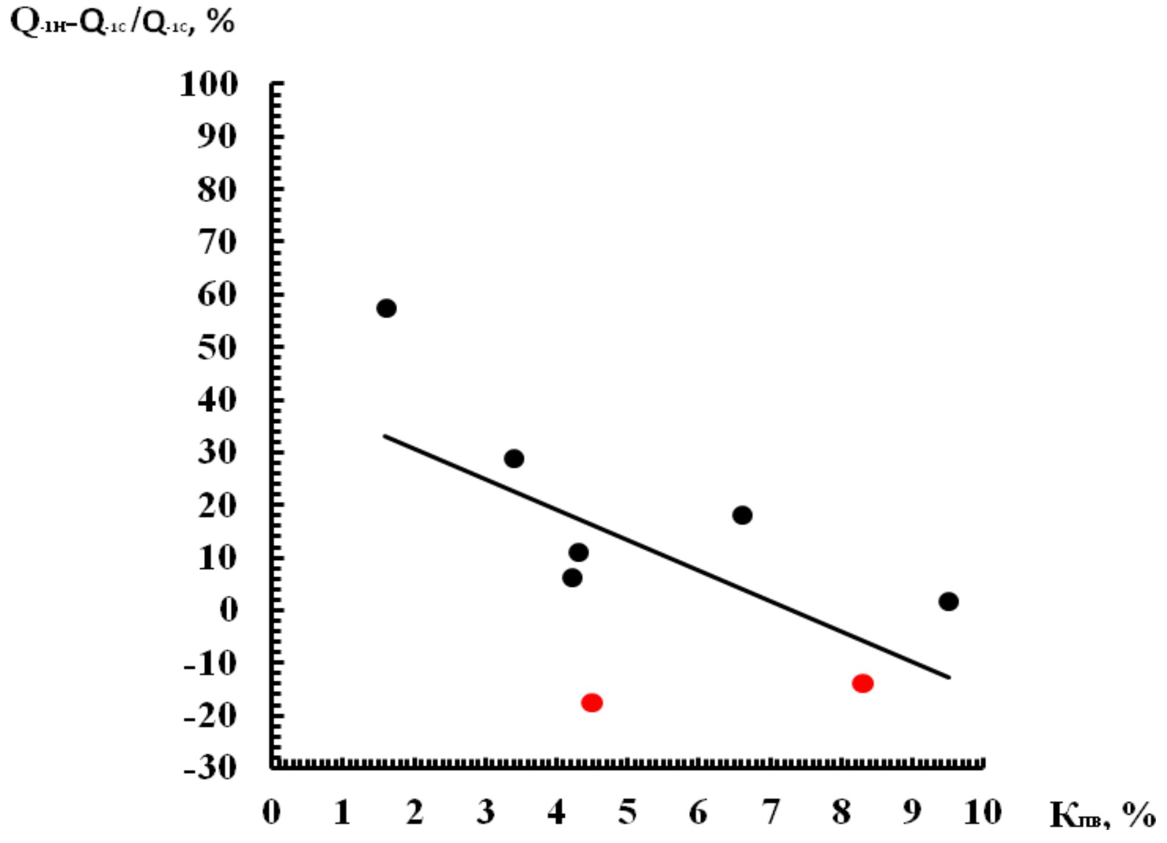

Fig. 6. Correlation dependence of the internal friction defect $\Delta Q^{-1}/Q^{-1}$ in SiO_2 from the open porosity coefficient $K_{PO} = V_{PO}/V$

$$E^*/E = \delta = \pi Q^{-1} = \alpha\lambda = \alpha V/f, \qquad (1)$$

where α is US attenuation coefficient, λ is the US wavelength, f is the US frequency. The logarithmic decrement of US attenuation δ oscillations with the amplitude $A = A_o e^{-\delta x}$ is equal to:

$$\delta = \ln(A_{n+1}/A_n), \qquad (2)$$

The shear modulus $G = \rho V_{\perp}^2$, where ρ is the specific density, $V_{\perp}$ is the quasitransversal US velocity.

The Poisson coefficient μ is equal to ratio of relative transversal $\varepsilon_{\perp}$ compression to relative longitudinal lengthening $\varepsilon_{\parallel}$ and equal [2]:

$$\mu = -\varepsilon_{\perp}/\varepsilon_{\parallel} = -(\Delta X/X)/(\Delta l/l) = -(\Delta X/\Delta l)(l/X), \qquad (3)$$

$$\mu = (1/2V_{\parallel}^2 - V_{\perp}^2)/(V_{\parallel}^2 - V_{\perp}^2). \qquad (4)$$

Therefore, the elastic waves, that elementary oscillators excite, can't carry the energy. There are stand waves. One oscillator produce 3 waves: 1 longitudinal and 2 transversal. Debye temperature θ_D was determined after the formula [3]:

$$\theta_D = h/k_B(9N_A\rho/4\pi A)^{1/3}/(1/V_{\parallel}^3 + 2/V_{\perp}^3)^{1/3}, \qquad (5)$$

where k_B - Boltzmann constant, h - Plank constant, N_A - Avogadro number, A - middle gram-molecular mass, ρ - density, $V_{\parallel}$ - longitudinal US velocity, $V_{\perp}$ - transversal US velocity.

The transversal US velocity $V_{\perp} = 768 \pm 30$ m/sec, shear module $G = \rho V_{\perp}^2 = 578$ MPa, the longitudinal US velocity $V_{\parallel} = 2485 \pm 30$ m/sec, dynamical elastic module $E = \rho V_{\parallel}^2 = 6{,}057$ GPa, Poisson coefficient $\mu = 0{,}44$ nanocomposite polyethylene with low density high pressure $(C_2H_4)_n$ + 3% MWCNT were determined from the oscillogram in fig. 7.

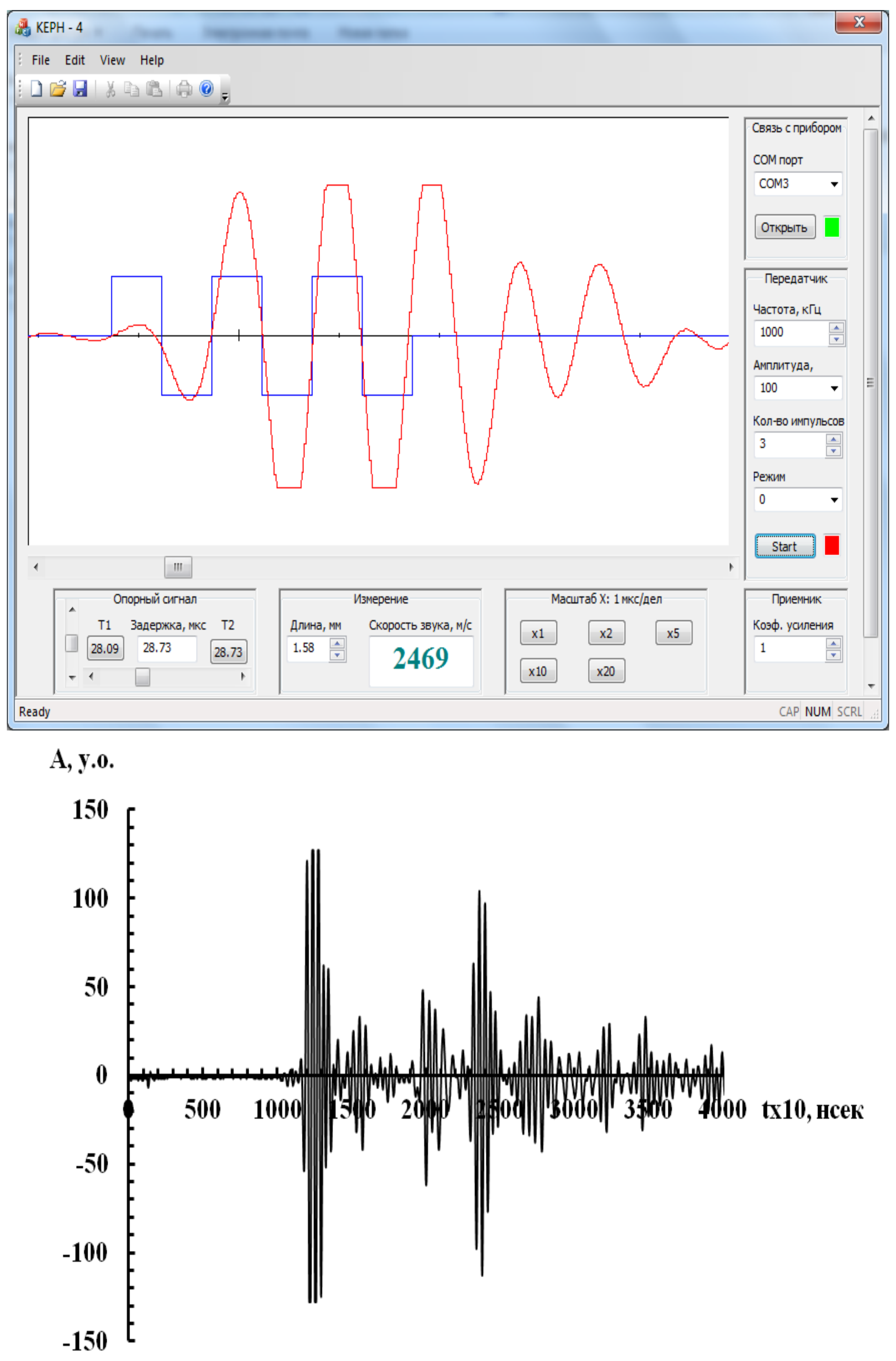

Fig. 7. The illustration of the window for processing data of longitudinal elastic wave velocity measuring $V_{\parallel} = 2469$ m/sec in nanocomposite polyethylene + 0,7% MWCNT by by impulse-phase ultrasonic method on frequence $f_{\perp} \approx 1$ MHz.

Logarithmic decrement of US attenuation

$$\delta = \ln\left(\frac{A_{n+1}}{A_n}\right) = \ln\left(\frac{102}{98}\right) \approx (4{,}00 \pm 0{,}1) \times 10^{-2}$$

CONCLUSIONS

1. The growth of internal friction maximum height Q_M^{-1} testifies the growth of the structural defects concentration, and the broadening of internal friction maximum ΔQ_M^{-1} here represents the relaxation process of structural defects new types in nanocomposite.
2. The annealing of the structure defects in nanocomposite bends out of shape the type of internal friction temperature spectrum $Q^{-1}(T)$.
3. The crater fusion depth Δh at constant intensity I and laser irradiation time t is limited by the local heat-conducting and establishment of "time-equilibrium" distribution of temperature gradients ΔT perpendicular to the crater axis and along it.

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