Characteristic Mechanical Spectroscopy of Nanocomposites of Multiwalled Carbon Nanotubes and Polyamide, Polyvinyl chloride, Polyethylene, Expanded Polystyrene

V. M. Popruzhko, A. P. Onanko, O. P. Dmytrenko, M. P. Kulish, Y. A. Onanko, D. V. Charnyi, M. V. Yatsiuk, T. M. Pinchuk-Rugal, A. A. Kuzmych, P. P. Ilyin

Kyiv national university, Volodymyrs'ka str., 64, Kyiv-01601, Ukraine.

E-mail: onanko@i.ua

INTRODUCTION

The nondestructive method for the technological control of the structure defects by measuring internal friction (IF) and elastic modulus E after laser radiation was developed. The leading factor of the elastic anisotropy forming is a crystallography orientation and the orientation of grains on the form with the orientation of microcracks, pores [1,2]. Outcomes of the evaluation of dynamic characteristics interstitial atoms, vacancy and O-complexes can be applied for account of a condition of an annealing with the purpose of deriving specific structural defects in SiO_2/Si wafer-plates.

EXPERIMENTAL PROCEDURE

The study of influence of structure defects on damping of vibrations in Si/SiO_2 plates by the diameter of D = 100÷60 mm and by the thickness of $h_{SiO_2} \approx 600$ nm, $h_{Si} \approx 470\,000$ nm, allows to estimate the degree of perfection of crystalline structure. Brief thermal influence is created by the powerful impulsive nanosecond neodymium laser resulted to local surface tissue fusion. After stopping of the laser radiation action of fusion solidification begun exactly from the surface, but the crater underbody is extended (molten) and created the additional squeezing mechanical tension σ_i, that „pull" the central part of crater surface in depth with the liquid crater fusion. The pressure dynamics Pi(t) is following: at the beginning of destruction Pi grows quickly, and on the completion of impulse action diminishes instantly on the value of the light pressure created by the laser. Then the diminishing pressure Pi becomes slower, for nanosecond times of laser influence the appearance of acoustic emission (AE) review is important in time range $\tau \approx 0.2$ nanosec [3,4].

Anelastic IF Q^{-1} and elastic E characteristics are essentially depended on morphology of surface layer. The SiO_2 surface after laser irradiation is shown on fig. 1. This process in a set of time phases mimics the "volcanic eruption".

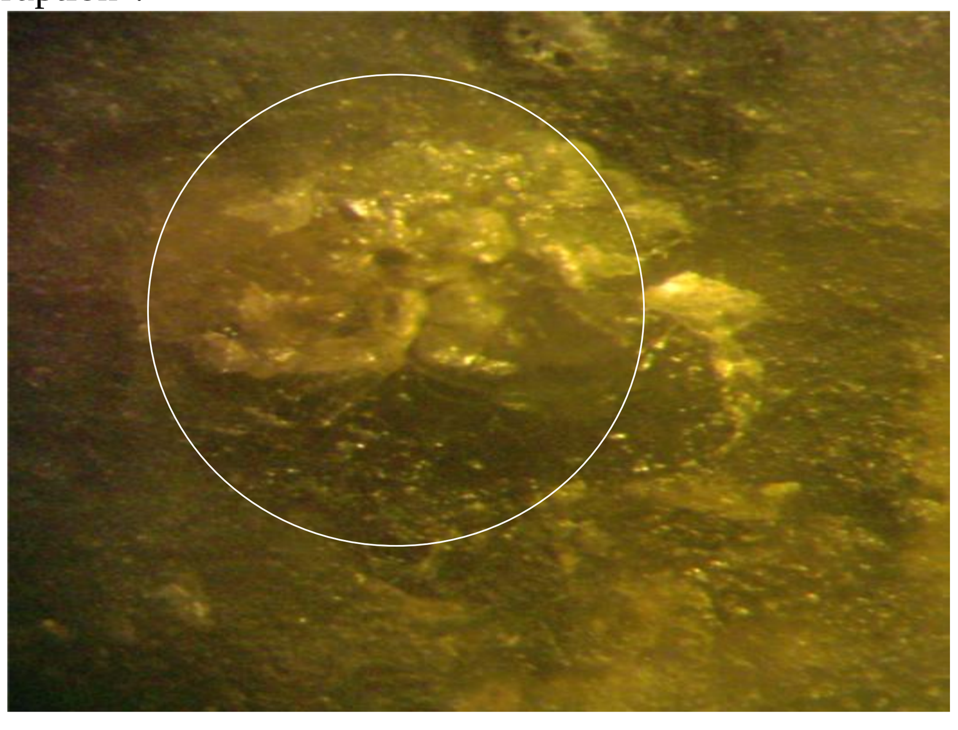

Fig. 1. SiO_2 surface after the nanosecond laser irradiation by the ruby laser with the intensity of I ≈ 300 Mw/cm^2 with the dose D = 4xI the duration of the ruby laser pulse $\tau \approx 20$ ns with the wavelength λ = 694 nm. The circle indicates the area of the laser irradiation (x56)

Ultrasound (US) pulse-phase method for determining the velocities of elastic waves using USMV-LETI, modernized USMV-KNU and computerized "KERN-4" on fig. 2 with frequencies $f_\parallel \approx 1$ MHz and $f_\perp \approx 0{,}7$ MHz [3,4] .

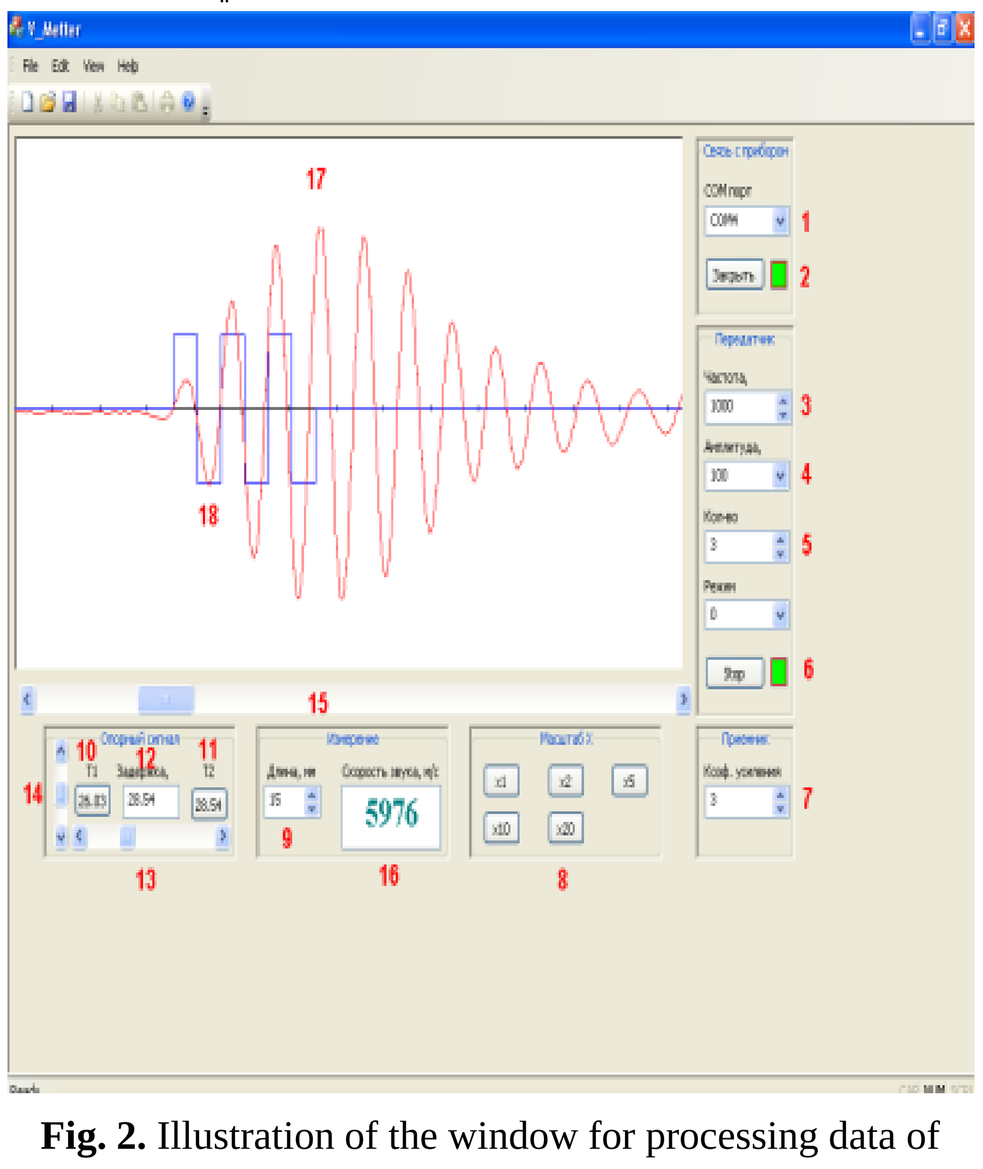

Fig. 2. Illustration of the window for processing data of elastic waves velocity $V_\parallel$ measurements in SiO_2/Si plate by echo-impulse method at frequency $f_\parallel \approx 1$ MHz and the presence of computer device KERN-4

RESULTS AND DISCUSSION

The quasi-longitudinal elastic wave US velocity measuring $V_\parallel$ = 3333 ± 10 m/sec, dynamical elastic modulus E = $\rho V_\parallel^2$ = 13,719 GPa, the quasi-transversal US velocity $V_\perp$ = 1215 ± 10 m/sec, shear modulus G = $\rho V_\perp^2$ = 1,823 GPa of nanocomposite polyamide-6 (PA-6) $(NH(CH_2)_5CO)_n$ + 1.7% methylene dye blue squaring (DBSQ) were determined from the oscillogram on fig. 3.

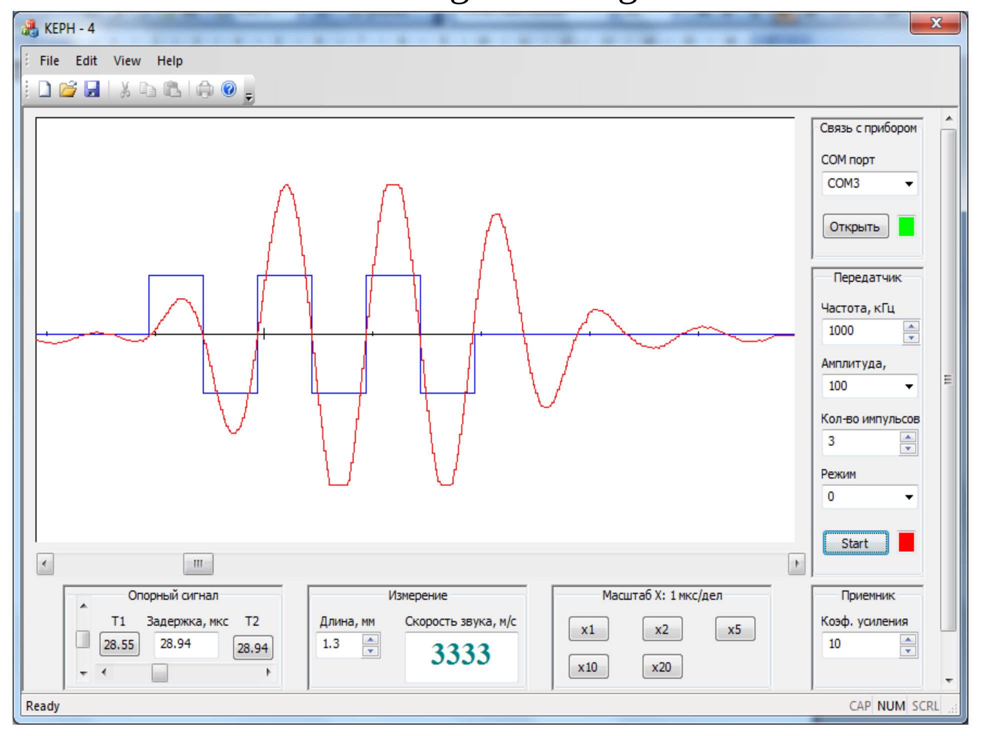

Fig. 3. Illustration of the window for processing data of quasi-longitudinal elastic wave velocity measuring $V_\parallel$ = 3333 m/sec in nanocomposite polyamide-6 (PA-6) $(NH(CH_2)_5CO)_n$ + 1.7% methylene dye blue squaring

Effects of AE after nanosecond neodymium and ruby laser irradiation in fluid SiO_2 are investigated. The fusion depth as the result of relaxation of photothermal elastic strains σ_i at the large time $\partial T/\partial t$ = (55±100)x10^9 K/sec and spatial $\partial T/\partial x$ = (1±2)x10^4 K/sm temperature gradients on the SiO_2 surface was appraised $\Delta h \approx 10000$ nm. The quantity of reflections N = $\tau/t \approx$ 0.2 nsec/0.02 nsec = 10, approximately 10 times forward-back in specimen. There was a small value of IF background in SiO_2 $Q_0^{-1} \approx 2 \times 10^{-6}$ to T ≈ 385 K. AE method was measured the group longitudinal wave velocity in fluid SiO_2 by water solution of NaCl with the concentration $\rho \approx 38.125$ g/l there was $v_\parallel = l/\tau \approx$ 0.03032 m/10.7 mcsec ≈ 2830 m/sec; shear wave velocity $v_\perp \approx$ 2300 m/sec. Oscilloscopegramma of impulses with transversal polarization, which are reflected in SiO_2/Si wafer-plate is represented on fig. 4.

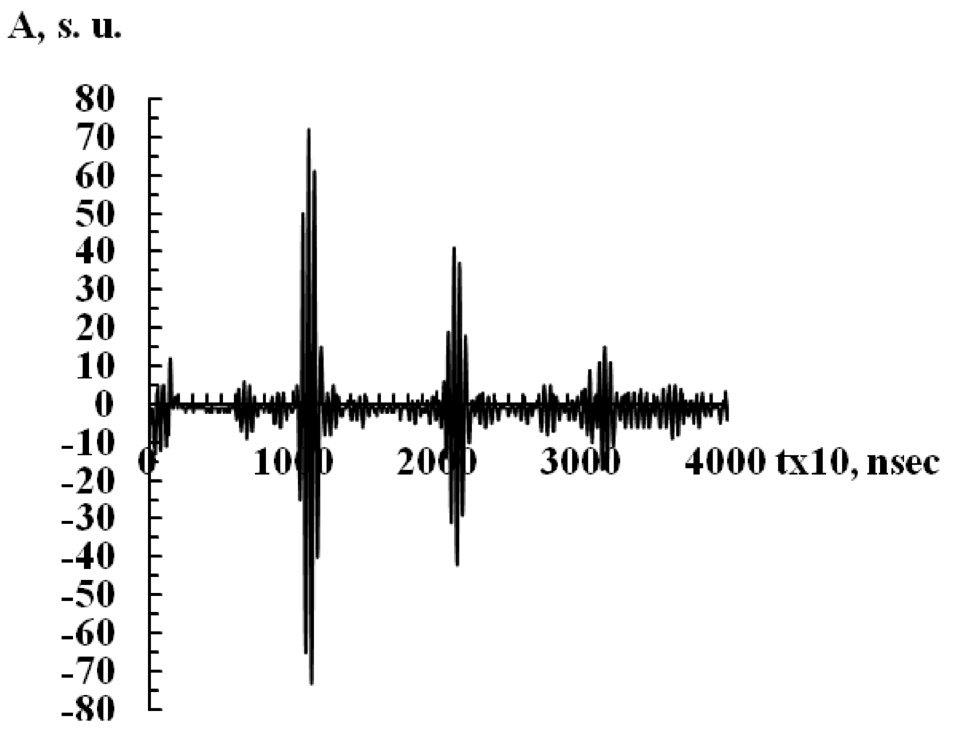

Fig. 4. Oscilloscopegramma of impulses with transversal polarization, which are reflected in SiO_2/Si wafer-plate

Taking into account the value of density $\rho \approx 2.63 \cdot 10^3$ kg/m^3, shear modulus G = $\rho v_\perp^2 \approx$ 13.91 GPa and elastic modulus E = $\rho v_\parallel^2 \approx$ 21.06 GPa were determined. The influence of US deformation ε_{US} studed on inelastic internal friction (IF) Q^{-1} and elastic modulus E characteristics of multiwalled carbon nanotubes (MWCNT) nanocomposites.

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. 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 $C_0 \approx 5\%$.

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

where α is US attenuation coefficient, λ is the US wavelength, f is the US frequency.

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 [1]:

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

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 ± 30 m/sec, shear module G = $\rho V_\perp^2$ = 578 MPa, the longitudinal US velocity $V_\parallel$ = 2485 ± 30 m/sec, dynamical elastic module E = $\rho V_\parallel^2$ = 6,057 GPa, Poisson coefficient μ = 0,44 nanocomposite polyethylene with low density high pressure $(C_2H_4)_n$ + 3% MWCNT were determined from the oscillogram on fig. 5.

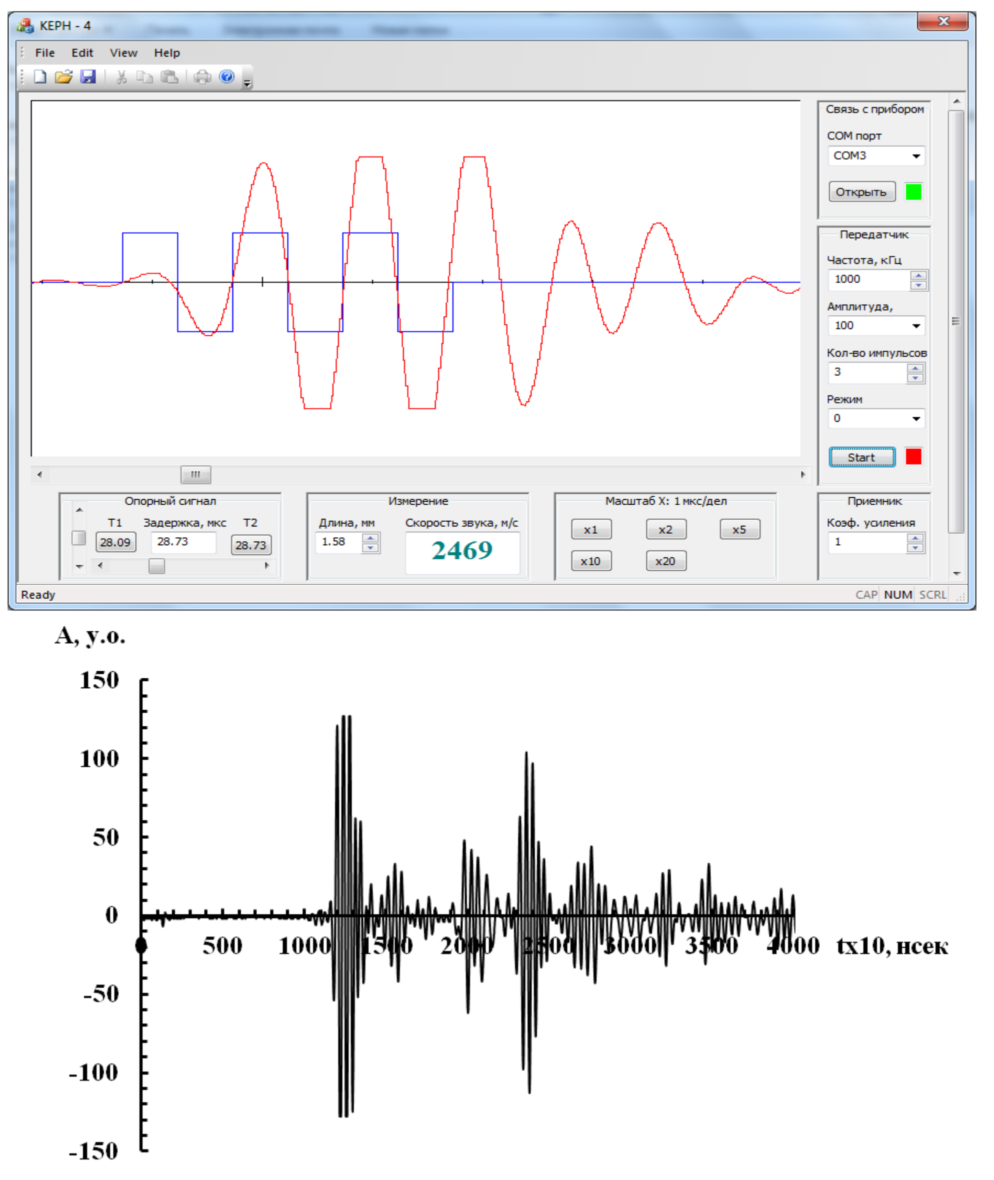

Fig. 5. The illustration of the window for processing data of longitudinal elastic wave velocity measuring $V_\parallel$ = 2469 m/sec in nanocomposite polyethylene + 0,7% MWCNT by by impulse-phase ultrasonic method on frequence $f_\perp \approx 1$ MHz.

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. Mechanical studies have confirmed the strong interaction between polyamide-6 (PA-6) $(NH(CH_2)_5CO)_n$ and methylene blue dye.
2. 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.
3. The annealing of the structure defects in nanocomposite bends out of shape the type of internal friction temperature spectrum Q^{-1}(T).

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