Indicatory Surface of Anelastic-Elastic Properties of Alloys, Nanocomposites of Multiwalled Carbon Nanotubes and Polyamide, Polyvinyl Chloride, Polyethylene, Porous Polystyrene

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INTRODUCTION

In this work nondestructive method, which is allow to determine from internal friction difference $\Delta Q^{-1}/Q^{-1}_0$ of elastic vibrations structure defects density N_d and the depth of broken layer h_b, is offered for SiO_2/Si wafer-plates. 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.

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]. Acoustic emission (AE) allow to receive the additional information about the process of* microcracks *[2]. The non-destructive method for the technological control of the structure defects by measuring internal friction (IF) and elastic modulus E after laser radiation was developed.*

EXPERIMENTAL PROCEDURE

The study of influence of structure defects on damping of vibrations in Si/SiO₂ 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. 3D atomic-force microscopy (AFM) of the microstructure image of TiO_2 is represented in Fig. 1.*

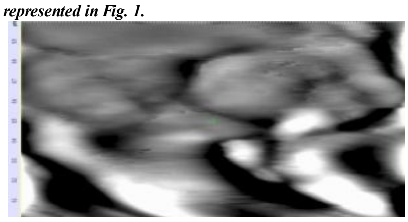

Fig. 1. *3D atomic-force microscopy image of TiO_2 microstructure* (1x1*x10³ nm)*

TiO_2 surface after laser irradiation is shown in Fig. 2. This process in a set of time phases mimics the "volcanic eruption".

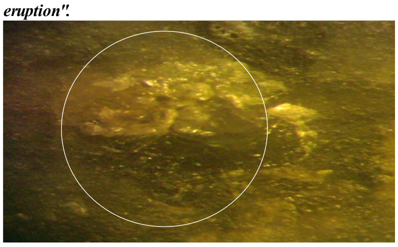

Fig. 2. *TiO_2 surface after the nanosecond laser irradiation by the ruby laser with the intensity of I ≈ 300 Mw/cm² with the dose D =* 4xI the duration of the ruby laser pulse $\tau \approx 20$ ns with the wavelength λ = *694 nm. The circle indicates the area of the laser irradiation (x56)*

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

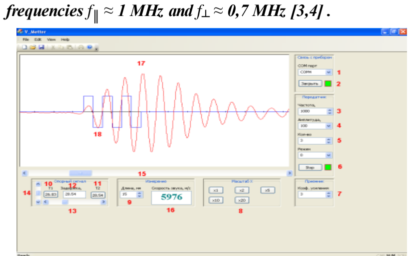

Fig. 3. *Illustration of the window for processing data of elastic waves velocity $V_\parallel$ measurements in Ti₃Al alloy by echo-impulse method at frequency $f_\parallel \approx 1$* MHz and the *presence of computer device KERN-4*

RESULTS AND DISCUSSION

Temperature dependencies of internal friction (IF) $Q^{-1}(T)$ and elastic modulus E(T) (indicatory surface of anelastic-elastic body) and 2D and 3D atomic force microscope (AFM) microstructure of Ti₃Al alloy after mechanical treatment and after hydrogenization H are presented in Fig. 4 and Fig. 5.

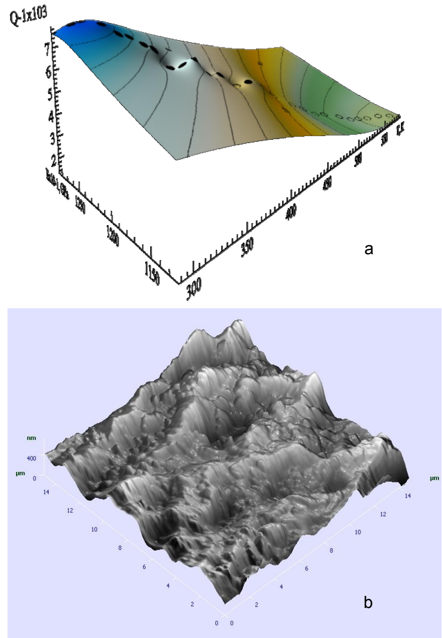

Fig. 4. *Temperature dependencies of $Q^{-1}(T)$ and E(T) a - (indicatory surface of anelastic-elastic body) and b - 3D AFM microstructures of Ti₃Al alloy after mechanical treatment*

The thermally activated IF maximum at $T_M \approx 400$ K is caused by the process of the reorientation of interstitial hydrogen atoms in dumbbell configurations H-H.

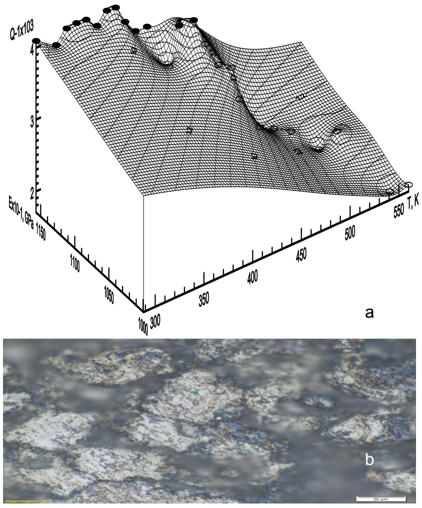

Fig. 5. *Temperature dependencies of $Q^{-1}(T)$ and E(T) a - (indicatory surface of anelastic-elastic body) and b - 2D microstructure of Ti₃Al alloy after hydrogenization H during $t_H \approx 14400$ sec*

The quasilongitudinal ultrasonic (US) velocity $V_\parallel$ = 504 m/sec, elastic modulus $E = \rho V_\parallel^2$ = 15,24 MPa, "fast" *quasitransversal US velocity $V_{\perp 1}$ = 280 m/sec, shear modulus $G = \rho V_{\perp 1}^2$ = 4,704 MPa, Puasson coefficient μ = 0,3532, specific density ρ = 60 kg/m3 of porous polystyrene (C₈H₈) are determined from the oscillograms [3,4].*

Taking into account the value of density $\rho \approx 2.63 \cdot 10^3$ kg/m³, 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 *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 [2]:*

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

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 in Fig. 6.

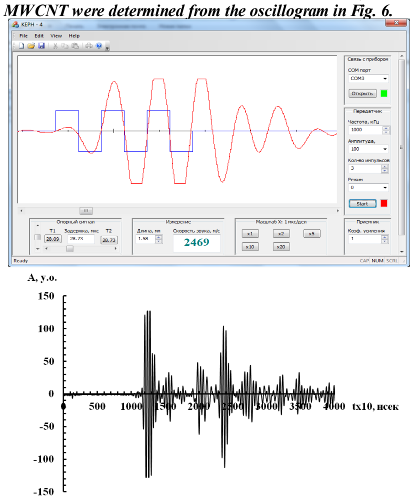

Fig. 6. *The illustration of the window for processing data of longitudinal elastic wave velocity measuring $V_\parallel$ = 2469 m/sec in nanocomposite polyethylene + 0,7% MWCNT by by impulse-phase ultrasonic method on frequence $f_\perp \approx 1$ MHz.*

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 correlation between internal friction Q^{-1}, elastic modulus* E *and temperature may be presented as a surface* ("indicatory *surface of anelastic-elastic* properties") *of alloys or nanocomposites, which gives an additional information about influence of the mechanical and thermal treatment.*
2. *The measurement of internal friction background Q^{-1}_0 after different heat treatments gives information about the changing of the fields of the heat tension* σ_i *in alloys, nanocomposites before and after satiation.*
3. *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.*
4. *The annealing of the structure defects in nanocomposite bends out of shape the type of internal friction temperature spectrum Q^{-1}*(T).
5. *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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