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Short Communication

Atomic Force Analysis of Elastic Deformations of CD

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The procedure for the determination of elastic parameters according to reference nanometer lithographic marks by atomic force microscopy on samples with up to microscopic sizes is proposed. Analysis of dynamic changes of elastic characteristics that makes it possible to establish the critical rotation velocity of a CD without plastic deformations has been made.

Keywords: Elastic effects, Atomic force microscopy, Nanoindenter, CD, Polycarbonate.

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1. INTRODUCTION

The transition to data recording of nanometer-scale range using devices of either nanometer- or micrometer-scale sizes or nanostructured devices has indicated challenges of restructuring in materials that are utilized at pre- and critical localized impacts of electronic, elastic, and thermal nature [1, 2]. Traditional diagnostic methods, including optical ones, [3] provide scanty information about structural changes in materials. Now the atomic force microscopy techniques (AFM) of microscopic entities are being developed, which are based on nano- and microindentation [4].

2. EXPERIMENTAL SECTION

Rectangular samples ($4 \times 4 \times 0.5$ mm) of polycarbonate, which is intensively used in electronic and computer techniques, for example in CD, were influenced by a localized elastic up to plastic deformation (Fig. 1a). The check of restructuring was realized by using a nanometer lithographic pattern that was made by an atomic- force microscope cantilever. The thickness of reference lines was dictated by the geometrical size of a probe and was equal to 7-10 nm. The depth of lines was determined by the number of probe pricks and the indentation power and was within 12-15 nm, and their orientation was chosen with consideration for directions of deformation.

The measurement of deformation magnitude is based on photoelasticity, in which changes in polarized radiation were recorded with a modified confocal microscope (AIST-NT OmegaScope). Stresses were calculated according to the technique described in [4] by using equation

$$\sigma = N\lambda / dK,$$

where σ is normal stress, N is the order of interference stripe proportional to σ, λ is the wavelength of a light source, d is the sample thickness, K is photoelasticity coefficient for polycarbonate (7×10^{-11} m^2/H).

Fig. 2 shows how nanometer-scale distance between reference nanometer lithographic marks (RNMs) changes with deformation. Characteristic areas of elastic, plastic deformation up to the sample destruction

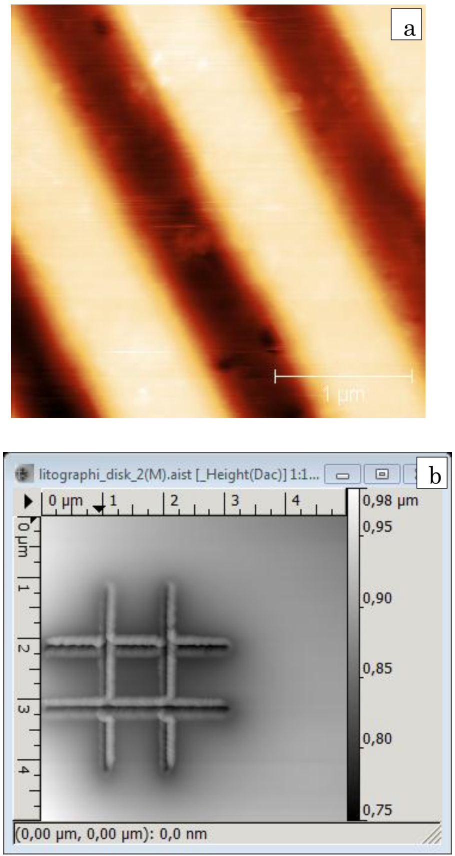

Fig. 1 – AFM image of tracks for the formation of pit information – a; nanometer lithographic pattern on the polycarbonate surface – b

are observed. Elastic modulus determined from the relation $E = F{\cdot}l/S{\cdot}\Delta l$ (F, S are the load and the area of its distribution, respectively, l, Δl are the pattern size and the variation of distance between RNMs) was equal to 2.4 GPa with the measurement error of 1.6 %. The elastic modulus of polycarbonate determined by the standard methods is equal to2.2 GPa. The measurement of E-value for the samples with sizes ($4 \times 4 \times 0.5$), which do not meet requirements of the standard methods, was equal to 4 GPa with the use of Instron 5882 (Fig. 2) (at a comparable measurement accuracy).

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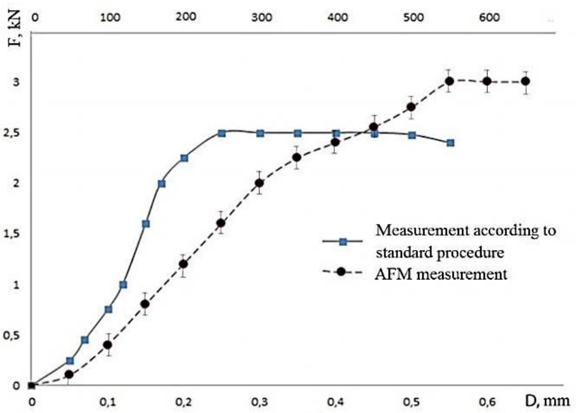

Fig. 2 – Dependence of changes in nanometer-scale sizes on the deformation applied

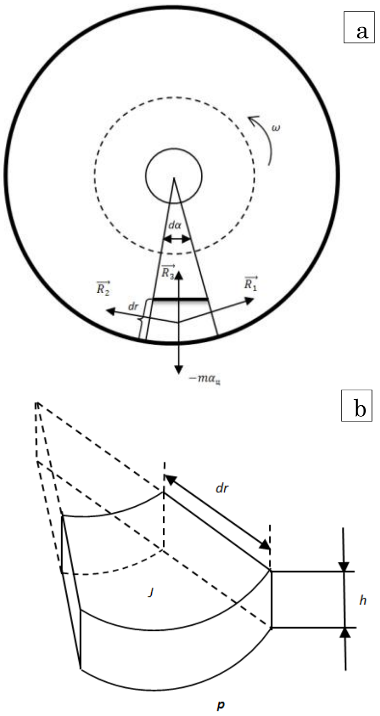

Fig. 3 – A schematic of a laser disk (a) and its elementary site (b)

As a practical application of the obtained nanoscale elastic modulus dynamic changes in elastic parameters have been analyzed, which correspond to critical (without plastic deformation) rotation velocities of a CD, that is in elastic deformation domain. As seen in Fig. 3, the external areas of a CD undergo a maximum effect of inertial force; as a result these deform most of all. Consider the elementary site of the CD at its edge with ω – a maximum rotation velocity, which is accompanied by a shift of the information pit edge through an angle $d\alpha$ as compared to the nearest edge of another pit (Fig.2).

Here $\overrightarrow{R_1}, \overrightarrow{R_2}$ и $\overrightarrow{R_3}$ are elastic forces that act on this site at its maximum deformation when in rotation and the resultant force set in opposite direction to the centrifugal force.

According to D'Alembert' principle:

$$\overrightarrow{R_1} + \overrightarrow{R_2} + \overrightarrow{R_3} + \overrightarrow{R_ц} = 0$$

Considering, that $R_1 = R_2 = R\ (\delta_1 = \delta_2 = \delta_x)$, projecting on the Y-axis

$$R_y = 2 \cdot R \cdot \sin\frac{d\alpha}{2} + \delta_y \cdot h \cdot r \cdot d\alpha.$$

Disk destruction and super critical shift of pits at deformation is determined by only two diagonal strain components δ_x и δ_y:

$$R_y = \alpha_ц \cdot dm = \alpha_ц . \rho \cdot dV = \omega^2 \cdot r \cdot \rho \cdot rh \cdot d\alpha \cdot dr = \omega^2 \cdot r^2 \cdot \rho \cdot h \cdot d\alpha \cdot dr,\ R = \delta_x \cdot h \cdot dr.$$

Considering smallness of $d\alpha$, $\sin\frac{d\alpha}{2} \approx \frac{d\alpha}{2}$:

$$\omega^2 \cdot r^2 \cdot \rho \cdot h \cdot d\alpha \cdot dr = 2\delta_x \cdot h \cdot dr \cdot \frac{d\alpha}{2} + \delta_y \cdot h \cdot r \cdot d\alpha$$
$$\rho \cdot \omega^2 \cdot r^2 \cdot dr = \delta_x \cdot dr + \delta_y \cdot r.$$

Obviously:

$$\delta_y = \frac{dR_ц}{rd\alpha h} = \frac{\omega^2 dr \cdot dm}{r \cdot d\alpha \cdot h} = \omega^2 \rho dr^2$$

Here dR_y is the difference between two centrifugal forces acting on sites with mass dm at a distance dr along disk radius.

$$\rho \cdot \omega^2 \cdot r^2 = \delta_x + \omega^2 \cdot \rho \cdot r \cdot dr$$
$$\rho \omega^2 r^2 \left(1 - \frac{dr}{r}\right) = \delta_x$$

Considering smallness of $dr\ (dr \ll r)$ and $\delta_x = \delta_{lim.el.}$ the maximum disk rotation frequency can be evaluated, at which irreversible changes still do not occur:

$$\omega \approx \frac{1}{2\pi R'} \sqrt{\frac{\delta_{lim.el.}}{\rho}} = 1532 \text{ rev/s},$$

where R' is the disk radius, $\delta_{lim.el.}$ is the elastic limit of polycarbonate, ρ is the disk density.

The elastic limit $\delta_{lim.el.}$ obtained in studying nanometer-scale deformations makes it possible to determine the maximum possible shift of pits with respect to each other dl_{max} for error-free reading data:

$$dl_{max} = \frac{\delta_{lim.el.} l}{E} = \frac{\delta_{lim.el.} \alpha R'}{E} = 145 \text{ nm}$$

3. CONCLUSIONS

The present results indicate the importance of development of special ways and methods to determine elastic parameters in covers on materials or in small-sized samples (up to nanometer-scale and microscopic) even along one coordinate axis.

REFERENCES

1. Yu.I. Golovin, *Phys. Solid State* **50**, 2205 (2008).
2. A. Kuzmenko, D. Timakov, P. Abakumov, M. Dobromyslov, L.V. Odnodvorets, *J. Nano- Electron. Phys.* **5** No3, 03024 (2013).
3. S.I. Gerasimov, *Appl. Mech. Tech. Phys.* **45**, 453 (2004).
4. A.P. Kuzmenko, *Nano Deformation of the CD Material. BSU Scientific bulletin* **106**, 108 (2011).