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AFM ANALYSIS OF ALUMINIUM ALLOYS

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ABSRACT
Application of SEM gives us very important information, significantly supplement traditional materials analysis. This work is deals with investigation of aluminium alloys by atomic force microscope (AFM). There are described samples and description of constituent methods, which were used in measurement.

Keywords: AFM, topography, Aluminium alloys

1. INTRODUCTION

1.1. The Properties Of Aluminum

Lightness: On a volume basis, aluminium is only about one-third the weight of steel. Significant weight savings can be made in almost every type of mechanical application.
Durability: Because aluminium quickly forms an impervious oxide skin on exposed surfaces, it is highly resistant to atmospheric corrosion, even in marine conditions. So it does not require painting for protection.
Conductivity: The specific electrical conductivity of aluminium makes it indispensable for electronics and electrics. Aluminium cables carry twice as much current as copper of the same weight. High thermal conductivity makes it very suitable for heating and cooling applications.
Workability: Aluminium can be formed by all the common metal-working techniques, more easily than most. It is easy to cast, or die-cast to precise and complex shapes. It can be forged, rolled to a superfine foil, and extruded into intricate sections, or pressed. Superplastic alloys can be worked almost like vacuum-formed plastics. Aluminium is also one of the easiest and fastest materials to machine.
Versatility: Aluminium alloys can be stiff or supple, especially strong or particularly corrosion-resistant. It is easy to tailor the metal, by alloying and heat treatment, to meet a wide range of needs.

Attractiveness: Aluminium is a "clean" material. It looks good without further finishing, but takes kindly to a wide range of applied coatings, from paints to coloured anodising.
Recyclability: Aluminium is easily reprocessed using 5% of the energy needed for primary smelting: almost one third of all the aluminium used today is produced from scrap, either from production processes or from recycled products.

1.2. Atomic-force microscope

Atomic-force microscope (AFM NT - 206 - Figure1.) in a complex with control and image processing software is intended for measurement and analysis of surface micro- and submicrorelief, objects of the micro- and nanometer range with high resolution [1].
Fields of application of the AFM are physics of solids, thin-film technologies, nanotechnologies; micro- and nanotribology, microelectronics, optics, testing systems of the precision mechanics, magnetic record, vacuum engineering etc.
The AFM can be used in scientific and industrial laboratories.
The image of a surface in the AFM is obtained at scanning a sample in a horizontal plane by a tip with the curvature radius about tens–hundreds of nanometers attached to the cantilever. A control system traces the probe position relative the sample surface in every measurement point and adjusts the tip to sample separation at constant level set by the operator. The changes of the probe vertical position in every point make an AFM data matrix which is recorded in a file and then can be used for further processing, visualization and analysis [2].

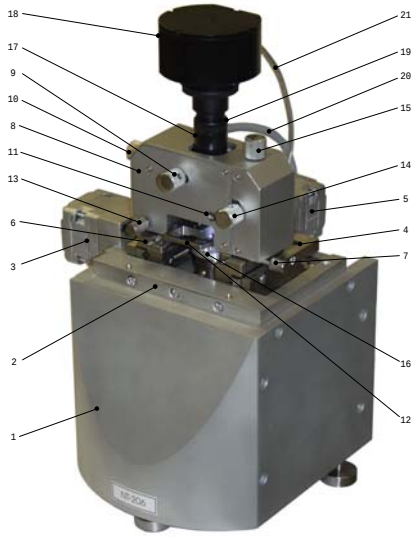

Figure 1. Scanning unit of atomic force microscope NT-206. 1 – case (base platform); 2 – Y positioning stage; 3 – driving stepper motor of Y positioning stage; 4 – X positioning stage; 5 – driving stepper motor of X positioning stage; 6 – a dove tail couple for mounting measuring head; 7 – screw for fixing the measuring head in dove tail; 8 – a measuring head; 9 – a knob of laser source adjusting mechanism for X direction; 10 – a knob of laser source adjusting mechanism for Y direction; 11 – a mirror axis; 12 – a probe holder; 13 – a screw for locking a probe holder; 14 – a knob of a photodetector adjusting mechanism for X direction; 15 – a knob of a photodetector adjusting mechanism for Y direction; 16 – sample platform on the piezoscanner top; 17 – a video system tube; 18 – a video camera module; 19 – a turnable ring for fine focusing of the video system; 20 – video system output cable (USB type); 21 – measuring head cable.

1.3. Possibility of atomic-force microscope

Using AFM it is possible to scan curves that show dependence of composite action force of the probe and surface of the sample on distance between them – they are curves of approach /moving off. These curves are very important for measurements of vertical force attached to the surface from the side of the tip in the process of scanning. Besides the force it is also possible to evaluate viscosity of dirty surface, thickness of the covering layer and also local variations of elastic features of the surface from the curve.

The curve of approach /moving off is a graphic dependence of measuring cantilever deviation on scanning device extension. Van der Waals forces are only one factor of cantilever deviation affecting. The measurement will be also influenced by thin layers of moisture that are usually present at working with AFM in the presence of air and also streaks and impurities.

The curves of approach / moving off that we obtain are specific enough for each sample and at the same time we can separate general characteristic sections in them, as shown in Fig. 2.

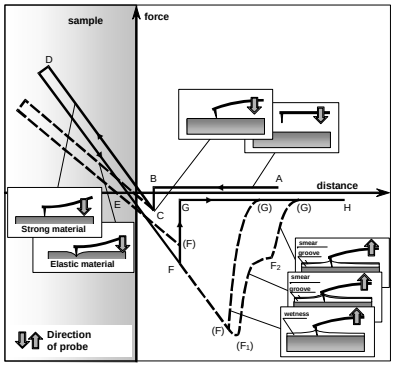

Figure 2. Nomogram of the curves - approach/ moving off. The solid lines are schematic presentation of curves obtained in vacuum. Dashed lines show variations of curves of approach/moving off conditioned by elastic features of the sample and by presence of surface layers of moisture and streaks (impurities).

Section A -B. In the left part of the curve there is a scanning device completely moved off and the cantilever is not swaying because the tip is not touching the sample. By approaching the surface the cantilever is not swaying until the Van der Waals forces start to force (point B). In this part the curve does not contain any useful information.

Section B -C. In point B the cantilever suddenly starts to move towards the surface and the tip touches the surface (point C). This part of the curve is known as "leap to contact". Working in air environment there will be a composite action of the surface moisture capillarity and also impurities, streaks and grease on the tip besides Van der Waals attractive forces and electrostatic forces. Change of the force in the part B – C of the curve can be related to the tip shrinkage in accordance with the Hook law ($F = -k\Delta x$) what allows to evaluate the thickness of absorbed layer on the sample surface.

Section C – D. This part characterises further approach of the probe to the sample, it is accompanied by driving needle tip to the surface and by nearly linear curve of the cantilever towards the surface. From the shape of the C – D section we can evaluate modulus of elasticity of the system probe – surface. In the case that, for example, the measuring probe is much softer than the surface of the sample, the curve inclination presents mostly elastic constant of the cantilever itself. Contrariwise, if the hardness of the cantilever is much harder than the surface of the sample, inclination of the section C – D allows us to study elastic

features of the sample. Section C – D does not have to be straight line at all, the inclination change of this curve part shows differences in surface reactions to different attached force [3].

Section D – E. Point D refers to the end of the approaching phase and the beginning of moving-off from the surface. If there is no hysteresis of the scanning device the section D – E is practically the same as the section of the curve C – D, which we obtained during the approach. In the case that both of these sections are straight and parallel they do not give us any additional information (besides above mentioned). In the case that they are unparallel it allows us to determine plastic and elastic deformation of the sample (if the speed of recovery of surface geometrical features is slower than moving-off of the probe).

Section E – F. Point E refers to the neutral divergence of the cantilever. During further moving-off of the probe from the surface, the cantilever starts to incline to the sample because adhesive or gravity force affects the tip. The form of the section E – F is influenced by presence of absorbing layers on the sample surface. In the case of vacuum work, Van der Waals and electrostatic forces affect the tip of the needle. If we work in air, quite strong capillary force of surface layer of moisture, grease and impurities adds to these forces. Thickness of the surface layer influences the length of the section E – F and its inclination, which is different to inclination caused by hardness of the sample, and points at raising of absorbing layers together with the moving-off probe. When the elastic response of the cantilever outruns gravity forces of the surface side and its layers, the probe separates from the sample surface. Point F, known as the point of separation, refers to this action in the curve of approach/moving off.

Section F – G. When the elastic response of the cantilever outruns the gravity force of the surface and its layers, the probe separates from the sample. In the curve of approach/moving-off there is a point F, known as the point of separation, referring to this. The size of straining in the point F is equal to the total maximum adhesive force between the probe and sample and provides key information on observation of adhesion. If the moisture layer is covered enough with grease layer or other impurities, it is the case when we can observe not only one point of separation (F1 and F2). Position of the points F1 and F2 depends on viscosity and thickness of these layers. Transition between the sections E – F and F – G does not necessarily have to have steep ascent. In the case that the absorbing layer has equal viscosity, the probe can move off from the surface gradually and the transition E – F - F – G will have round shapes.

2. EXPERIMENTAL PART

In presented measurements by using of spectroscopic curve were evaluated the homogeneity and ratio of Young modulus on aluminium alloys. For each sample was creation the curve by using of five different places – points.

We employed the general approximation and Snedonn's formula for analysis dates and calculation of Young's modulus off complete rake curve.

The Sneddon's model gives the relationship between load gradient, dP/dh, and Young's modulus, E, in the form [4], [5]:

$$\frac{dP}{dh} = \frac{2A^{1/2}}{\pi^{1/2}} E \qquad (1)$$

Where $E = \left\{\left[\left(1-\nu_m^2\right)/E_m\right] + \left[\left(1-\nu_c^2\right)\right]/E_c\right\}^{-1}$ (2)

Is the composite elastic modulus,

E_m, E_c, ν_m, ν_c Young's modulus and Poisson's ratio of a material and a cantilever, respectively,
P - Normal load,
A - Contact area,
h - The indentation depth.

Following the formula 1 results for the modulus of two different samples

$$\frac{dP_1}{dh_1} = \frac{2A^{1/2}}{\pi^{1/2}} E_1 \Rightarrow E_1 = \frac{dP_1}{dh_1}\frac{\pi^{1/2}}{2A^{1/2}} \qquad \frac{dP_2}{dh_2} = \frac{2A^{1/2}}{\pi^{1/2}} E_2 \Rightarrow E_2 = \frac{dP_2}{dh_2}\frac{\pi^{1/2}}{2A^{1/2}}$$

The relation of modulus of modulus of elasticity:

$$\frac{E_1}{E_2} = \frac{\frac{dP_1}{dh_1}\frac{\pi^{1/2}}{2A^{1/2}}}{\frac{dP_2}{dh_2}\frac{\pi^{1/2}}{2A^{1/2}}} \Rightarrow \frac{E_1}{E_2} = \frac{\frac{dP_1}{dh_1}}{\frac{dP_2}{dh_2}}$$

The linear equation is: $y = kx + q$, $k = \frac{dP}{dh}$

where $\frac{dP_1}{dh_1} = k_1$ a $\frac{dP_2}{dh_2} = k_2$

$$\Rightarrow \frac{E_1}{E_2} = \frac{k_1}{k_2}$$

The equations of line we obtained from spectroscopic curves by approximation and their values are presented in the Table 1.

Table 1. The values of k_1 a k_2 obtained by approximation of spectroscopic curves to the line

k_{1-1}	k_{1-2}	k_{1-3}	k_{1-4}	k_{1-5}	k_1
-2,015	-2,021	-2,017	-2,025	-2,011	**-2,0178**
k_{2-1}	k_{2-2}	k_{2-3}	k_{2-4}	k_{2-5}	k_2
-1,921	-1,932	-1,929	-1,933	-1,925	**-1,9280**
k_{3-1}	k_{3-2}	k_{3-3}	k_{3-4}	k_{3-5}	k_3
-1,811	-1,814	-1,815	-1,822	-1,813	**-1,8150**

By using of average values

$k_1 = -$ 2,0178 Al99
$k_2 = -$ 1,9280 AlMg3
$k_3 = -$ 1,8150 AlMn1

There hold for the comparing of samples modulus

$$E_2 = \frac{k_2 E_1}{k_1} \qquad E_3 = \frac{k_3 E_1}{k_1}$$

where
E_1 – Young's module – Al99
E_2 – Young's module – AlMg3
E_3 – Young's module – AlMn1

$$\Rightarrow E_2 = \frac{k_2 E_1}{k_1} = \frac{-1{,}9280}{-2{,}0178} E_1 \qquad \Rightarrow E_3 = \frac{k_3 E_1}{k_1} = \frac{-1{,}8150}{-2{,}0178} E_1$$

$$E_2 = 0{,}955 E_1 \qquad E_3 = 0{,}899 E_1$$

3. RESULTS

From spectroscopy curves and following calculations were occurred that the Young modulus of AlMg3 is the 0,955 times lesser than Al99 and the Young modulus of AlMn1 is the 0,899 times lesser than Al99. From these surface topography and spectroscopic curve inclination is possibly to say that all used samples are homogeneous.

4. REFERENCES

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