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AFM ANALYSIS OF ALUMINIUM ALLOY 7075

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Abstract

In this paper we present the results of atomic force microscopy (AFM) characterization of the surface morphology new type of composite based on the high-tensile aluminium alloy 7075 strengthened with nanoparticles of diamond powder and tungsten is developed, stored for 28 months under different conditions. One sample was stored on Earth at room temperature and second one was mounted on the outer side of the International Space Station.

Introduction

Requirements for the materials and them properties which are used in extreme conditions leads to new materials development and using. One of the conditions for exploitation is that they are light and hard. These materials need to have determined properties — heat resistance, high modulus of elasticity, wear, low density and other useful property for space materials engineering application. They must work in non-standard conditions — temperature fluctuations, cosmic radiation and mechanical stress: acceleration, vibration and others. To function in outer space, which is why it is extremely important to produce appropriate materials.

Due to the unique combination of properties, the aluminium and its alloys are one of the most important materials of today's aviation, aerospace and missile/rocket industry [1–3]. They are also called "space materials" because they meet the requirements that apply to space materials.

The aluminium alloy AA 7075 is the most widely used alloy for the production of high strength structures operating in extreme conditions. These aluminium alloys have a complex chemical composition, and refers to the four component system Al-Zn-Mg-Cu- highly hardened by heat treatment [4–6].

Due to the fact that the alloy AA 7075 is used in extreme conditions and is used in modern aeronautical structures and space techniques, it is especially proposed additional introduction of nanodiamond particles and other alloying additives to improve the properties of alloy.

In the presented scientific development a new composite material based on aluminium AA 7075 was investigated, with quantitative addition of ultrafine diamond powder (UDPD) [7] and Tungsten (W). The material is suitable, has the necessary properties and for this purpose the "OBSTANOVKA" experiment is planned and performed in the Russian module of the International Space Station (ISS) [8–9].

Materials and Methods

Materials

Two types of samples were prepared and studied of aluminium alloy AA 7075 with additions of ultra-dispersed diamond powder (UDDP) and Tungsten. Some specimens were stored as a "reference" under natural terrestrial conditions for 28 months, while other specimens were subjected to "space" conditions — outside the International Space Station (ISS) for the same period.

The "space" sample was subjected to space radiation [10], which changed rapidly in intensity and type, depending on the coordinates, geophysical and helio-physical conditions, during orbiting of the station around the Earth

The temperature changes varied over a wide operating temperature range from −120 to +150°C for 2 hours over a period of 2 years and 4 months.

The above composite was obtained by casting and subjected to subsequent heat treatment. Cylindrical samples were made from it. For the presented below studies cylindrical specimens were cut with a diameter of 6 mm and a height of 6 mm. The analysed surfaces for both types of samples are performed in the centre, periphery and end. By periphery is meant the middle between the centre and the end along the radius.

Characterization methods

AFM imaging was performed on the NanoScope V system (Bruker Ltd, Germany) operating in tapping mode in air at room temperature. We used silicon cantilevers (Tap 300Al-G, Budget Sensors, Innovative solutions Ltd, Bulgaria) with 30 nm thick aluminium reflex coatings. According to the producer's datasheet the cantilever spring constant and the resonance frequency are in the range of 1.5 to 15 N/m and 150 ± 75 kHz, respectively. The tip radius was less than 10 nm. The scan rate was set at 1 Hz and the images were captured in height mode with 512×512 pixels in JEPG format. Subsequently, all images were flattened by using NanoScope software. The same software was also used for section analysis and roughness.

Results and Discussions

Atomic Force Microscopy (AFM) can be applied to measure the surface topography with great accuracy and thus facilitate the quantification of material roughness. Measurements of three samples from the “reference” R-1, R-2, R-3 and three samples from the “space” samples S-1, S-2, S-3 were performed. For each type of sample measurements were made in the centre, periphery and edge. The topography of a surface consists of structures of different length scales. The surface roughness caused by these structures plays a decisive role in interfacial properties.

Fig. 1 and Fig. 2 present the AFM images in 2D and 3D format of the samples. These images are accompanied by cross sections (Section) on the surface of the materials.

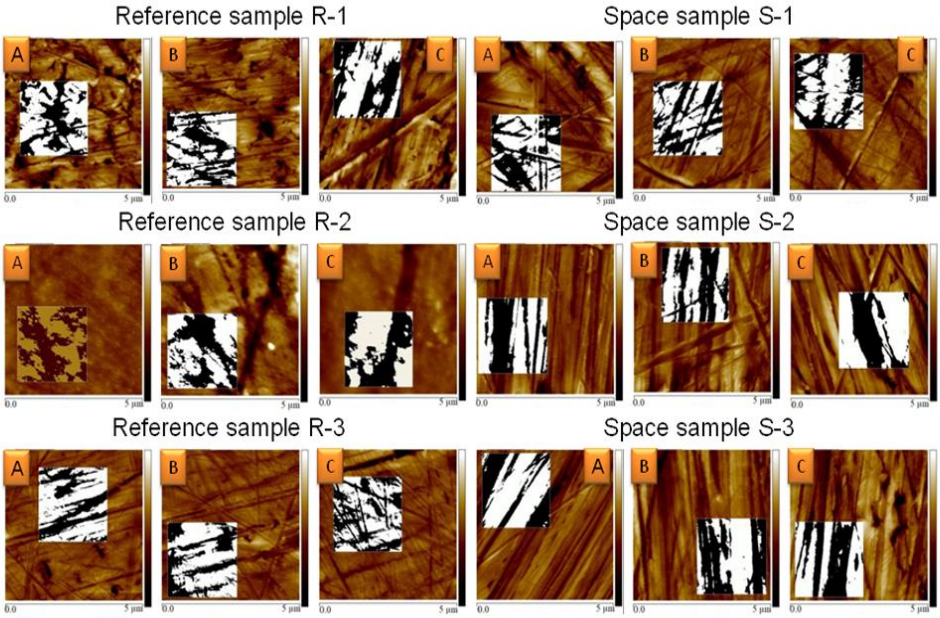

Fig. 1. 2D AFM images 5 µm of the Roughness of the aluminium alloy 7075 strengthened with nanoparticles of diamond powder and Tungsten: from left in the images – “reference” sample, the right of the image – “space” sample, (A) centre, (B) periphery and (C) edge

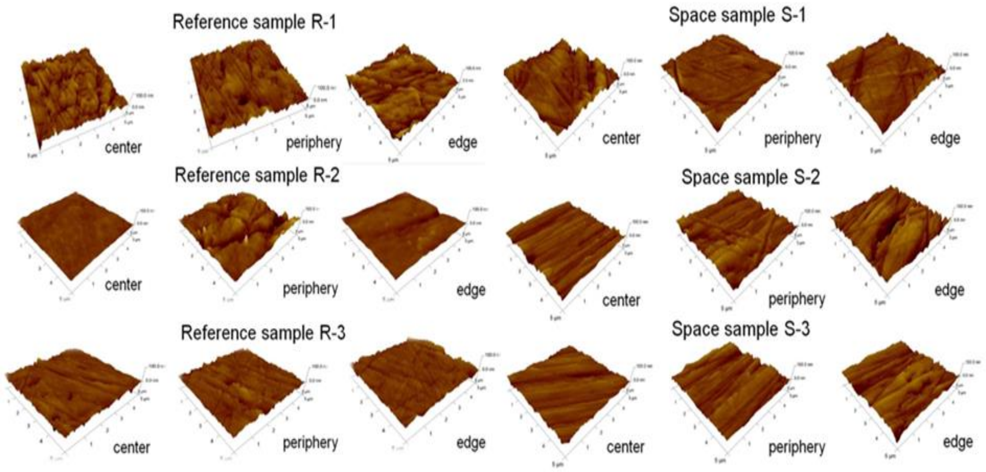

Fig. 2. 3D AFM images 5 µm of the surface of aluminium alloy 7075 strengthened with nanoparticles of diamond powder and Tungsten: from left in the images – "reference" sample, the right of the image – "space" sample

Images from three independent locations of the samples were taken for reproducibility purposes. From the applied roughness analysis statistical values according to the relative heights of each pixel in a particular AFM image are calculated. The roughness analysis gives the value R_a, which is an arithmetic average of the absolute values Z_i of the surface height deviations measured from the mean plane, i.e.

1) $$R_a = \frac{1}{N}\sum_{i=1}^{N}|Z_i|$$

while the image R_q is the root mean square average of height deviations taken from the mean image data plane, expressed as

2) $$R_q = \sqrt{\frac{1}{N}\sum_{i=1}^{N} Z_i^2}$$

The obtained values for the roughness of the two types of samples are shown in Table 1 and Fig. 3.

Table 1. Values of surface Roughness for the "reference" and "space" sample

Surface Roughness (*size scanned area*)	**Reference sample R-1**			**Reference sample R-2**			**Reference sample R-3**			**Space sample S-1**			**Space sample S-2**			**Space sample S-3**		
	center [nm]	periphery [nm]	edge [nm]	center [nm]	periphery [nm]	edge [nm]	center [nm]	periphery [nm]	edge [nm]	center [nm]	periphery [nm]	edge [nm]	center [nm]	periphery [nm]	edge [nm]	center [nm]	periphery [nm]	edge [nm]
R_q (*5μm x 5μm*)	16.5	12.3	16.1	15.4	15.2	24.7	8.95	8.32	8.98	13.4	7.35	9.46	9.13	10.3	16.9	10.4	11.1	14.0
R_a (*5μm x 5μm*)	12.0	8.84	12.3	11.9	11.1	16.2	5.87	5.76	5.65	10.0	5.53	7.34	7.22	8.16	12.5	7.95	8.78	11.2
R_{max} (*5μm x 5μm*)	167	178	210	108.8	151	248	273	193	239	166	76.8	93.1	77.4	94.3	124	90.0	96.2	118

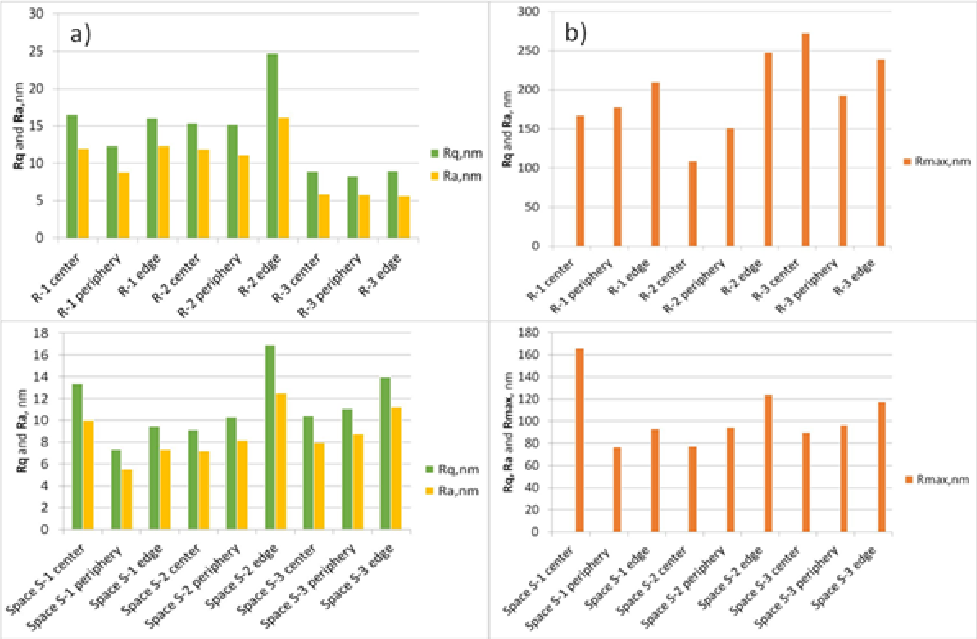

Fig. 3. Analysis of the roughness of AFM images 5 μm for the aluminium alloy 7075 strengthened with nanoparticles of diamond powder and Tungsten: R_q and R_a for "reference" sample and "space" sample (a) and R_{max} for "reference" sample and "space" sample (b)

From the analysis of the surface roughness performed for the "reference" and "space" samples shown in Fig. 3, as well as in Table 1, it was found that the "reference" sample R-1 has a rougher surface R_q compared to the "space" sample S-1 at three points of analysis. The difference in roughness of R-1 compared to S-1 on the measured surfaces is 3.1 nm in the centre and respectively 6.64 nm higher roughness at the end of the image. The “reference” sample R-2 has a rougher surface R_q compared to “space” sample S-2 at the three analysis points. The difference in roughness for R-2 compared to S-2 on the measured surfaces is 6.27 nm in the centre and respectively 7.8 nm higher roughness at the end of the image. For “reference” sample R-3 were found, that the values for R_q to be approximately comparable to those values for sample S-3. The difference in roughness for S-3 compared to R-3 on the measured surfaces is not large and is in the order of 1.45 nm in the centre and respectively 5.02 nm higher roughness at the end of the sample.

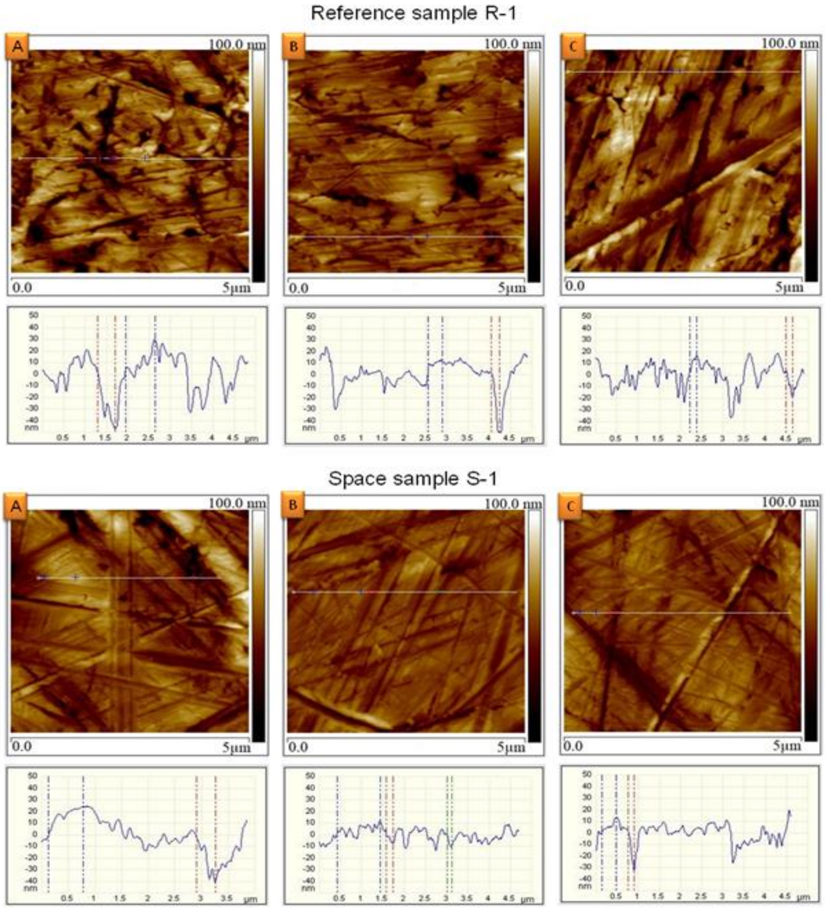

Fig. 4. Section analysis of the surface of “reference” sample and “space” sample in the centre, periphery and end

From the measured roughness of the “reference” and “space” samples, the values R_{max} was determined for the two types of samples at three points of analysis — centre, periphery and end. For the “reference” samples R-1 and R-2, the R_{max} values were found to increase from the centre to the periphery and the end, while for the “reference” sample R-3 these values decrease. For the “space” samples S-1, S-2 and S-3, it was found that the values of R_{max} increases from the centre to the periphery and the end.

From the section analysis of the “reference” and “space” samples presented in Fig. 4, it was found that in the “reference” samples microcracks with a diameter of 0.5 microns in the centre, periphery and at the end of the analysed surface were observed compared to the “space” samples.

The differences in the roughness between the “reference” R-1, R-2 and R-3 and the “space” S-1, S-2 and S-3 samples is explained by the environment conditions at which the “reference” material was stored, the terrestrial conditions temperature, atmospheric pressure, radiation, etc.

Conclusion

From the measurement by an atomic force microscope of “reference” and “space” samples of aluminium alloy 7075 was found that:

1. The “reference” samples R-1, R-2 and R-3 have a rougher surface compared to the surface of the “space” samples S-1, S-2 and S-3 at three points of analysis — in the centre, periphery and the end.
2. For the “space” samples S-2 and S-3, it was found that the values of R_{max} and the values of R_q increases from the centre to the periphery and the end.
3. From the roughness of the sectional analysis for the “reference” R-1 sample it is established presence of microcracks at three points of analysis due to storage conditions

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AFM АНАЛИЗ НА АЛУМИНИЕВА СПЛАВ 7075

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Резюме

В тази статия представяме резултатите от Атомно-силова микроскопия (AFM) за охарактеризиране морфологията на повърхността на нов тип композит на базата на високоякостна алуминиева сплав 7075 уякчена с наночастици от диамантен прах и Волфрам, съхранявана за 28 месеца при различни условия. Една серия от образците са съхранявани на Земята при стайна температура, а втората серия образци са били монтирани от външната страна на Международната космическа станция.