NANOSTRUCTURED ALUMINUM-MATRIX COMPOSITE MATERIAL REINFORCED WITH FULLERENES C_{60}

НАНОСТРУКТУРНЫЙ АЛЮМОМАТРИЧНЫЙ КОМПОЗИЦИОННЫЙ МАТЕРИАЛ, УПРОЧНЕННЫЙ ФУЛЛЕРЕНАМИ C_{60}

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Abstract: *The effect of nanostructuring and reinforcement of aluminum alloy AMg6, with fullerenes C_{60}, produced by mechanical activation and hot extrusion, has been investigated. The specific features of obtained nanostructured aluminum-matrix composite materials have been studied by X-ray analysis, differential scanning calorimetry and electron microscopy. Structure, phase composition and its relation with mechanical properties had been studied as a function of consolidation temperature.*
KEYWORDS: NANOCOMPOSITE, FULLERENE, ALUMINIUM, MECHANICAL ACTIVATION, CARBON NANOMATERIALS

1. Introduction

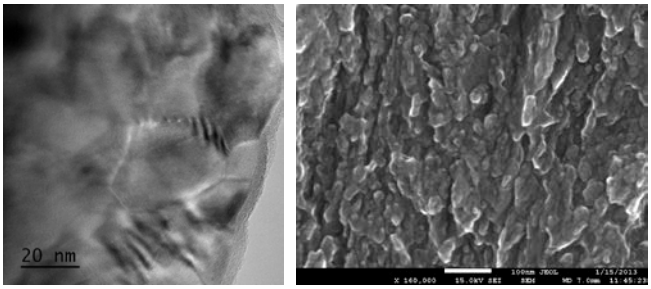
Aluminum and its alloys are the most widely used materials in modern science and industry. Unfortunately such materials produced by traditional technologies of casting, forging, liquid punching etc., mostly reached the limit of their mechanical, physical and technological properties. Nowadays, nanostructuring and modifying with high modulus nanoparticles, whiskers or fibers are one of the promising ways to improve the complex of material's properties.
Discovered in last decades such carbon nanostructures as fullerenes, carbon nanotubes, nanodiamonds, graphenes ets., are considered as one of most promising reinforcements for modern composites, due to their unique outstanding physical and mechanical properties.
In this work structure, phase composition and its relation with mechanical properties of nanostructured composite materials based on aluminum-magnesium alloy, modified with fullerenes C_{60}, are studied.

2. Experimental

Commercial aluminum-magnesium alloy AMg6 (1560, Al – 6 Mg – 0.6 Mn (wt.%)) and fullerenes C_{60} (99.9 %) were used as initial materials. Components (AMg6+0.3 wt.% C_{60}) were mechanically activated in planetary ball mill AGO-2U for 45 minutes. To prevent oxidation and other unwanted chemical reactions all manipulations with initial materials and nanostructured powders were carried out in glovebox with argon atmosphere (O_2 < 0.1 ppm, H_2O < 0.1 ppm). Nanostructured powders were consolidated via hot extrusion at temperature 300-400 °C and deformation ratio > 6.
Structure and phase composition were studied with X-Ray diffraction (XRD), transmitting (TEM) and scanning (SEM) electron microscopy. Thermal stability was studied on Perkin Elmer differential scanning calorimeter (DSC).

3. Results and discussion

According to XRD data, average aluminum crystallite size after 45 minutes of mechanical activation is 45-55 nm. It is well known that nanomaterials often exist in metastable condition. Under heating, deformation or other external stresses, nanomaterials demonstrate fast transitions to more energetically favorable state. For metallic nanomaterials this transitions usually occur in recrystallization and other structural transformations. DSC measurements show that obtained nanostructured composite materials are stable up to 350 °C. At higher temperatures irreversible transformations of structure and phase composition appear. Using XRD and Raman spectroscopy it was found, that DSC thermal effect corresponds to grain growth and aluminum carbide (Al_4C_3) formation. Thus, to prevent it extrusion temperature has been chosen at 300°C. After extrusion average crystallite size has not changed, it was confirmed with TEM (fig. 1a) and SEM (fig. 1b) investigations.



a b

***Figure 1** – TEM (a) and SEM (b) images of nanostructured aluminum-matrix composite material, reinforced with C_{60}*

It should be noted, that the structure doesn't change at elevated temperatures. Average crystallite size and phase composition in the extruded samples, exposed to heating up to 190 °C for 170 hours, remain unchanged. Treated in such a way samples demonstrate 5-10% increase of strength and plasticity in comparison with non-treated ones. This can be explained by the aging effect combined with internal stress relaxation.
Mechanical tests show that the samples of nanostructured aluminum-matrix composite materials, reinforced with fullerenes C_{60}, demonstrate significant increase of physical and mechanical properties (table 1).

***Table 1** – Physical and mechanical properties of nanostructured aluminum-matrix composite materials, reinforced with fullerene C_{60} (Along extrusion axis)*

Material	Extrusion temp. °C	Ultimate strain, MPa	Elongation, %	Micro-hardness, HV	Specific strength, km
Initial alloy	-	350	15	65	13
AMg6+C_{60}	300	800	2	220	31
AMg6+C_{60}	350	560	7	205	21
AMg6+C_{60}	400	520	20	200	20

4. Summary

Obtained nanostructured aluminum-matrix composites demonstrate high thermal stability, good machinability and significantly increased mechanical properties. Such composites could be used in varies brunches of science and industry as constructional or functional material.