



Multilayer aluminum composites prepared by rolling of pure and anodized aluminum foils



Milan T. JOVANOVIĆ, Nenad ILIĆ, Ivana CVIJOVIĆ-ALAGIĆ, Vesna MAKSIMOVIĆ, Slavica ZEC

Department of Materials Science, Institute of Nuclear Sciences “Vinča”,
University of Belgrade, P. O. Box 522, 11001 Belgrade, Serbia

Received 17 August 2016; accepted 27 January 2017

Abstract: Experimental results on processing, structural and mechanical characterization of a multilayer composite based on commercially pure aluminum foils were presented. A multilayer composite was produced by hot-rolling of anodized and non-anodized aluminum foils alternately sandwiched. In addition, the same process was applied for bonding of non-anodized foils. In both cases, obtained multilayer composites were compact and sound. In order to study composites microstructural evolution and mechanical properties, optical and scanning electron microscopy (SEM), energy dispersive spectrometry (EDS), X-ray diffraction (XRD) analysis, hardness, tensile and three-point flexural tests were performed. Microstructural characterization confirmed that the rod-like particles distributed in parallel rows in the composite aluminum matrix with anodized foils correspond to Al_2O_3 . Maximum and minimum peaks of oxygen and aluminum, respectively, suggest that after the final hot-rolling of composite with non-anodized foils, a small amount of coarser particles were formed at boundaries between foils. Hardness, strength, modulus of elasticity and flexural strength of both multilayer composites were much higher than those of pure aluminum, whereas ductility was significantly less. The composite with anodized foils exhibited the highest strength and modulus of elasticity, but lower ductility compared to composite processed from non-anodized foils. Fracture failure corresponded to the change of ductility.

Key words: aluminum foils; anodization; multilayer composite; Al_2O_3 particles; strength; fracture

1 Introduction

Metallic multilayer composites with different component metals have some special advantages in mechanical, electrical and magnetic properties [1–3], which cannot be obtained simply by the counterparts. Many processing methods for multilayer composites, such as physical vapor deposition [4], magnetic sputtering [5], jet-vapor deposition [6] and electroplating [7] have been reported in the literature. Recently, much attention has been focused on the development of multilayer composites in the form of bulk via deformation processes such as repeated folding and rolling of two or more sheets stacked securely on top of the other, the process called accumulative roll bonding (ARB) [8,9], and repeated extrusion and rolling methods [10]. ARB, regarded as a new kind of severe plastic deformation method, is an efficient way to produce metallic multilayer composites [11–13] with ultra-fine grains and different interface structures [14].

Due to their high corrosion resistance and thermal stability, aluminum and its alloys are popular material choices for structural applications in the aerospace and automotive industries [15–17]. Over the past few years, ARB has been successfully used to produce multilayer structures of different Al-based systems, including Al–Cu [18,19], Al–Zn [20–22], Al–Ni [23], Al–Mg [24,25], Al–Mn [26], Al–Ti [27,28].

The particle reinforced aluminum matrix composites are widely used in aerospace [27], military [29,30] and automotive industries [31] because of their properties such as high specific strength, improved elastic modulus, high wear resistance, high thermal conductivity and excellent corrosion resistance [16–31]. Al_2O_3 particles are the most commonly used reinforcements in aluminum matrix composites and addition of this reinforcement to aluminum alloys has been the subject of several research works [24,31]. In spite of the matrix strengthening and fine grain size which certainly lead to the improvement of mechanical properties, in composites prepared by the conventional

liquid metallurgy route, Al_2O_3 nano-particles as reinforcement often tend to agglomerate even when mechanical stirring is applied before casting [32,33]. The influence of the non-uniform distribution and poor wettability of reinforcing oxides on mechanical and electrical properties of composites is the main drawback of this process [34].

To avoid the problem of agglomeration, fine Al_2O_3 particles were uniformly dispersed between strips of Al1100 and subjected to thirteen cycles of ARB [35]. The excellent distribution of Al_2O_3 particles in the aluminum matrix and the sound bonding between Al_2O_3 particles and the matrix were reported. In another work, fine Al_2O_3 powders with $0.47 \mu\text{m}$ particle size were dispersed between commercially pure aluminum sheets to produce aluminum- Al_2O_3 composite by ARB [36]. In both works, the strength of composites was significantly increased compared to aluminum used as original raw material. The ARB process coupled with Al_2O_3 particles is applied for manufacturing high-strength and highly-uniform composites as a new technique [37–41].

Many of above mentioned processing routes are usually expensive and their manufacturing parameters are rather difficult to maintain. The objective of this work was an attempt to introduce economical and controllable parameters in processing aluminum matrix reinforced with Al_2O_3 . The process involved the formation of thin Al_2O_3 film on commercially pure aluminum foil by anodizing. The bonding between foils was achieved by hot-rolling in order to crush the Al_2O_3 film and disperse it into the aluminum matrix.

2 Experimental

2.1 Material and processing

The commercial household aluminum foils $17 \mu\text{m}$ thick (technical specification: alloy 8011; temper O; chemical composition (mass fraction, %): 98.73 Al, 0.5 Si, 0.68 Fe, 0.024 Cu, 0.01 Mn, 0.009 Ti, up to 0.15 residual; brand name: Shenzhou Aluminum) were used as a material (referred as “pure aluminum” in the following text) for multilayer composite processing. The chemical composition of the commercial household aluminum foils was specified by the supplier (Jiangsu Shenzhou Aluminum Industry Co., Ltd., China).

Strips with dimensions of $25 \text{ mm} \times 70 \text{ mm}$ were cut for anodization which was performed in a 20% water solution of H_2SO_4 , with 100 A/m^2 of current density. A round platinum grid was used as a cathode. Anodization was performed at room temperature with duration ranging from 5 to 30 min. Experiments showed that the optimal results were obtained after 20 min of anodization. Such foils together with pure aluminum foils were used for processing of multilayer composites. After

anodization, foil was rinsed with water jet, dried with hot air, whereas the upper part of the foil not immersed into the acid was cut. The total number of foils was 100, i.e., 50 anodized and 50 non-anodized foils were alternately packed (designation as A in the further text).

Another “package” of 100 non-anodized foils with the same dimensions as those anodized was also prepared (designation NA). “Packages” were wrapped with wider aluminum foil to prevent the dismount of foils during annealing and hot-rolling.

The binding of foils was performed following the procedures:

1) Foils were wrapped with a wide aluminum foil to prevent the dismount of foils during the first stage of annealing and hot-rolling. The thickness of such a “package” was approximately 3 mm;

2) All annealings were performed using the laboratory furnace in air at $500 \text{ }^\circ\text{C}$ and duration of the first annealing was 2 h, whereas the temperature of rolls was maintained at $250 \text{ }^\circ\text{C}$;

3) Hot rolling (hot rolling procedure was performed using the rolling mill supplied by Albert Mann Engineering Co. Ltd.) to the thickness of “package” up to 3 mm, when the binding started to occur;

4) Intermediate annealing at $500 \text{ }^\circ\text{C}$ for 15 min;

5) Three passes of hot-rolling up to $D_0=2.3 \text{ mm}$ thickness (starting thickness);

6) Intermediate annealing at $500 \text{ }^\circ\text{C}$ for 15 min;

7) Three passes of hot-rolling up to $D_1=1.5 \text{ mm}$ thickness (between 10% and 15% reduction per pass, and about 35% reduction in total for the first stage);

8) Final annealing at $500 \text{ }^\circ\text{C}$ for 1 h;

9) Three passes of rolling to the final thickness $D_2=0.7 \text{ mm}$ of compact material (approximately 15% per pass, and about 50% reduction in total for the second stage).

The total amount of hot deformation, i.e., $(D_0-D_2)/D_0$, was about 70%.

The same process was applied for the “package” of 100 non-anodized foils.

It was expected that during annealing the thin film formed on the surface of anodized foil would be transformed to the oxide layer. The purpose of the subsequent hot-rolling was twofold: 1) to crunch the oxide layer and to embed oxide particles into the aluminum matrix; 2) to enable the stable and strong interconnection and bonding between alternately arranged pure aluminum foils and those with oxide layers.

In both materials (A and NA), in the form of sheet approximately 4 mm wide, hot-rolling induced strong mutual bonding of foils, i.e., obtained multi layer material was compact and sound, with relatively straight and non-ragged edges, without peeling of the surface (Fig. 1).

Download English Version:

<https://daneshyari.com/en/article/8011808>

Download Persian Version:

<https://daneshyari.com/article/8011808>

[Daneshyari.com](https://daneshyari.com)