Effect of Solution and Aging Process on Microstructure and Properties of Rgo/Al Matrix Composite

Linli Hu

ABSTRACT

In present work, the effect of solution and aging process parameters on microstructure and properties of graphene reinforced aluminum matrix composites was investigated. The results indicated that as the solution temperature and time increases, the average grain size of the RGO/Al matrix composite decreases firstly and then increases, while the microhardness increases firstly and then decreases. The lattice distortion and grain refinement caused by alloy elements solution are the main strengthening mechanisms. With the increase of aging temperature and aging time, the average grain size gradually decrease to a certain stable value, while the microhardness increase firstly and then decrease. The CuAl$_2$ dispersed distribution in matrix is the main reason for the microstructure refinement and hardness increase. The optimized solution treatment parameters were 510°C×40min, and the optimized aging treatment parameters were 190°C×12h$^1$.

INTRODUCTION

Due to the low density, high strength, medium plasticity in quenching and quenching conditions, good spot welding and good machinability, Al-Cu-Mg aluminum alloy is widely used in aerospace and automotive industries [1]. In order to further increase the hardness, a method of adding a reinforcing phase, such as SiC, whisker or carbon fiber, is often employed. The graphene oxide (GO) has high strength (125 GPa), high modulus (about 1.0 TPa), large specific surface area (about 2630 m$^2$g$^{-1}$) and excellent elongation properties [2,3]. Because of a large number of hydrophilic groups presenting on the surface, such as hydroxyl groups and carboxyl

$^1$ Linli Hu, Department of Materials and Engineering, Jiangxi Vocational College of Mechanical and Electrical Technology, Nanchang, China, 330013
groups, the GO has the good wettability and is considered as an ideal reinforcement for the preparation of high performance aluminum matrix composites [4].

As a heat-treated strengthened Al-Cu-Mg aluminum alloy, the mechanical properties are significantly improved after proper solution treatment. However, few literature has reported the effect of solution and aging treatment on the microstructure and properties of graphene reinforced Al matrix composites[5]. In this paper, the effect of solution and aging process parameters on microstructure and properties of graphene reinforced Al matrix composites is analyzed, the process parameters were optimized.

EXPERIMENT

The mass percent of Cu and Mg are 4.5% and 1.5% in the Al-Cu-Mg composite powder. The 0.5 wt.% RGO/Al matrix composite was prepared by repressing and resintering process and then was machined into the size of 8mm×8mm×4mm. Before the solution and aging treatment, the specimens were polished sandpaper and cleaned by alcohol. Specimens were first solution treated with temperature range of 450-530°C and time range of 20-60min, then quenched into water. The solution treated specimens were aging treated with temperature range of 170-210°C and time range of 8-16 minutes, then cooled in air.

The phase composition of the composite was determined by X-ray diffraction (XRD, D8 Advance). The microstructure were observed by field emission scanning electron microscopy (FESEM, Nova Nano SEM450, FEI) with energy dispersive spectroscopy (EDS, Oxford INCA 250X-Max50). The microhardness of the specimen was measured on an HV-1000 Vickers hardness tester. The average grain size of the samples was measured by the cut line method.

RESULTS AND DISCUSSION

The Original Microstructure of Rgo/Al Matrix Composite

Figure 1(a) shows the XRD pattern of RGO/Al matrix composite. It can be seen that the major XRD peaks were identified as the Al matrix and the CuAl2 phase, a distinct C diffraction peak near 2θ=21° was detected, illustrating the presence of graphene in the matrix. In addition, there is no characteristic diffraction peaks of Al2O3 and Al4C3 phase. Literature reported that the brittle phase of Al4C3 is produced at higher temperatures, and the lower sintering temperature in this test can effectively inhibit the interfacial chemical reaction, making the interface structure of graphene/Al matrix generally good.

The SEM image and EDS analysis of prepared RGO/Al matrix composite are presented in Figure 1(b). Many irregular black dots are distributed in the matrix. In
addition, there are irregularly shaped structures inside the grain and at the grain boundary. The energy spectrum analysis results show that Al and C are the main components of the white region, which indicates that graphene has a certain degree of agglomeration.

**Effects of Solution Treated On Rgo/Al Composite**

Figure 2 shows the microstructures of untreated composite and solution treated composites at different temperatures and times. The matrix color of untreated composite is dark, and its grain boundary is wider (figure 2(a)). While for solution treated composites, the matrix color is bright and the grain boundaries are fine. The XRD pattern of solution treated composite shows that only the diffraction peak of Al is detected (Figure 3(a)). These indicate that alloying elements, such as Cu and Mg, are solid-dissolved into the Al matrix after solution treatment. The average grain size of the samples after solution treated at different temperatures was measured by the cut line method. The results are listed in Figure 3(b). With the solution treated temperature increase, the average grain size of RGO/Al composites decreases first and then increases. When the solution temperature is 510°C, the grain size are the smallest (about 12.1μm). The increase of solution temperature will cause more alloying elements to solidify into the matrix, which will hinder grain boundaries migration and inhibit the grain growth. In additional, the presence of graphene also hinders grain boundary migration and weakens the tendency of grain growth caused by temperature rise[6]. When the solid solution temperature rises to 530°C, the grain growth driving force caused by the excessive temperature is higher than the resistance due to the alloying elements and graphene, so that the grains are coarsened, resulting in an increase in the average grain size. The microhardness of the RGO/Al matrix composites increases first and then decreases with the increase of the solution temperature. When the solution temperature is 510°C, the microhardness reaches a maximum of 92 HV.
Figure 2(g)-(i) show the microstructures of RGO/Al composite solution treated at 510°C for 20-40min. As the holding time increases, the grain boundary become smaller. Increasing the solution time will make the distribution of the alloying more uniform in matrix. However, when the holding time is too long, the grains will be coarsened, and the strength of the material will be lowered. It can be seen that the grain are the fine when the holding time is 40 min (figure 2(h)). When the holding time is 60min, few grains abnormally grow, as shown by the dotted line in Figure 2(i). The average grain size and hardness analysis results indicates that the optimal solution time is 40min.
Effects of aging treated on RGO/Al composite

Figure 4 presents the microstructures of aging treated RGO/Al composite. Seen from figure 4(a)-(e), the black precipitated particle was detected after aging treated. As aging temperature increase, the precipitated particle increased. At 190°C, the precipitated particles are dispersive distributed in the matrix. While the aging temperature is higher than 200 °C, the precipitated particles agglomerate. The XRD pattern shows that the precipitated particles is CuAl$_2$ (Figure 4(a)). With the increase of aging temperature, the average grain size of RGO/Al composites decrease firstly and then tends to be stable. At an aging temperature of 190°C, the sample grain size is the smallest, about 9.7μm. Figure 5(b) shows the microhardness values of the samples treated at 170-210°C. It can be seen from the figure that with the increase of aging temperature, the microhardness of RGO/Al matrix composites first increases and then decreases. When the aging temperature is 190°C, the hardness reaches a maximum value of 100.8HV. The microstructure and XRD analysis indicated that the CuAl$_2$ phase precipitates during the aging process, and the amount increases with the increase of the aging temperature. The dispersion distribution of CuAl$_2$ phase will pin dislocation and grain boundary migration, and then suppressing grain growth[7]. While aging temperature is too high, the CuAl$_2$ phase aggregation weak the effect of dispersion strengthening and fine grain strengthening, so that the microhardness of the sample decreases.

Figure 5(c) presents the average grain size and hardness of RGO/Al composites after aging treated for 8-16h. The results indicates that the average grain size is minimum and the microhardness reaches maximum when the aging time is 12h.
Figure 4. Microstructures of after aging treated: (a) 170°C × 12h, (b) 180°C × 12h, (c) 190°C × 12h,
(d) 200°C × 12h, (e) 190°C × 8h, (f) 190°C × 16h.

Figure 5. (a) XRD pattern of aging treated composite, (b) average grain size and hardness after aging
treated for 12h at different temperature, (c) average grain size and hardness after solution treated at
190°C for different time.

CONCLUSIONS

1) As the solution temperature and time increases, the average grain size of the RGO/Al matrix composite decreases firstly and then increases, while the microhardness increases firstly and then decreases. The alloying elements solution into the Al matrix hinders the grain boundary migration, which is the main reason for the microstructure refinement. The lattice distortion and fine grain strengthening caused by alloy elements solution are the main mechanisms of strengthening. The optimum solution treatment parameters were obtained: 510°C × 40min.

2) With the increase of aging temperature and aging time, the average grain size of RGO/Al matrix composites gradually decrease to a certain stable value, while the microhardness increase firstly and then decrease. The CuAl₂ dispersed distribution in matrix is the main reason for the microstructure refinement and hardness increase. In the later stage of aging, CuAl₂ aggregation reduce the performance of the RGO/Al
matrix composite. The optimum aging treatment parameters were obtained: 190°C×12h.

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