FABRICATION OF GRAPHENE REINFORCED AL MATRIX COMPOSITES USING FLAKY POWDER METALLURGY METHOD

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Graphene has been paid extensive attention since it was isolated from bulk graphite and its extraordinary characterization had been disclosed. It has extremely high mechanical and physical properties, i.e., the single-layer graphene exhibited Young's modulus of 1.0 TPa and unique thermal conductivity of about 5000 W·$(mK)^{-1}$. Similar to carbon nanotubes (CNTs), graphene has been tried to be reinforcement for the next generation metal matrix composites. In the past few years a lot of studies were devoted to fabrication of graphene reinforced Al, Mg, Cu matrix composites. Among these attempts, graphene enhanced strength and thermal conductivity simultaneously, especially it exhibited very high strengthening efficiency for mechanical properties.

Unfortunately, a great challenge in mass production of graphene reinforced metal matrix composites restricted their wide industrial application. Graphene has poor wettability with most of metallic materials. As a result, clustering of graphene is hard to avoided using traditional casting. Meanwhile, graphene is easier to react with metals such as Al, which consumes graphene and deteriorates mechanical properties largely. Based on that, powder metallurgy has become the most common method for fabrication of graphene reinforced metal matrix composites. Due to huge discrepancy of specific surface between metal and graphene, flaky powder metallurgy was developed in order to avoid graphene clustering among metal powders. However, the increased surface produced by flaky powder metallurgy gave rise to difficulty in condensation of powders due to increment of interior friction force between powders. Further, oxide increased especially for Al powders, leading to lower ductility of the composites.

In this study, we fabricated aluminum matrix composites reinforced with graphene oxide (GO/Al) using flaky powder metallurgy. Al-4.0wt.% Cu powders were firstly milled into flake shape using high energy milling technique. The flaky Al-Cu powders were mixed with 0.5wt.% GO in aqueous solution, producing the composites powders with uniformly distributed GO on surface of the Al powders, as shown by Fig. 1. Then Mg powders were added into the composites powders. The mixed powders were vacuum hot pressed into billets. The billets were hot forged with forge ratio of 4:1. Microstructure examination and tensile test were conducted using the forging billets. Compared to the GO/Al composite condensed directly, the composite containing Mg exhibited enhanced mechanical properties. The GO/Al composites containing Mg exhibited enhanced strength and almost same ductility compared to the unreinforced Al matrix. As shown by table 1, it is seen that increments of 17% in ultimate tensile strength and 10% in yield strength were achieved, respectively. Elongation of the composite was 8.6% which was almost same with that of the unreinforced Al matrix. $MgAl_2O_4$ phase formed because Mg reacted with Al_2O_3 on surface of Al powders, which was beneficial to achieve good bonding between Al powders. The optimized flaky powder metallurgy was demonstrated to be a potential method for fabrication of high mechanical properties GO/Al composites.

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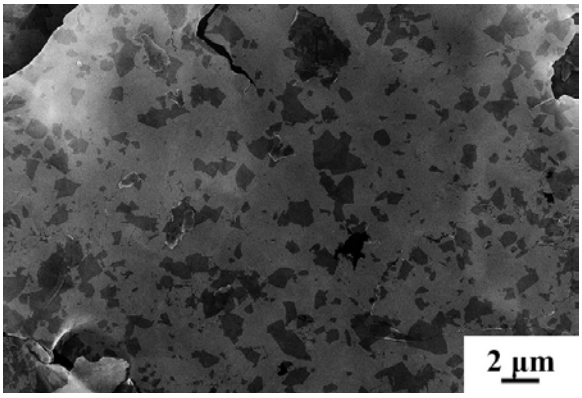

Figure 1: GO/Al composite powders, black GO uniformly dispersed on surface of Al powders.

Table 1 Tensile properties of GO/Al composite and unreinforced alloy

	YS (MPa)	**UTS (MPa)**	**EL. (%)**
Matrix	**305±6**	**456±8**	**8.8±1.8**
0.5 wt.% GO	**355±4**	**502±10**	**8.6±1.2**

REFERENCES

[1] K. S. Novoselov, A. K. Geim, S. V. Morozov, D. Jiang, Y. Zhang, S. V. Dubonos, I. V. Grigorieva, A. A. Firsov, Electric field effect in atomically thin carbon films, *Science*, 306, 2004, pp. 666-669 (DOI: 10.1126/science.1102896)

[2] C. Lee, X. Wei, J.W. Kysar, J. Hone, Measurement of the elastic properties and intrinsic strength of monolayer graphene, *Science*, 321, 2008, pp. 385-388 (DOI: 10.1126/science.1157996)

[3] A.A. Balandin, S. Ghosh, W. Bao, I. Calizo, D. Teweldebrhan, F. Miao, C.N. Lau, Superior thermal conductivity of single-layer graphene, *Nano Letters*, 8, 2008, pp. 902-907 (DOI: 10.1021/nl0731872)