Effect of interfacial reaction on Young's modulus in CNT/Al nanocomposite: A quantitative analysis

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Abstract:

1.5 wt.% CNT/Al nanocomposite with limited, moderate and severe interfacial reaction were prepared by flake PM and annealing to study the effect of interfacial reaction on Young's modulus. Both qualitative and quantitative characterizations of CNT/Al interfacial reaction were conducted through TEM observation and electrochemical dissolution. The results showed that the strong reinforcing effect of reaction-formed Al_4C_3 and the significant volume expansion effect during CNTs-Al_4C_3 transformation resulted in Young's modulus increase with greater CNT/Al interfacial reaction degree. The significant role of raw CNTs quality in "Young's modulus-interfacial reaction degree" relationship was discussed. Both raw CNT quality and CNT/Al interfacial reaction need to be well controlled and optimized for fabricating CNT/Al nanocomposite with higher Young's modulus.

Key words: carbon nanotube; aluminum matrix composite; interfacial reaction; Young's modulus; quantitative analysis

1 Introduction

Carbon nanotubes (CNTs) have been widely used as reinforcements in metal matrix composites owing to its exceptionally high modulus and strength [1]. CNTs reinforced aluminum (CNT/Al) nanocomposites have attracted lots of attentions due to the potential application to lightweight structures in aerospace and automotive industries. Generally speaking, lightweight design calls for high stiffness to retain functionality by structural rigidity, which put forward higher demand in material's Young's modulus rather than yield strength [2-4]. To this point, CNT/Al nanocomposites with enhanced Young's modulus are more attractive than high strength Al alloys with a relatively low Young's modulus of 70~72 GPa.

But unfortunately, Young's modulus of CNT/Al nanocomposite was not studied as extensively as yield/tensile strength. Only limited and scattered Young's modulus values were reported in previous studies, as demonstrated in Figure.1 [5-24]. Here, taking an example of the most frequently studied 1.2 vol% CNT/Al nanocomposite, the measured Young's modulus varied from 63.6 to 102.2 GPa in different reports [8, 15, 17, 19-24]. The lowest value was even lower than Al matrix (70.0 GPa), while the highest one (102.2 GPa) was far beyond the upper bound of the rule of mixture (predicted as 79.7 GPa with the Young's modulus of CNTs assumed as 800 GPa, which is the highest measured value in Multi-Walled CNTs [25]). Such large data scattering should be attributed to differences between multiple factors, including the quality and dispersion