CNT reinforced Aluminum Composite

S. Moon, D. Lee, S. Jung

Applied Carbon Nano Technology Co., Ltd.
Room 104, Pohang Techno Park, Repubric of KOREA, behappy@acntech.co.kr

ABSTRACT

The multi-walled carbon nanotubes (MWCNTs) reinforced alumium composite is developed by Applied Carbon nano technology (ACN) as a commercial scale. In this paper, the advantage of ACN's fabrication process for MWCNTs reinforced Aluminum composite and the properties of MWCNTs reinforced Aluminum composite are discussed. ACN process is composed of two steps, preparing MWCNTs dispersed Aluminum powder and consolidation. Using high energy milling, the MWCNTs are inserted and dispersed in each Al powder. MWCNTs dispersed Al powder is consolidated by hot powder forging or powder extrusion. The composite shows specific gravity of aluminum and steel grade strength. In case of using A2024 alloy as a base material, at 5 wt% of MWCNT dispersion, over 700 MPa of tensile strength could be achieved. By adding MWCNTs in aluminum alloy, Thermal expansion behavior of MWCNTs reinforced Aluminum composite is unique that there are no thermal expansion to 100℃. MWCNTs addition increase the mechanical properties of metal matrix, for instance, the wear resistance is also increased by adding MWCNTs in A2024 alloy. It could be applicable to a industry of aviation, transportation, leisure etc, as a high strength light weight material.

Keywords: carbon nano tubes, composite, aluminum, light weight, high strength

1 INTRODUCTION

CNT is known as a pioneer material for new century because of its excellent physico-chemical properties. Despite the good properties of CNT itself, CNT's application is restricted by its size problem. We have to contemplate how to apply CNT to the meter scale world. CNT is a very attractive reinforcing agent for metal matrix composites, mainly focusing on their contribution to the enhancement of mechanical performance of the final products. Therefore, many researchers have investigated the processing of MWCNT reinforced aluminum metal composite(AMCs) via various processing methods. However, fabrication of CNT-reinforced AMCs is difficult because of the i) dispersion of CNTs in the Al matrix while poor wettability between CNTs and Al ii) developing suitable processing methods, and iii) controlling the Al-CNT interface. There were no reports of successful fabrication of the AMCs through solid process. Therefore, to overcome the drawbacks and accomplish successful fabrication of the CNT reiforced AMC, powder metallurgy can be an effectual method by comparison with the other methods. Actually, many reports about homogenous dispersion of CNTs in Al matrix with much enhanced mechanical properties using powder metallurgical methode. But most report shows lab scale results of fabrication and properties of CNT reinforced AMCs.

ACN have developed the new process for CNT reinforced Aluminum metal composite as a commercial scale.

In this paper, the ACN process for CNT reinforced Aluminum composite and the properties of CNT reinforced Aluminum composite is discussed.

2 PROCESS

ACN process is based on high energy ball-milling process for the dispersion of MWCNTs inside metal powders. Figure 1 shows the mechanism of MWCNT dispersion inside aluminum powders on ACN process schematically. In the initial stage, MWCNT is de-bundled by collision among balls. After then, aluminum powder added to milling jar is coated by de-bundled MWCNTs. The MWCNT coated ductile aluminum powder gets flattened by the ball-powder-ball collisions, because of elastic and plastic deformation. After further milling, the flattened aluminum powders are agglomerated together before cold welding. By cold welding, MWCNT embeded aluminum powder have been achieved.

Figure 2 is the SEM image of MWCNT is embeded in aluminum powder. Homogeneously dispersed, not bundled MWCNT could be seen in aluminum matrix.

For using MWCNT reinforced AMCs as a industrial materials, various consolidation routes have been suggested such as sintering, hot pressing, hot extrusion, hot rolling, spark plasma sintering, and spark plasma extrusion etc.

To produce the bulk cylinder and bar from the MWCNTs embeded aluminum powders, hot powder forging and powder extrusion process is adopted by ACN as a consolidation process . In hot powder forging process and powder extrusion process, cold pressing step is added reinforced for making pre-form of MWCNT embeded

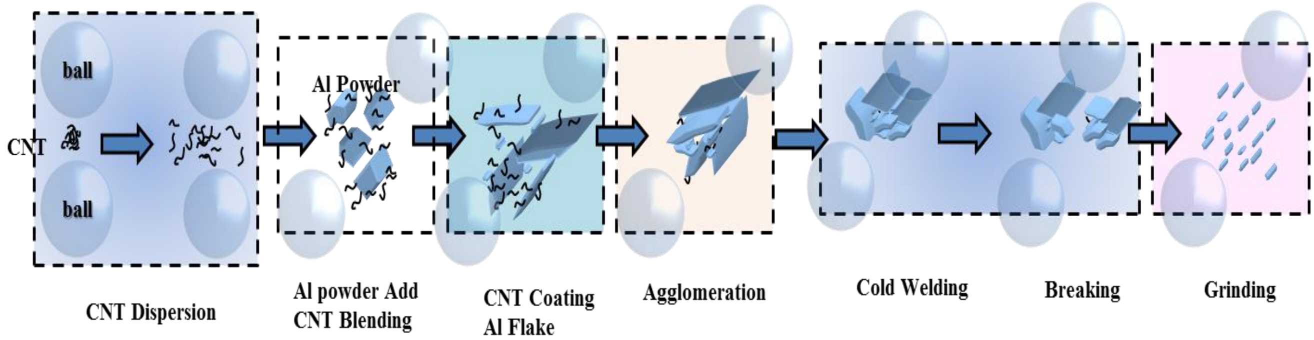

Figure 1 The mechanism of CNT dispersion inside Al powder

aluminum powder before hot forging and extrusion. By adding cold press step, the density and physical properties of MWCNT reinforced AMC could be enhanced. ACN can produce 100 mm diameter cylinder with hot powder forging process and 25 mm diameter bar with powder extrusion process for commercial use.

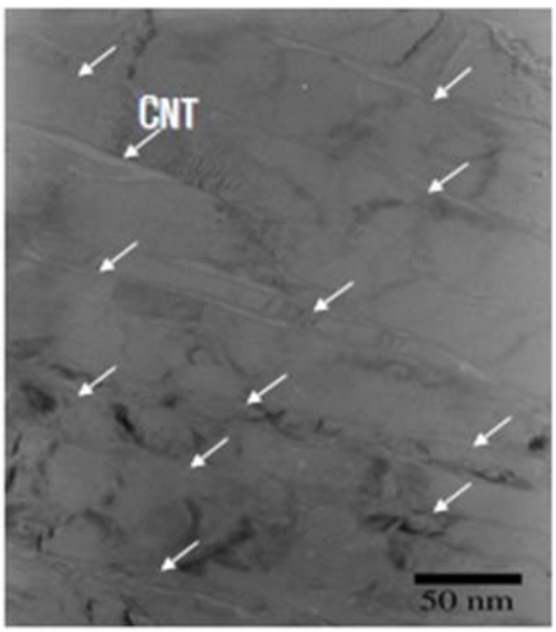

Figure 2 SEM Image of CNTs dispersed in Aluminum

reinforced AMC is 1.5 times higher than that of common Al2024 alloy.

In case of cylinder processed by hot powder forging methode, We can achieve 700 MPa in tensile strength, 2 % in elongation. The MWCNT reinforced AMC made by ACN process could be called the steel strength aluminum weight composite materials.

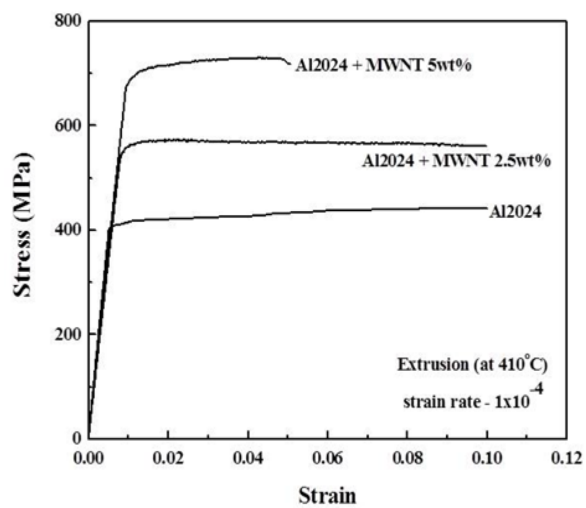

Figure 3 Tensile strength of CNT reinforced AMCs in case of A2024 alloy

3 PROPERTIES OF COMPOSITE

MWCNT reinforced AMC shows unique physical/ electrical properties. Figure 3 shows the effect of MWCNT contents on the tensile strength of MWCNT reinforced A2024 aluminum composite processed by powder extrusion methode. By MWCNT addition, the tensile strength of the composite increase to over 700 MPa at 5 vol% , but the elongation decrease to 5 %. Tensile strength of MWCNT

Figure 4 is the result of wear loss test of MWCNT reinforced AMC(Al2024), Al2024 alloy, Al7075 alloy and Ti-6Al-4V. MWCNT reinforced AMCs revealed to be small wear loss such ,as about 70% were loss of Al2024 alloy, 50% wear loss of Ti-6Al-4V alloy at 3 vol. % CNT addition.

Considering the CNT's lubrication properties, it may be resonable results. But to disclose the mechanism of wear loss, more scientific research is needed.

CNT reinforced AMCs could be used not only structural materials, but also functional materials.

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The thermal expansion properties of MWCNT reinforced AMC were checked and the results are shown at Figure 5.

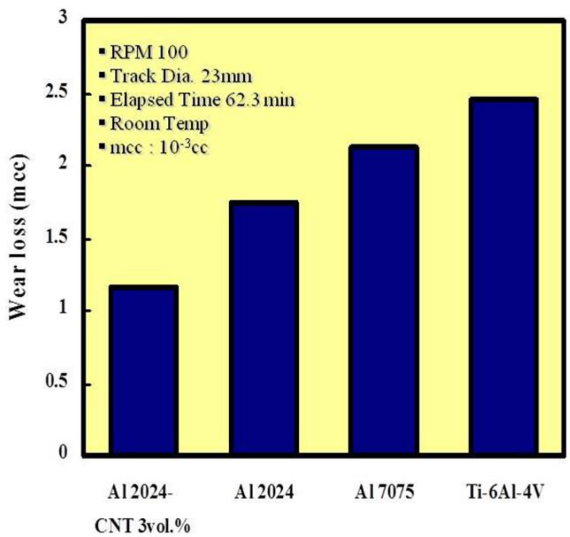

Figure 4 Results of Wear loss

MWCNT reinforced AMC shows different behavior with common aluminum in every kind of aluminum alloys used as a matrix in the experiments. A pure aluminum is expanded with temperature as a linear relationship from 0 ℃.

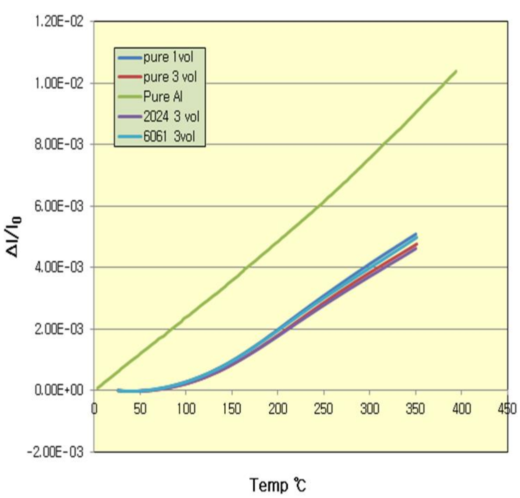

Figure 5 Thermal expansion behavior of CNT reinforced AMCs

In case of MWCNT reinforced AMCs, there are no thermal expansion to the temperature of around 100℃ for all kind of aluminum alloy matrix. Over 100℃, the inclination is slightly gentle compare with that of pure aluminum.

When CNT reinforced AMC is heated, aluminum matrix would be expanded by it's own thermal expansion propertiy by increasing temperature. Also, CNTs, a tube shape elastic material with void inside, absorb the thermal expansion strain to it's shrink limits. After shrink limit, aluminum matrix is expaned with temperature. But this is our hyperthetical opinion, more in-depth study is need for revealing the mechanism of the unique thermal expansion behavior..

As mentioned above, CNT reinforced AMC has a good mechanical properties enough to use a structural materials.

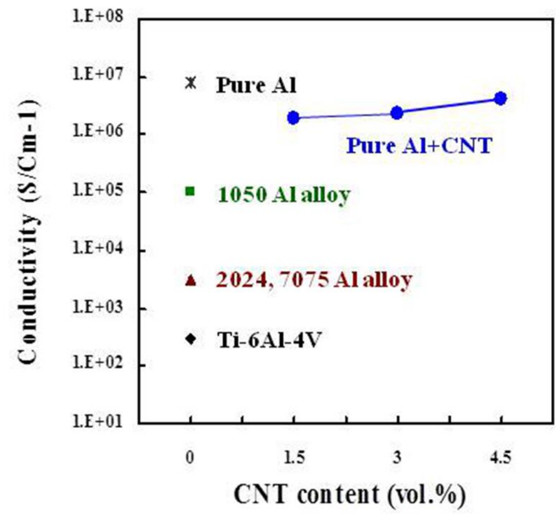

Figure 6 Electrical Conductivity of CNT reinforced AMC

CNT is known as a excellent electrical conductor. So, CNT has been expected as a good agent of increasing electrical conductivity of metal metrix. It is hard to find the research report on enhancement effect of electrical conductivity by CNT addition. Many researcher said that it is caused by contact problem among CNTs in matrix.

CNT itself is a excellent electrical conductor. But showing good electrical conductivity in composite, CNT must contact each other. If not, total electrical conductivity of composite is dominated by matrix.

Figure 6 shows the effect of MWCNT on electrical conductivity. A metal could get a strengthening effect on mechanical property by alloying elements. But, electrical conductivity of alloy shows conspicuous decrease compare with that of pure metal (pure Al, 1050, 2024, 7075 alloy).

MWCNT reinforced AMC shows good mechanical properties and electrical conductivity.

4 CONCLUSION

The multi-walled carbon nanotubes (MWCNTs) reinforced alumium composite is developed by Applied Carbon nano technology (ACN) as a commercial scale.

MWCNT reinforced AMC made by ACN process shows good mechanical properties, as follows,

- Over 700MPa of tensile strength
- No thermal expansion to 100℃
- good wear resistance
- better electrical conductivity compare to high strength Al alloy

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