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Development and Characterisation of Aluminium Alloy Composites Reinforced With Multi Walled Carbon Nanotube by Powder Metallurgy Route

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Abstract: *Light weight materials coupled to the need for cost-effective processing have combined to create a significant opportunity for aluminium powder metallurgy as its increasing interest. Aluminium alloy (AA 2219) metal matrix composite reinforced with multi walled carbon nanotube (MWCNT) produced by powder metallurgy (P/M) technique was analysed and CNTs dispersion were traced. The micro hardness and the electrical resistivity of the composites were measured from room temperature. The reasons for decrease in electrical resistivity at room temperature with increasing volume fraction of the carbon nanotubes were investigated These composites are being projected for use in structural applications for their high specific strength as well as functional materials for their exciting thermal and electrical characteristics. The good dispersion of CNTs in the matrix as well as the processing problems and processing time are the major challenges inhibiting the development of these composites.*
Keywords*: CNT, MMC, Powder metallurgy.*

I. Introduction

Majority of the research has been carried out on reinforcement of polymers and ceramic matrix by CNT. Research in MMC with CNT is less even most structural materials used in today’s world are metals. Reason for lag in studies on CNT-MMC was the difficulty in processing, making uniform distribution, giving structural and chemical stability for CNT and forming good interfacial bonding. The greatest attention is need to focuses on the influence of mixing technique and processing [3]. Introducing CNTs into molten metal was a difficult task, so most of the works used powder metallurgical (PM) even the processing cycle is longer and high cost. The high processing temperature in conventional casting leads the formation of unstable or undesirable phases. Facilitate the development of reactive and refractory materials with exceptional mechanical properties and complicated shape can be process by using this PM route **[**31**].** The inadequacy of metals and alloys in providing both strength and stiffness to a structure has led to the development of metal matrix composites (MMCs), where upon the strength and ductility is provided by the metal matrix and the strength and/or stiffness is provided by the reinforcement that is either a ceramic or high stiffness metal based particulate or fibre [2]. Investigations showed that CNTs were the strongest reinforcement known to mankind that possess exceptional properties. Hence, a systematic study of the efforts towards development of CNT-reinforced MMCs was found necessary for the above reasons. For perfectly structured CNTs have sp^2 carbon carbon chemical bonding and this is stronger than the sp^3 bonds found in diamond.

Both low weight and low cost materials have high demand in automotive industry in order to reduce fuel emissions and improve fuel economy, hence aluminium metal matrix have a wide range of application **[**31**].** Increased interest on Al for its excellent strength, low density and corrosion resistance properties. Recently, researchers have gradually paid much attention to CNTs reinforced metal matrix composites. Among these metals, aluminium has been considered as an ideal metal matrix for lightweight high-strength composites which are widely applied in the automotive and aerospace industries.

II. Experimental Details

The Aluminium alloy AA2219 powder with apparent density 1.3 g/Cm^3 from AMPAL INC U.S. has been used to prepare the Nano composite and MWCNT sourced from Redex [India] and has been used to prepare the nano composite. The material obtained contains mainly pure carbon nanotubes. Scanning electron microscopy revealed that the tubules have an average outer diameter ~20 nm, inner diameter ~5 nm, length ranging from 50 µm, average number of walls in the range between 5-15, Specific Surface Area of 350 m^2/g. Fig. 1 shows a typical SEM micrograph of the used carbon nanotube material

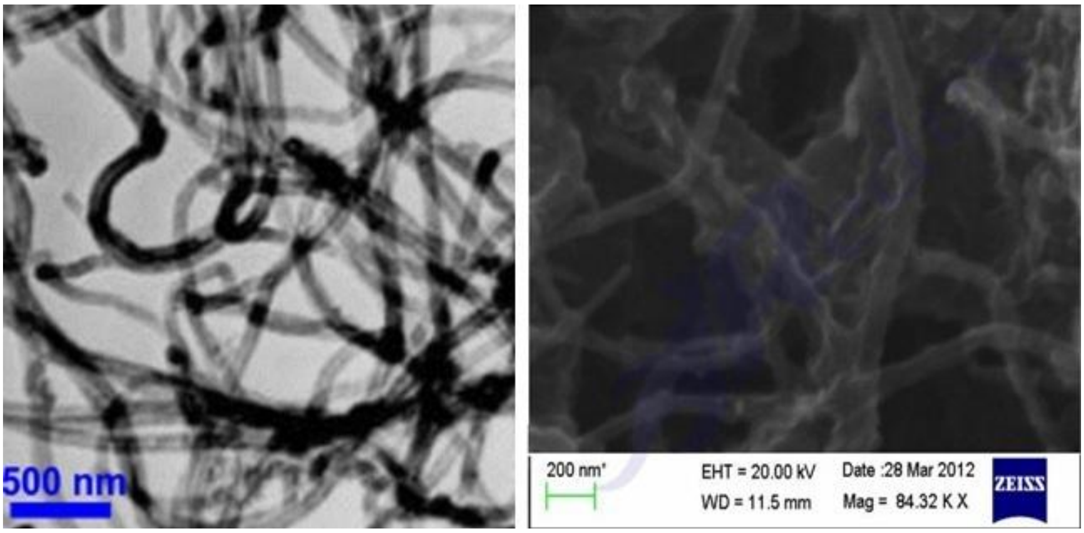

Fig: 1 SEM images of MWCNT

Aluminum powder specifications had showed in the table 1. 0.75 wt. % multi walled carbon nanotubes mixed with aluminum powder were homogeneously mixed by ball milling using Stainless steel balls for 4 hours at a speed of 200 rpm and Methanol as Process Controlling Agent respectively. The mixtures were undergone Compaction at a load of 250 MPa. Using Nitrogen atmosphere and at a temperature of 450^0C sintering has done for 90 minutes. In order to find the electrical resistivity at room was measured in the Department of Physics, VIT University.

Composition	**EXPECTED (%)**	**ACTUAL**
Aluminium	Remaining	
Copper	5.8 – 6.8	5.8
Silicon	0.2 max	0.07
Manganese	0.20 – 0.40	0.28
Iron	0.30 max	0.08
Zinc	0.10 max	0.01
Titanium	0.02 – 0.10	0.07
Zirconium	0.10 – 0.25	0.18
Vanadium	0.05 – 0.15	0.1

Table: 1 AA2219 composition

III. Results And Discussion

3.1. Microstructure and density of the composites

The major factor influencing the Al-CNT MMC for a high mechanical properties are the processing technique. It will also dent the homogeneous distribution of CNTs in the metal matrix, agglomeration of CNTs in the matrix, the interfacial reaction between CNT and metals at a temperature above critical level and bond formation in MMC. The content of nanotubes in the matrix is proportional to the micro-hardness. The increased hardness is due to the changes occurring in grain size. The low density is usually attributed to the presence of open pores in the bulk material. In the present work, the density increases with the increase of the CNT. For AA2219 the density was about 2.56 g/cm^3, and for AA2219+0.75 Wt% MWCNT it was about 2.62 g/cm^3. Micro hardness of Al alloy is improved by 22% with 0.75 wt% of MWCNT compared to unreinforced Al.

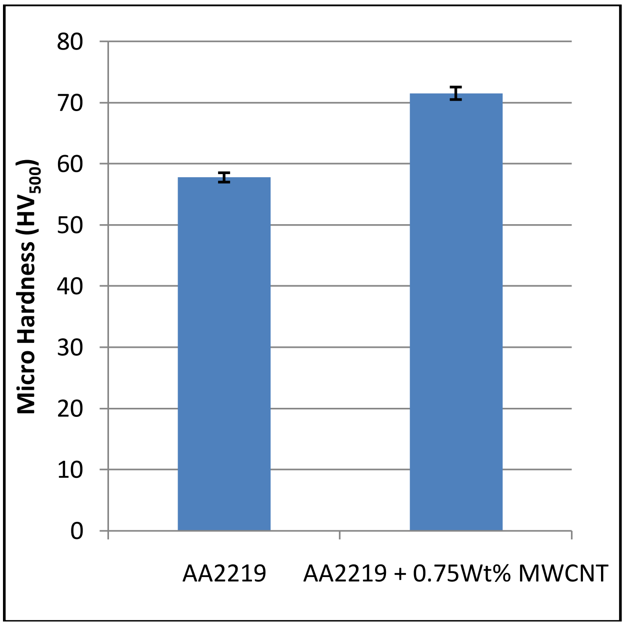

Fig 2: - micro hardness values for AA2219 and with 0.75wt% MWCNT addition.

3.2. Electrical properties of the composites at room temperature

Reinforcing CNTs to Al metal matrix with good distribution and bonding can enhance electrical properties. The results of the electrical resistivity for Al 2219 and Al2219+ 0.75wt % multi walled carbon nanotubes at room temperature are shown in fig 3 & 4. Electrictrial conductivity is decreased with the addition of carbon nanotubes content, due to the porosity or any other processing defects including non uniform dispersion. Theoretical calculations predicted that the carbon nanotubes have the electrical conductivity of a metal or a semiconductor. Experimental measurements of the electrical resistance showed an electrical resistance for AA2219 is in the order of 8.0418 Ω-cm and that's for AA2219+ 0.75WT% MWCT was 10.19368 Ω-cm.

In general, at the same sintering temperature the conductivity increases with the increase of the CNT content in the nano composites as more CNTs are inside the composite there is a more chance for CNTs to form network which will significantly improve the electrical conductivity. Increase in the electrical conductivity can be achieved by bulk density; good element distribution and microstructure; increased sintering temperature which will result in reducing the spacing between nanotubes and will enhance the tunnelling effect of electron transport between nanotubes or bundles; by increases CNTs fraction which gives an average distance between CNTs become small and give a better physical contact will leads to an easy flow of electrons tunneling through the CNT bundles; last one is by increasing CNT with less damage at open pores are inter connected and enhance the electrical conductivity even with low relative density.

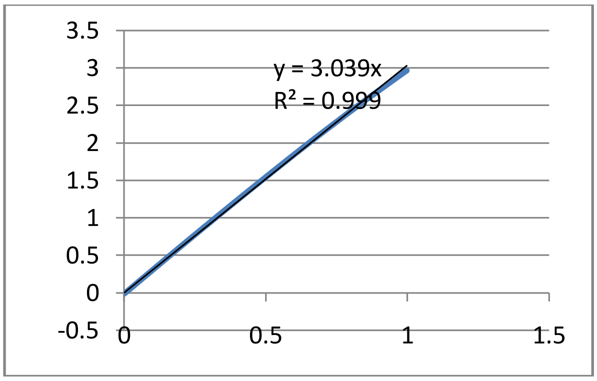

Fig 4: - Electrical conductivity Sample: AA2219+0.75 Wt % MWCNT

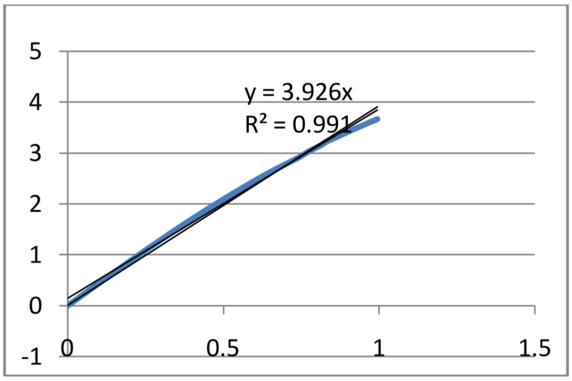

Fig 3:- Electrical conductivity Sample: AA2219

In the present work it is noted that the electrical conductivity of AA2219 is getting decrease from 0.124 S/cm to 0.0981 S/cm by adding 0.75 wt% MWCNT. Decrease in the electrical conductivity due to agglomeration of CNT form grain boundary will increase scattering of electron and causes for the decrease in conductivity. Formation of new inter metallic phase of low conductivity; high porosity and microstructure change of the matrix due to CNT incorporation will also cause for the decrease in conductivity. In general the electrical resistivity decreased linearly as the temperature decreased. CNTs are favourable to the applications where energy saving becomes increasingly important.

III. Summary

The Al–carbon nanotube composites were successfully fabricated by the respective powders. The electrical resistivity at room temperature seems to gets decrease slightly and the micro hardness gets increase with increasing volume fraction of the carbon nanotubes in AA2219. Further work is necessary to explain the mechanism of this transition. Al-CNT MM composites have a great potential in aviation, spaceflight, automobile industries, load bearing applications and electronic packaging due to their high specific strength, stiffness, high thermal conductivity and low coefficient of thermal expansion. In fabrication of micro electro mechanical system (MEMS), CNT reinforced aluminium composites have a successful usage. Al-CNT metal matrix composites need to explore new application in MEMS and light weight metal industries.

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