Behavior of Nano Composite Coatings with Carbon Nanotubes

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ABSTRACT
The surfaces of metals and alloys are usually modified by formation of thin layer of coatings for application in various aggressive conditions. The coatings are formed by various methods such as physical vapor deposition (PVD), chemical vapor deposition (CVD), cold spray technique, plasma spray and high velocity oxy-fuel techniques. Recently the trend of application of nanocomposite coatings with the addition of carbon nanotubes is increasing, owing to their remarkable improvement in the properties. This is an emerging field for researchers working in the area of surface modification. This study has presented the reported work related to carbon nanotubes and nanocomposite coatings.

Keywords
Coating, CNT, Nanocomposite, CVD, PVD

1. INTRODUCTION
Material scientists working worldwide are now focusing their research towards development and study of nanostructured materials, nanocoatings and nanocomposite coatings with the inclusion of carbon nanotubes (CNTs) [1]. This rise in trend of working at nanoscale is mainly because of achievement of tailor made properties as compared to traditional materials. Since not much work is reported in this area, thus there is still need of fabricating new materials and coatings at nanoscale and study the effect on their properties for different applications. In this study a brief review of carbon nanotubes and their application in fabricating nanocomposite coatings is presented.

2. CARBON NANOTUBES
Carbon nanotubes are formed by rolling single layer of carbon atoms and are the third allotropic form of the carbon alongwith graphite and diamond [2-4]. These were discovered as minor byproduct during fullerene synthesis in 1991 [2,3], and its minimum diameter is limited by its induced curvature to approximately 0.4 nm [4]. Carbon nanotubes (CNTs) are made of carbon atoms which have covalent SP2 bonds, which results in high strength and stiffness. CNTs can behave as metal or semiconductor, which depends upon the geometry of arrangement of carbon atoms [3]. The type and characteristics of carbon nanotubes are decided by the dimensions of the sheet of carbon atoms (graphene sheet) and also on the method of rolling of the sheets. The properties of nanotubes are related to the length, diameter and orientation of carbon atoms in the rolled graphene sheets. Difference forms of CNTs are illustrated in Fig. 1 [5]. The number of concentric rolling layers of graphene sheets have distinguished the CNTs such as singlewall (SWCNT), doublewall (DWCNT), and multiwall (MWCNT) [6]. Depending upon the geometry of carbon atoms in CNTs formed by different methods CNTs tensile strength upto 120 GPa (56 times more than steel) and upto 1Tpa of Young's modulus (19 times more than steel) with one-fifth the density in comparison to high strength steels [3-10]. As compared to conventional carbon fibres, the weight of CNTs is less than half [3]. Also thermal conductivity of around five times of copper is reported for CNTs with high electrical conductivity and capacity of carrying current [10]. Therefore the interest of the researchers in CNTs is tremendously increasing due to their exceptional electrical, thermal and mechanical properties. Another remarkable property of CNT is that without any bond breakage it can be bent into an acute angle, as reported by Yakobson in Fig. 2 [11]. This further helps to recover its original tubular form [11]. It is also reported that CNTs are usually self assemble themselves into arrays by vander waals forces, which are known as bundles or ropes [4].

3. NANOCOMPOSITE COATINGS
12 Keshri et al. [12] has reported the effect of energy sources on CNTs for various processes HVOF, cold spray, plasma spray and plasma spray of liquid precursor. It is reported in this study that except liquid precursor plasma spray (PSLP) all other spray methods successfully retained CNTs in composite coatings. In PSPL vaporization of CNTs are reported, however in other processes thermal shield was provided by micron sized composite powder particles.

Cold spray process was successful in depositing ternary composite coatings of Cu-CNT-SiC, as reported by Pialago et al. [13]. The ternary powder was prepared by mechanical alloying (MA). It this study the 0.3 mm Cu substrate was cold sprayed by single-layer Cu,Cu–5CNT, Cu–5CNT–10SiC, andCu– 5CNT–20SiC (vol%). In this process multiwalled CNTs used with assumed density of 2.1g/cc, diameter of 5–20nm, length of 10 μm and aspect ratio > 500. It is reported that the deposition efficiency cold spraying increased when the SiC content in the composite coating was increased from 10 to20 vol%. Also the dispersion of SiC in the composite powder particles, as well as within the coatings was not homogeneous and the surface pores of the SiC containing coating were finer in comparison with other coatings.

Balani et al. [14] has reported the 1.5 times improved wear resistance of HA – 4 wt.% CNT plasma sprayed coating in comparison to HA coating. This enhancement in wear resistance properties is mainly because of connection of splats by CNTs which further restricted their movement in the splats.

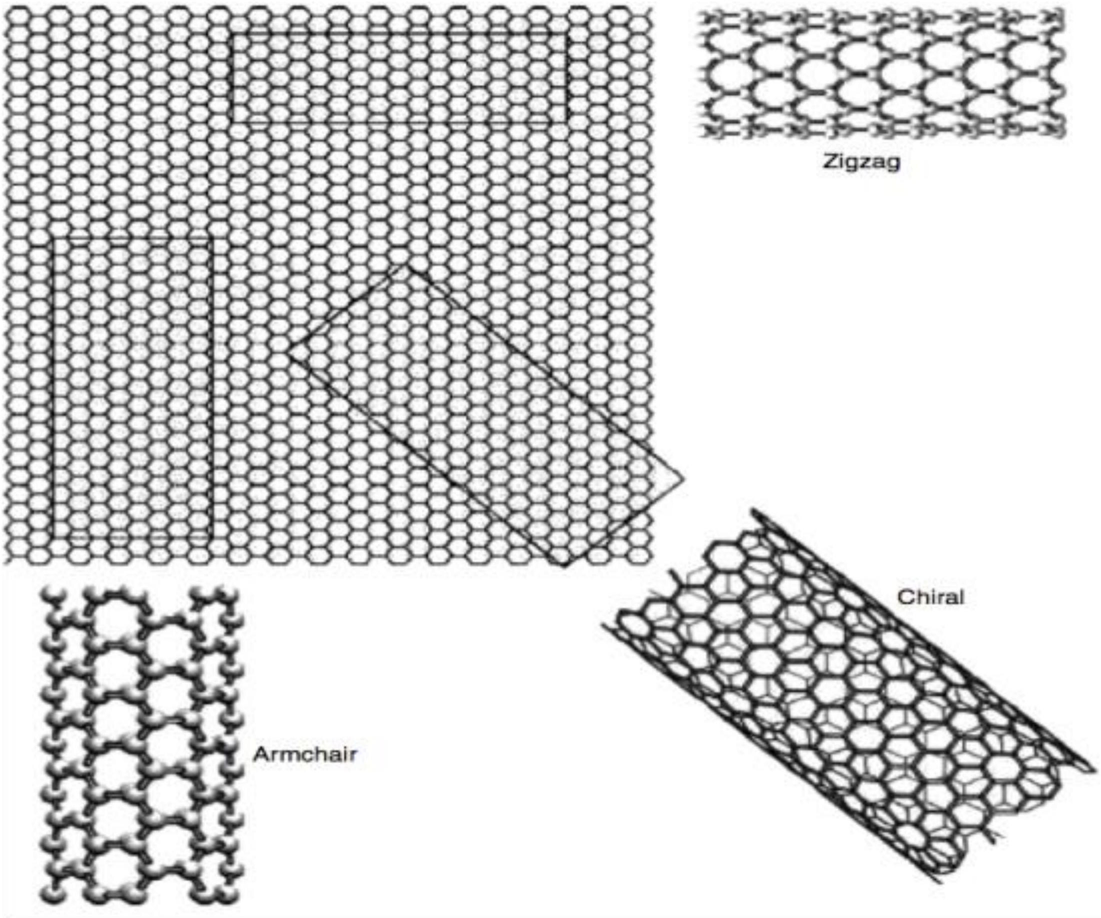

Fig 1: Relation between nanotubes and graphene, as adapted from [5]

Fig 2: Transverse deformation of a carbon nanotube (Computer simulation), as adapted from [11].

Balani and Agarwal [15] has examined the nanocomposite coatings prepared by blending of Al2O3 with 4 wt. % and 8 wt. % CNTs on AISI 1021 steel substrates. The plasma sprayed composite coating has shown improvement in fracture toughness. The coating microstructure is formed of fully and partially melted and solid state zone, as CNTs has an effect on the heat transfer characteristics due to their high thermal conductivity.

Bakshi et al. [16] have dispersed the Multiwalled carbon nanotubes (MWCNTs) within the Al–Si eutectic alloy powder by spray drying process for further cold spraying on grit blasted 6061 aluminum alloy substrate. The CNT diameter and length used was 40–70 nm and 1–3 μm, respectively, and its content in the powder was 0.5 and 1 wt.%. Eight layers of cold spraying have resulted in the formation of the coating of the order of 500 μm in thickness. The impact and shearing have resulted in reduction of lengths of MWCNTs. It is reported in the study that of the elastic modulus varies in the coating region varies from as high as 229 GPa for 0.5 wt.% CNT and 191 GPa for 1wt.% CNT coating. This variation is reported due to the locally high of CNTs and reinforcement effect of CNTs. This study reported that cold spray successfully sprayed the CNTs within the coating on aluminum alloy substrate using helium as main gas and nitrogen as powder carrier gas.

Keshri et al. [12] reported the vaporization of CNTs during plasma spraying of liquid precursor. This behavior of carbon occurred due to the intense heat of the plasma which exceeds

4200 K. Carbon vapor is a stable phase at 1 atm and around 4200 K, as shown in Fig. 3. Laha et al. [10] has reported the plasma sprayed synthesis of Al-based nanostructured composite with 10 wt.% CNTs (bulk density as 1.3–1.5 g/c.c., diameter 40–70 nm and 0.5–2.0 µm length) as second phase. The characterization results has reported that CNTs were stable chemically stable during spray process and did not reacted to form oxides or aluminum carbides. CNTs were retained in the composite structure and shape of hollow conoid (taper-length-100mm, diameter-62mm and thickness-2mm). Hardness was enhanced with the addition of CNTs and measured density was reported higher than the theoretical.

Pialago and Park [17] has successfully cold sprayed composite coatings with 5, 10 and 15 (vol.%) multiwalled carbon nanotubes (MWCNTs) by mechanical alloying (MA) with Cu using an attrition ball mill. Cu-CNT composite coatings were fabricated on 0.3-mm Cu plate substrates. The MWCNTs used in the coating process have diameter of 5–20 nm and approximate length of 10 µm with aspect ratio more than 500. It has been observed in this study that the coating surface contained 1.0–2.5 vol.% micropores, however, there were more pores in the composite coatings with10% MWCNT. It is also reported that there is decrease in deposition efficiency (DE) with the increase of CNT and the number of coating layers. The characterization results have confirmed the composition and uniform dispersion of MWCNTs within the cold sprayed composite coatings. The microstrains have been observed in the composite powders and coatings.

4. CONCLUSIONS

There is need to modify the material surface properties for their applications in different aggressive conditions. Nanocomposite coatings are going to play a major role is surface modification industry. The major advantage of working at nanoscale is that properties of the materials and their surfaces through coatings can be tailor made as per their required application. This field is still open for researchers to work for the fabrication of nanocomposite coatings especially with the addition of carbon nanotubes. There is need to study the characteristics of these materials for various industrial applications especially in harsh conditions such as high temperature corrosive environments.

5. REFERENCES

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