Study of carbon nanotubes process for their application in the aerospace engineering

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SUMMARY. – *The unique carbon nanotubes properties (mechanical, electrical, thermal, etc.) are considered as a key factor for future improvement of technical characteristics of many engineering macro and nano systems. The synthesis, the purification and the characterizations of carbon nanotubes are the primary requirements for a realistic use of it in many engineering sectors (structures, electronics devices, biomedical systems, advanced composites). A possible field of application of carbon nanotubes, for example, is represented by electromagnetic applications and telecommunication for Aerospace Technologies. Using the theoretical electrical and electromagnetically carbon nanotubes properties, is possible to improve the characteristics of many apparatus installed on space systems. This new generation of material find concrete and interesting application in the modern aerospace engineering. This paper reports the authors' studies on the synthesis (arc discharge with inert gas, in water immersion and laser ablation methods), purification (oxidation and chemical etching) and morphological analysis (Optical, SEM, TEM, X-Ray and Chemical) of carbon nanotubes. In particularly the morphological analysis is discussed as the fundamental instrument necessary to evaluate the carbon nanotubes characteristics and therefore their concrete integration for space applications. Besides, is shown a simple numerical examples about the reduction of weight of a space structure employing carbon nanotubes.*

1. Introduction

Using the properties (mechanical, electrical, magnetic) of the carbon nanotubes (CN) (discovered by S. Ijima in the 1991) it is possible to improve the characteristics of many advanced Engineering System (aero-

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space structures, nano-electronics devices, biomedical apparatus, etc.) (2). The primary goal for a realistic use of this new futuristic material, is the ability to synthesize and purify high quantity of CN, with high quality and low cost. The microscopy analysis (optical, SEM, TEM, chemical EDS) is the principal tool for understand the CN morphological configuration (single o multi wall, arm chair, zig zag, chiral). For the space applications the study of the CN dispersion in a polymeric matrix (composite materials) is requested. With the CN mechanical properties (theoretical Young's modulus = 1 TPa) is possible to obtain a significant gain in the mass structure reduction.

2. Synthesis of carbon nanotubes

Three CN synthesis facilities are developed (arc discharge in inert environment (7), arc discharge water immersed (9), laser ablation CO_2 (6)). Figure 1 shown the arc discharge facilities (dc current, 20-23 V, 50-60 A, argon pressure: 0.2 bar) and the SEM analysis of the deposit on the cathode electrode surface.

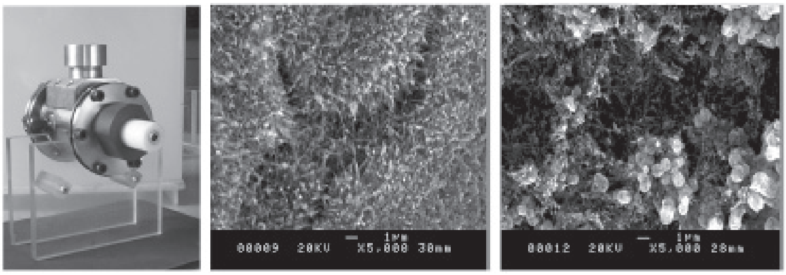

FIG. 1

Arc discharge facilities and the SEM analysis of the cathode electrode deposit

Figure 2 shown the arc between two graphite electrodes in the water immersed conditions (dc current, 20-25 V, 60-90 A) and the relative SEM analysis. Finally, figure 3 reported the laser ablation CO_2 (900 W, wave length: 10.6 mm, Argon flux: 60 l/min) and the SEM analysis. All test are performed using graphite rod (diameter: 6.15 mm, purity: 2 ppm).

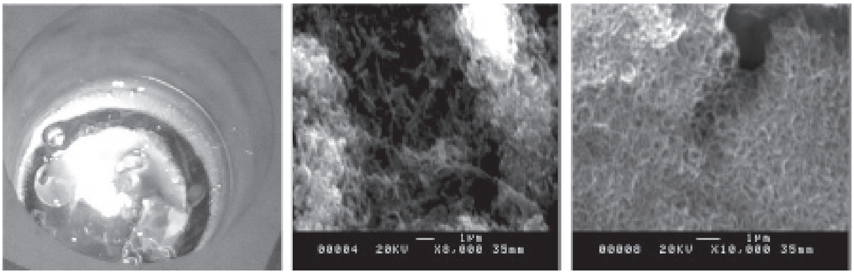

FIG. 2

Water immersed arc discharge and the SEM analysis of the cathode electrode deposit

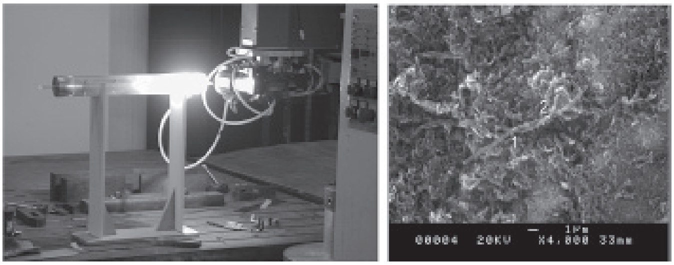

FIG. 3

Laser ablation test and the SEM analysis of the collector deposit

3. Purification of carbon nanotubes

To maximize the CN properties integrated in a advanced system, after the synthesis, a purification phase is required to eliminate all impurities (catalysts, amorphous elements, etc.). A chemical etching (DT-TGA analysis, oxidation flux: N_2 90%, O_2 10%, T_{max}=530 °C for 5 hours) was applied on raw CN produced with the arc discharge method. Figure 4 shows the deposit before and after the purification test.

Besides, a purification experiment with ultrasounds treatment (time test: 25 minutes in ethylic alcohol) was tested (4). Figure 5 shows that by this method there is not significant improvement of the deposit morphology.

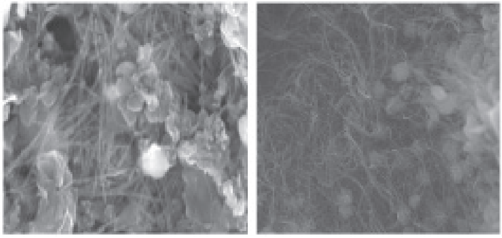

FIG. 4

The arc discharge deposit before and after the chemical etching purification test

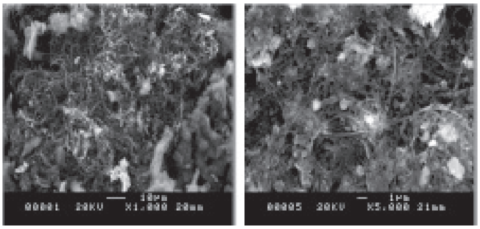

FIG. 5

The deposit morphology before and after the ultrasound purification test

4. Morphological analysis

Since the CN are characterized by nanometric dimensions, it is necessary to use optical, SEM and TEM microscopy and EDS analysis. The electronic microscopy is the principal tool to investigate the characteristics of the CN synthesized and purified. The preparation methodologies of the samples (1) are important. In order to reduce time and costs, the target is to acquire the ability to determine the CN presence with only a reduced number of analysis. With the studies performed, for example, has been determined that in the cathode electrode (arc discharge method) the CN are contained in a grey zone of the deposit in full agreement with the bibliography (5). Figure 6 show the optical, EDS, SEM and TEM analysis.

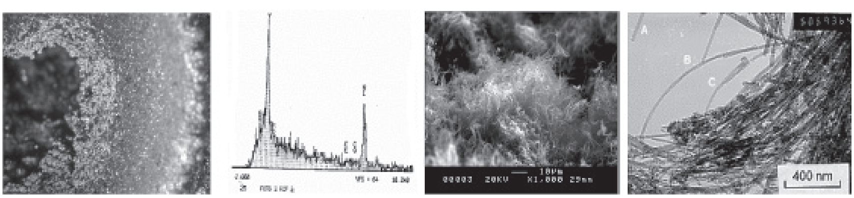

FIG. 6

Optical, EDS, SEM and TEM analysis

5. Application of carbon nanotubes in space structures

The anisogrid lattice structures are realised in the form of thin walled cylindrical or conical shell and consist of a system of helical and circumferential ribs (respect to the element axis) with an angle ±ϕ (Fig. 7). By means of the Vasiliev model (3) the mass ***M*** of these structures was calculated, using a typical aeronautics alloy (Al2024), a composite (Hs/Ep: epoxy resins + unidirectional carbon fibers (8)) and the Hs/Ep composite with a 5% in wt of carbon nanotubes dispersed (Table 1).

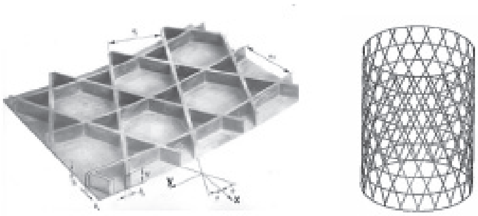

FIG. 7

The anisogrid lattice structures cylindrical configuration

Table I

The anisogrid lattice structure mass (***M***) in function of the employed material

MATERIAL	Al 2024	Hs/Ep	Hs/Ep +5% CN
YOUNG'S MODULUS [Pa]	70E9	12E10	16E10
MASS [Kg]	206.3	84.1	69.7

The dispersion of the nanometric powder in a polymeric matrix (epoxy resin) are studied. In Fig. 9 are showed the SEM fracture analysis of a specimen (epoxy resin + powder with carbon nanotubes) mechanically tested. The use of CN improved the mechanical behaviour (the Young's modulus increases).

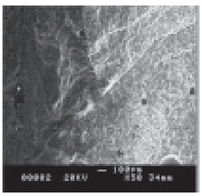

FIG. 8

The SEM fracture analysis of the composite specimen

6. Conclusions

This paper shows how the synthesis and the purification of CN requires a significant improvement (parameters control, reliability) for a real application in advanced Engineering Systems. The microscopy analysis allows to define the morphological characteristics of the synthesized material. Beside, using the Vasiliev model, the reduction of the anisogrid lattice mass was shown, when replacing the traditional aerospace materials (aluminum alloy) with a composite (epoxy resin + unidirectional carbon fibers) carbon nanotubes reinforced.

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