ELECTRICAL AND MECHANICAL PROPERTIES OF COMPOSITE MATERIALS BASED ON CARBON NANOTUBES FOR AEROSPACE APPLICATIONS

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Synthesis and Characterization

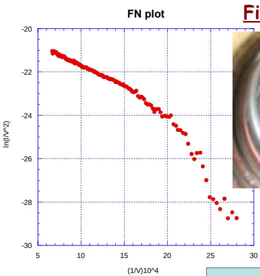
Introduction

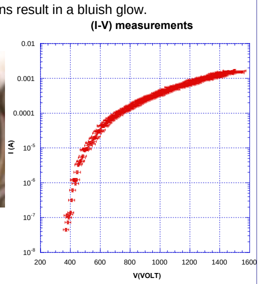
Several methods have been used to produce single-walled as well as multi-walled carbon nanotubes. The diameter of the MWNTs typically range from 10 to 50 nm, while the length exceeds 10 micron. For SWNTs, the diameter is ~ 1 nm and the lengths can be up to 100 microns.. CNTs exhibit unique physical and chemical properties. Mechanically, they have high structural perfection in their structures and the highest modulus of all known materials. Owing to their extreme properties, lightweight and chemical inertness, CNTs yield suitable candidates for aerospace applications, such as CNT-based electron field emitters and composite materials for extreme conditions (large temperature and pressure gradients, radiation).

Synthesis of CNT

CNTs were synthesized in a dc arc plasma system in helium atmosphere at a pressure of 600 torr. Arc was struck between two high purity graphite rods which served as electrodes. The discharge is carried out at 20 V voltage and a current in the range of 100 – 150 A. Some amount of the evaporated carbon condenses on the tip of the cathode, forming a slag-like hard deposit (cathode deposit). The deposit consists of two regions, *viz.*, an inner fibrous black core and an outer gray, hard shell. The inner core has a columnar structure that is made up of bundles of CNTs and flocks of polyhedral carbon particles. On the other hand, the hard shell is made of polycrystalline graphite. CNTs thus synthesized (without any purification treatments were used for field emission studies. Using a phosphorescence screen coated on a conducting glass the emitted electrons result in a bluish glow.

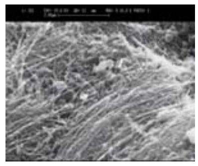
Field emission studies

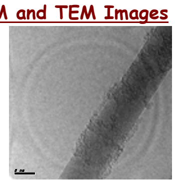


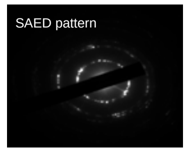


1. Turn on electric field:
   - E = 0.4 V/μm (current density was about 10 μA/cm²)
2. Current density :
   - J = ~ 10mA/cm² (when the electric field E is 1V/μm)
3. Current stability:
   - I = 377±17μA (mean value of current at 1 KV over a duration of 1 hour)

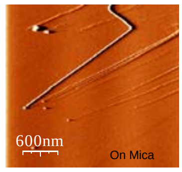
SEM and TEM Images

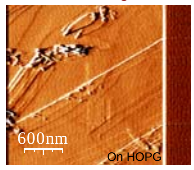


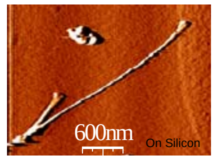




AFM Images



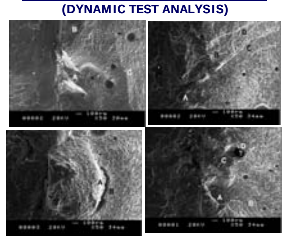




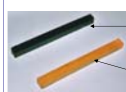
COMPOSITE WITH CARBON NANOTUBES

- RESIN, CURING AGENT, NANOPARTICLES
- SPECIMEN PREPARATION
- UNIFORM DISTRIBUTION OF THE NANOMETRIC PARTICLES (GRAPHITE, CARBON NANOTUBES, ETC.) IN THE POLYMERIC MATRIX
- MECHANICAL TEST
- MORPHOLOGICAL ANALYSIS
- COMPOSITE MECHANICAL FRACTURE BEHAVIOUR
- COMPOSITE CHARACTERIZATION
- AEROSPACE STRUCTURE APPLICATIONS
- THEORETICAL AND NUMERICAL STUDIES

COMPOSITE WITH CARBON NANOTUBES (DYNAMIC TEST ANALYSIS)

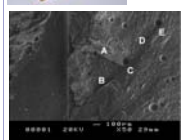


TEST OF COMPOSITE SPECIMENS

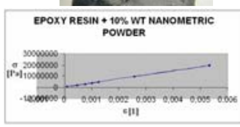


RESIN + NANOPARTICLES

ONLY RESIN



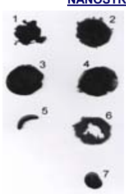
SEM ANALYSIS OF THE FRACTURE LINES



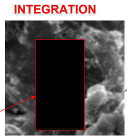
TRACTION TEST RESULTS

WITH NANOMETRIC PARTICLES (GRAPHITE AND CARBON NANOTUBES) THE YOUNG MODULUS IMPROVEMENT IS LARGER THAN 12%

NANOSTRUCTURED THIN FILM



PREPARATION
CHARACTERIZATION
FUNCTIONALIZATION
PROPERTIES
INTEGRATION

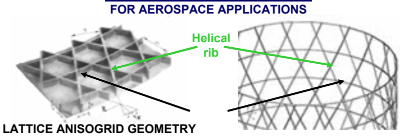


NANOPARTICLES OF GRAPHITE

THICKNESS: 6÷25 μm

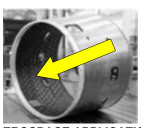
CARBON NANOTUBES EMBEDDED IN A POLYMERIC MATRIX

ANISOGRID LATTICE STRUCTURES FOR AEROSPACE APPLICATIONS



LATTICE ANISOGRID GEOMETRY

FEM MODEL



AEROSPACE APPLICATION

MANUFACTURING FACILITY (FILAMENT WINDING)

USING VASILIEV MODEL WE GET AN ANISOGRID LATTICE STRUCTURE WITH REQUIREMENTS:

◊ MINIMUM MASS ◊ STATIC RESISTANCE ◊ LOCAL AND GLOBAL STABILITY (BUCKLING)

WITH THE CARBON NANOTUBES IT IS POSSIBLE TO OBTAIN A VERY HIGH MASS *M* REDUCTION OF THE ANISOGRID LATTICE STRUCTURE

USING, FOR EXAMPLE, THE STRUCTURE PARAMETERS BELOW :

radius R = 1.5 m height L = 4 m helical ribs number ne = 20
Applied load P = 3 MN

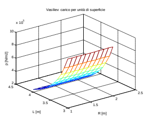
VARYING THE MATERIALS USED :

MASS \ MATERIALS	Al (2024) *	Hs/Hp **	5% CN ***
CALCULATED MASS *M* [Kg]	206	84	**69**

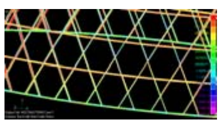
* = aluminum alloy 2024
** = epoxy resin and uni-directional traditional carbon fibers composite (Hs/Hp)
*** = the above composite Hs/Hp with a 5% in wt of carbon nanotubes embedded in the matrix

ANISOGRID LATTICE STRUCTURE DESIGN

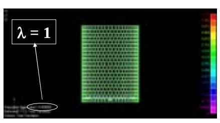
REQUIREMENTS ANALYSIS:
MINIMUM MASS – STATIC RESISTANCE – STABILITY



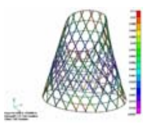
NUMERICAL MODEL



STATIC RESISTANCE ANALYSIS



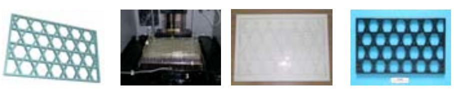
BUCKLING ANALYSIS



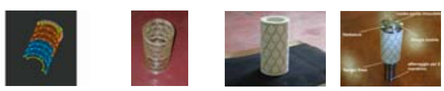
DYNAMIC ANALYSIS

ANISOGRID LATTICE STRUCTURES PRELIMINARY FLAT PROTOTYPE REALIZATION

ANISOGRID LATTICE STRUCTURES FLAT AND CYLINDRICAL PROTOTYPE REALIZATION

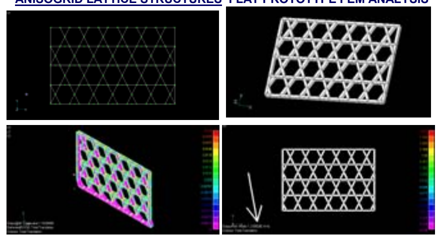


CAD MODEL | RAPID PROTOTYPING | SILICON NEGATIVE MOULD | FLAT PROTOTYPE

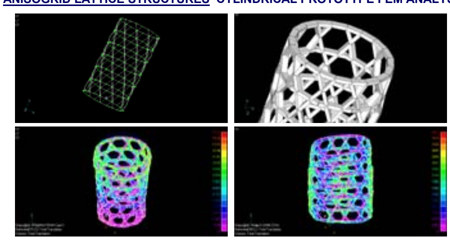


CAD MODEL | POSITIVE MOULD | SILICON NEGATIVE MOULD | MANDREL FOR PROTOTYPE PRODUCTION USING FILAMENT WINDING

ANISOGRID LATTICE STRUCTURES FLAT PROTOTYPE FEM ANALYSIS



ANISOGRID LATTICE STRUCTURES CYLINDRICAL PROTOTYPE FEM ANALYSIS



ISOGRID LATTICE STRUCTURES RECTANGULAR AND TRIANGULAR CELLS