SINGLE WALL NANOTUBES BEHAVIOUR IN RF FIELD

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Abstract: Nanomedicine represents a new discipline which combines nanoscience and nanotechnology. It opens new areas of development, like drug delivery by nanoparticles, nanotubes or fullerenes, nanostructures to be used in medical diagnostics, prevention, labeling and imaging. Our study will certificate that the temperature doesn't have any influence above Carbon Nanotubes in our interest range (40-43°) – obtained and controlled using RF field.RF can be used in their delivery into the cell. Current radiofrequency ablation (RFA) techniques are limited by accuracy of targeting and are used for thermoablation of specific pathologies. The aim of our research was to demonstrate and to use further the fact that SWNT are ideal transporters, due to immunity at thermal variations. The biological and medical aim of the study is to evaluate this process in cancer cells. Our experiments where done into the ICECHIM Laboratory for Analysis and Testing - Laboratory testing for hazardous substances, waste and wastewater . Our results presents the mass loss correlated with degree of temperature in order to be used in the future studies as background into the cancer treatment by nanotubes delivery.

Key words: *RF, nanotubes, cancer cell, nanobiotechnology*

I.INTRODUCTION. DEFINITION. HISTORY. WHAT ARE SWNT. NANOTUBES PROPERTIES.Definition:

Two decades ago pure carbon started to be used in a new architecture puting together carbon units under new symmetries and structures with remarkable physical properties[1] like fullerenes. Multiple models of carbon nanotubes represent examples of this technology[2]. A carbon nanotube can be considered as the ultimate fiber, with a very accurate architecture, near ideal sp^2 bonded carbon structure[3]. This organization of the hexagonal carbon network into cylinders with helical structure and hexagonal arrays has revealed a specific and very powerful macromolecular structure that is known to be the most superior carbon fiber.

History:

Carbon nanotubes have been produced and observed under a variety of conditions prior to 1991:

- In 1979 John Abrahamson presented at the 14th Biennial Conference of Carbon at Pennsylvania State University[4], first results considering carbon nanotubes;
- In 1981,carbon nanoparticles were characterised at chemical and structural level by a group of Soviet scientists produced by a specific chemical procedure called: thermocatalytical disproportionation of carbon monoxide[5].
- In the last eightees,Howard G. Tennett of Hyperion Catalysis received a U.S. patent for the development of "cylindrical discrete carbon fibrils" having as essential feature a "constant diameter between about 3.5 and about 70 nanometers"[6].
- The initial great discovery was made by Iijima, in 1991, and opened the opportunity to charcaterise the conducting properties of those carbon nanotubes. Nanotube research accelerated greatly immediate after the discoveries[7,8] by Bethune at IBM[9] and Iijima at NEC of single-walled carbon nanotubes and their methods to produce them in an arc discharge.

What are SWNT

Carbon nanotubes SWNT are allotropes of carbon with a cylindrical nanostructure. Nanotubes have been constructed with length-to-diameter ratio of up to 132,000,000:1.

Nanotubes properties

These cylindrical carbon molecules have novel properties that make them potentially useful in many applications in nanotechnology, electronics (the first radio based on NT was created and even exist a tape with , optics, medicine and other fields of materials science. They exhibit extraordinary strength and unique electrical properties, and are efficient thermal conductors.Due to theirs chemical structure, they can be also viabilised and used in medicine.

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Parameter	Value and units
Length of the unit vector	2.49 Å
Current density	>109 A/cm2
Thermal conductivity	6600 W/mK
Young modulus	1 TPa
Mobility	10000-50000 cm2V-1s-1
Mean free path (ballistic transport)	300-700 nm semiconducting CNT 1000-3000 nm metallic CNT
Conductance in ballistic transport	G = 4e2 / h =155μS
Luttinger parameter g	0.22
Orbital magnetic moment	0.7 meVT-1 (d = 2.6 nm) 1.5 meVT-1 (d = 5 nm)

***Table 1**. [10]*

We remark that:

- The current density is 1000 times larger than than the current density in copper
- The thermal conductivity is bigger than most crystals
- Stronger than the steel with many orders of magnitude
- The electrons are strongly correlated in CNTs

II.HYPERTEMIA STUDY OF SWNT

Cancer became in this century the most important cause of death worldwide. It is prevalent in all countries with different specificities for localization.The new era of molecular biology, genome identification and nanotechnologies, opens enourmous opportunities for a modern medicine in cancer treatment, the personalized medicine, meaning a specific treatment for each patient.

In respect to this ideea, several studies[11,12,13] presented the benefits of using RF in theromoablation of liver, pancreas and lungs and renal tumors, all of them very aggresive cancers. One of the major limitation in in RF ablation is done by the zone of necrosis. RF ablation is a new local used as a minimal invasive tool for unresecable tumors[13]. Hyperthermia is recognized as an alternative treatment that can be performed alone or combined with radiotherapy and chemotherapy in cancer treatment. Controlled temperature between 40° and 42-43° increase the effects of chemotherapy and radiotherapy and even induce apoptosis, considering that temperatures have enlarged citotoxic effect on cells. Going further with the treatment using functionalized nanostructures, the magnetic properties are used to control the position of nanostructure, and chemical properties can be adjusted to release the drug inside the body in a controlled process.

The target temperature have to be more than 40°, because this temperature is normal for a body, and less than 43°, for the reasons already mentioned.

III. THERMAL *IN VITRO* STUDY OF SWNT HEATING IN RF FIELD (WITH AND WITHOUT KENTERA SOLUTION)

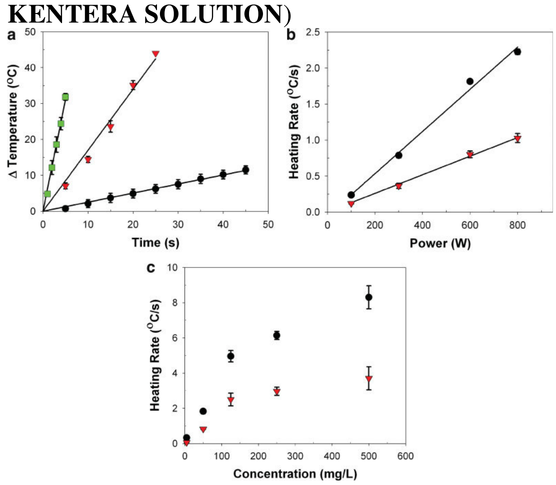

***Figure1**. [15]*

a.The first graphic reveals a very important fact – linear dependence between time of radiofrequency emission and the variation of temperature. (the measurements are made under 600 W RF field, at 13,56 MHz frequency, using different concentrations of SWNT (dots-only Kentera solutions, without SWNT, triangles-50 mg/l of SWNT in Kentera solution, and squares-250 mg/l)

b.The second reveals the heating rate (in Celsius degrees / second) with the power.

There is also a linear dependence (very convinient for our purpose).

The dots represent the Kentera suspension with SWNT and the triangles represent the SWNT heating rate, calculated substracting Kentera solution.

*c.Under a constant power – 600 W, the graphic exhibit the **nonlinear** dependence between Heating rate (in degrees/second) and concentration (in mg / l).(C.Gannon[14]).*

So, as a conclusion, the graphic shows us the possibility to obtain a desired temperature (42-45 deg Celsius) in a calculated way.

IV. OBJECTIVES OF THE STUDY:

Opposed by thermoablation alone, the goal (the purpose of our study) is a combination of hyperthermia with radiation therapy to exploit the synergy between the two treatment methods (mainly studied in prostate cancer). By enhancing biological dose of radiation with hyperthermia, lower doses of radiation can produce equally effective results with a lower radio-induced toxicity. A biological exposure and the pozitive results at thermoradiotherapy of prostate cancer has been demonstrated in vitro and in vivo.

Materials used for generating hyperthermia are nanoparticles. The temperature of the target depends on the SAR (Specific Absorbtion Rate), the power and beam focus and time of application.

V. MATERIAL AND METHODS

As we already indicated, the study was performed at ICECHIM Laboratories using the equipment in the image below to evaluate the relationship between temperature scale and loss weight.

Figure2*.Equipment TGA/SDTA 851 Mettler Toledo; DSC 823 Mettler Toledo (ICECHIM Bucharest)*

VI. RESULTS

The results of our experiments are presented in the following section.
Study of SWNT – weight loss with temperature.
Choosing nanotubes as carriers or as the target of bombing is, in terms of heat , a certainty of sustainability, as SWNT is keeping its properties up to 250-300° (according to attached graphs - ICECHIM experiments in laboratories).
Definitions :
TGA - THERMOGRAVIMETRIC ANALYSIS - is used primarily for determining thermal stability of polymers. The most widely used TGA method is based on continuous measurement of weight on a sensitive balance (called a thermobalance) as sample temperature is increased in air.
SDTA - simultaneously differential thermal analysis – shows the derived TG curve (peak reveals sites).
The two experiments were performed on SWNT products IIMT Cluj (courtesy of Dr. A.Biris) (sample 1) and provided ICECHIM (sample 2).
Experimental results:
Our results are represented in the following graphics performed in the nominated laboratory.
The two axes represents:

a. weight (mg) OX
b. temperature (Celsius degrees) OY

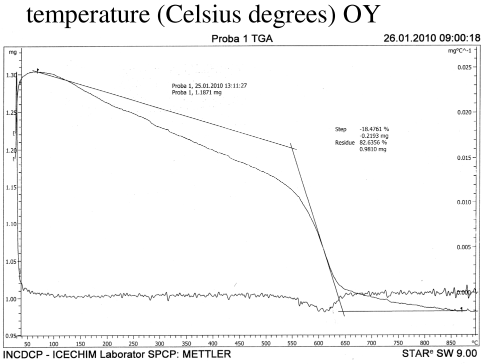

Figure 3.*-TGA for SWNT produced by ITIM Cluj (courtesy of A.Biris)*

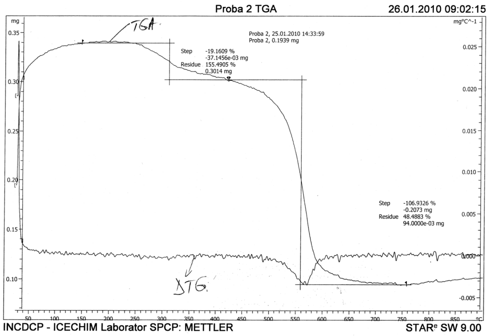

Figure 4.- *TGA for SWNT produced by ICECHIM Bucharest*

Using SWNT from different sources (the two figures above), we observe that the behaviour is very similar :
The mass loss remains almost constant up to 140 –150 Celsius Degrees (Probe 1), and started to lose mass at about 550 Celsius Degrees. The second probe keeps its mass up to 240-250 Celsius Degrees and started to loss mass at about 500 Celsius Degrees.

VII.CONCLUSION AND FUTURE WORK:

Figure 3 and Figure 4 demonstrate that the TGA measurements reveal that the SWNT are suitable from thermal point of view for our purpose (guided transporter for DNA or drugs), because they don't suffer any modifications (weight loss) with the temperature in the desired temperature range.
Also, the two graphics are certificating the thermal stability of the transporter (SWNT), who remains at the same properties under temperature modification in our target interval.
We can calculate the temperature into a desired target (*in vitro*, for the beginning, and *in vivo*, later, into different tissues, at different angles of radiation, in different concentrations, at different power levels of RF radiation and at different time exposure), knowing the behaviour of SWNT and substracting it from the functionalised structure (SWNT + drug).
The Power RF Amplifier on 2-30 MHz, 0-400 W is now under construction and it shall be used for evaluation of different power effects on the cellular membrane, of the temperature and electromagnetic effects in an functionalised structure.

REFERENCES

[1] Abrahamson, John; Wiles, Peter G.; Rhoades, Brian L. . "Structure of Carbon Fibers Found on Carbon Arc Anodes". *Carbon* **37**: 1873. 1999.
[2] Izvestiya Akademii Nauk SSSR, Metals., #3, pp.12–17 (in Russian) 1982
[3] US patent 4663230, "Carbon fibrils, method for producing same and compositions containing same", granted 1987-05-05 ,1987
[4] Iijima, Sumio . "Helical microtubules of graphitic carbon". *Nature* **354**: 56–58.1991
[5] The Discovery of Single-Wall Carbon Nanotubes at IBM. IBM. 1991

[6] Krätschmer, W.; Lamb, Lowell D.; Fostiropoulos, K.; Huffman, Donald R. "Solid C60: a new form of carbon". *Nature* **347**: 354–358. 1990
[7] Kroto H W, Heath J R, O'Brien S C, Curl R F, Smalley R E. *Nature (London)* 318:162–164.1985
[8] Dresselhaus M S, Dresselhaus G, Eklund P C. *Science of Fullerenes and Carbon Nanotubes.*New York: Academic; 1996.
[9] P. M. Ajayan, J.-C. Charlier, and A. G. Rinzler *Carbon nanotubes: From macromolecules to nanotechnology* Proc Natl Acad Sci U S A.; 96(25): 14199–14200,1999
[10] Nanoelectronics: Principles and Devices by Mircea Dragoman, Daniela Dragoman,Artech House, Boston, 2009
[11] Crocetti L, de Baere T, Lencioni R :*Quality improvement guidelines for radiofrequency ablation of liver tumours.* Cardiovasc Intervent Radiol. 33(1):11-7.2010
[12] Casadei R, Ricci C, Pezzilli R, Serra C, Calculli L, Morselli-Labate AM, Santini D, Minni F. *A prospective study on radiofrequency ablation locally advanced pancreatic cancer.*Hepatobiliary Pancreat Dis Int. 9(3):306-11. 2010
[13] Liang HH, Peng ZW, Chen MS, Peng HP, Xue P, Zhang YJ, Zhang YQ, Li JQ. *Efficacy of combining temperature- and power-controlled radiofrequency ablation for malignant liver tumors.*Chin J Cancer. 29(4):408-12.,2010
[14] Siriwardena AK. *Radiofrequency ablation for locally advanced cancer of the pancreas*. JOP ;7:1-4. 2006
[15] Christopher J. Gannon, MD,Paul Cherukuri, PhD,Boris I. Yakobson, PhD, Laurent Cognet, PhD, John S. Kanzius, Carter Kittrell, PhD, R. Bruce Weisman, PhD, Matteo Pasquali, PhD, Howard K. Schmidt, PhD Richard E. Smalley, PhD Steven A. Curley, MD, *Carbon Nanotube-enhanced Thermal Destruction of Cancer Cells in a Noninvasive Radiofrequency Field* Cancer 2007;110:2654–65.2007
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