PHYSICAL CHEMISTRY 2006

Proceedings

of the 8th International Conference on Fundamental and Applied Aspects of Physical Chemistry

September 26-29,
Belgrade, Serbia

ISBN	86-82139-26-X
Title:	Physical Chemistry 2006. (Proceedings)
Editors	Prof. dr A. Antić-Jovanović
Published by:	The Society of Physical Chemists of Serbia, Studentski trg 12-16, P.O.Box 137, 11001 Belgrade, Serbia
Publisher:	Society of Physical Chemists of Serbia
For publisher:	Prof. dr S. Anić, president of the Society of Physical Chemists of Serbia
Printed by:	"Jovan" Printing and Published Comp; 250 Copies; Number of Pages: x + 442; Format B5; Printing finished in September 2006.
Text and Layout:	Aleksandar Nikolić

250 – copy printing

AN SIMPLE TECHNIQUE FOR SYNTHESIS OF CARBON NANOTUBES BY UNDERWATER ARC PLASMA

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Abstract

Applicable, low cost technique for the production of carbon nanotubes by underwater (or solution) AC arc plasma discharge is described. The growth takes place in an AC arc in water solution between graphite electrodes.

Introduction

Since their discovery by S. Iijima[1], carbon nanotubes have attracted considerable attention because of their intriguing and remarkable physical properties. They can be thought of as a sheet of graphite (a hexagonal lattice of carbon) rolled into a cylinder. There are three conventional methods of synthesizing carbon nanotubes: a) arc discharge in an inert gas, b) laser vaporization and c) chemical vapor deposition (CVD). All three methods require sealed, water cooled vacuum chambers together with complex and time consuming gas handling equipment. From the stand-point of applications, the importance is still on high quality, high purity and low cost nanotubes growth by using a simple method.

The arc-discharge method has been easy adapted for operation in aqueous environment that avoid vacuum systems, inert atmosphere and very high temperature. Such an experimental set-up was used in this study to produce carbon nanotubes.

Experimental

Two graphite electrodes (spectrographic grade and 6 mm in diameter) were immersed into the glass vessel containing 2.4 dm^3 of double distilled water or 5 % NaCl solution, Figure 1. Arc plasma was ignited and maintained at 30 V and AC current strength of 60 A, for a period of about 12 min. During the synthesis time, solution was continuously stirred. Solutions were cooled and kept to slag the carbon soot. The slag (the yields were 85 mg min^{-1} and 77.6 mg min^{-1} for pure water and NaCl solution, respectively) was sucked, washed and purified [2]. The purification was done by refluxing the slag with concentrated sulphuric and nitric acids (3:2) mixture, for 2 hours at 150 °C. After the slag has been washed with bidestiled wather it was centrifuged for 20 minutes. The sample was prepared by suspending the soot in ethyl alcohol. The soot was investigated by TEM microscopy (Philips EM-400, 120 kV).

Results and Discussion

After the discharge finished, two types of products are observed in the vessel: in the case of pure water, floating material on the surface and hard carbon soot species dispersed, but in the case of NaCl solution much less floating material was present. Also, arc burns more stable in solution of NaCl, in comparison to the pure water. Dimension of obtained soot species looks more uniform and without grains of graphite. The superior cooling ability of NaCl solution is useful for synthesizing carbon nanotubes and electrical conductivity supports arc discharge.

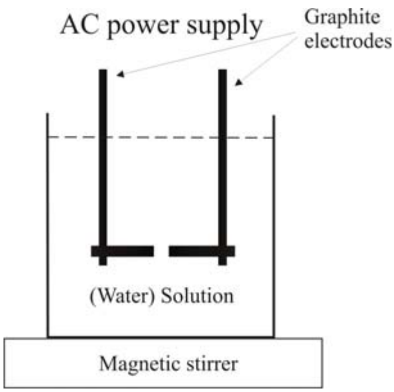

Fig. 1. A shematic drawing of the synthesis device.

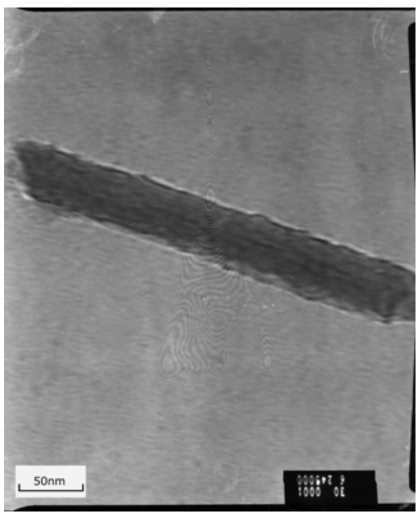

Fig. 2. TEM photograph of a single carbon nanotube produced by arc discharge in 5 % NaCl solution. Maximal magnifying of 310 000 is used.

An example of the single carbon nanotube produced in 5% NaCl solution is presented on Figure 2. This is well defined, 4.5 nm in diameter and 33.5 nm long carbon tube. It seems to be a single wall nanotube (SWNT).

Conclusion

The results have proofed that very simple arc discharge configuration in liquid environment can be used for synthesis of carbon nanotubes. The procedure allows a low cost continuous operation with minimal invention.

Acknowledgments

This work has been financially supported by Ministry of Science and Environmental Protection, Republic of Serbia, under Project No. 142065.

*This work has been a Bachelor degree thesis.

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