III. ON THE PROCESSES OF CARBON NANOSTRUCTURES FORMATION IN LIQUID PHASE

Zolotarenko An.D., Zolotarenko Al.D., Schur D.V., Zaginaichenko S.Yu., Dubovoy A.G.
Frantsevich Institute for Problems of Materials Science of NAS of Ukraine
Krzhyzhanovsky st . 3, 03142 Kiev, Ukraine
∗ *Fax: 38 (044) 424 0381 E-mail: shurzag@ipms.kiev.ua*

Introduction

For the last decade, arc discharge in the liquid phase (ADL) is used in increasing frequency to produce different nanostructures as the method alternative to arc discharge in the gas phase (ADG). ADL is considered to be a profitable method of nanostructures synthesis. This method does not require using of unhealthy gases, vacuum equipment or expensive lasers. In the present work we consider the processes occurring on the electrodes and in the liquid phase during the ADL process and explain the mechanism of carbon nanostructures (CNS) formation proposing the model based on the analysis of existing regularities in behaviour of charged particles under extreme temperature and pressure gradients.

Results

Synthesis of CNS by the ADL method is performed in dielectric liquids: hydrocarbons, liquid gases (N_2, Ar, He etc.), deionized water and others. Suspension containing clusters of synthesized nanostructures is formed by the synthesis.

Discharge in liquid is initiated by moving apart electrodes that were initially clamped. High-temperature arc column that appears between the electrodes converts both the anode material and the liquid phase surrounding this anode into the vapor phase.

When electrode spacing does not exceed 1mm, the deposit similar to that formed in ADG is generated on the cathode.

When moving apart the electrode is more than 1 mm, deposit on the cathode does not formed and the whole resulting product is either in suspension in the liquid phase or on the bottom as residue.

Efficiency of this method is sharply increased by using arc discharge in the liquid phase where a layer of powder reagent is used as an anode (ADLP) (Fig.1). In this case in clamping the electrodes, each conducting particle being among the similar ones is, on the one hand, an anode and, on the other hand, a cathode. To increase the frequency of electrodes clamping and moving apart, this method uses an electromagnetic vibrator

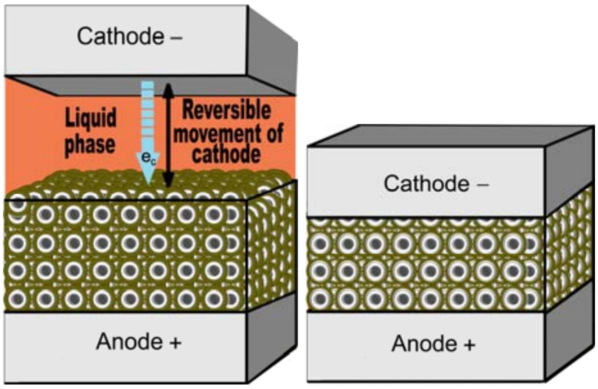

Fig.1. Schematic diagram of action of the arc discharge apparatus in the liquid phase with a dispersed anode.

that brings and takes away the cathode from the powder reagent at a specified frequency. A large amount of nanoproduct is formed by a large number of electric discharges.

Discussion

On the basis of our phenomenological model of the processes occurring in the electrode spacing in the liquid phase, one can expect the following variants of the process proceeding.

1.During ADL, when electrode spacing is less than 1 mm, liquid phase goes into a vapor state (Fig.2) thus providing conditions similar to those in ADG. As this takes place, carbon vapor, carbon nanostructures and fragments of graphene sheets interact under the action of electromagnetic forces and move in different directions.

The vapor phase at the interface (g-l) condenses due to the temperature gradient. The charged particles, moving from the anode to the cathode, form deposit. When colliding with electron flux, a minor part of these particles and neutral particles are thrown out the arc zone and quenched in crossing the interface.

Near the quenching zone, the particles constituting the gas phase agglomerate through the saturation of dangling bonds, create different nanoforms and assemble in clusters.

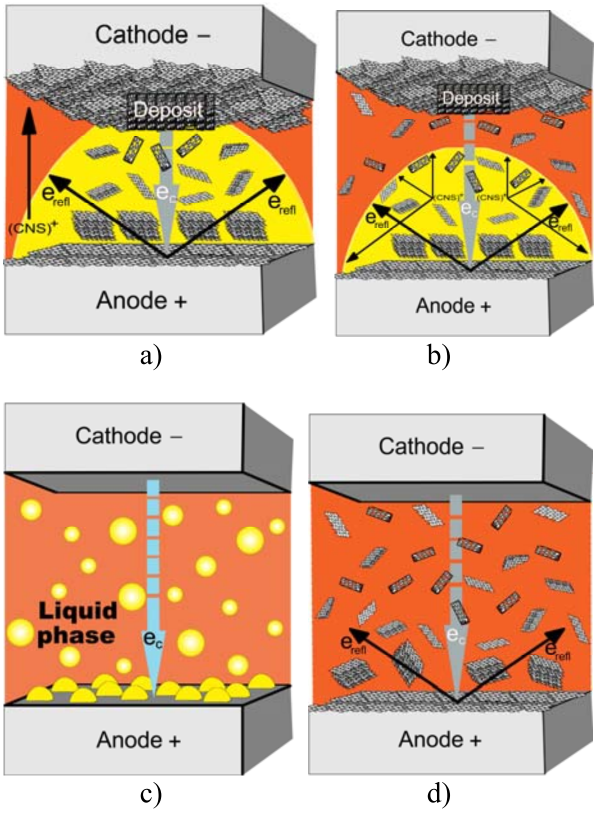

Fig.2. Mechanism of carbon nanostructures and their composites formation in the liquid phase.

2. When electrodes are moved apart at the distance exceeding a vapor bubble diameter, deposit stops to form on the cathode (Fig.2, b). This is attributed to that the particles forming the deposit and having plasma temperatures now must overcome the layer of liquid. Approaching to the interface (g-l), these particles undergo quenching. In the quenching zone, the particles begin to agglomerate, form clusters and lose their reactivity.

Breaking away from the anode surface, the bubbles go into the volume of liquid phase (Fig.2,c). All structures contained in a bubble and formed by anode evaporation remain enclosed in the volume of the bubble. Vapor, getting to the zone of lower temperatures, condenses, bubbles shut and their content goes in the liquid phase (Fig.2,d). Nanoparticles in liquid can assemble in clusters and precipitate or be in suspension.

In the case of co-evaporation of metal and graphite or metal in the hydrocarbons medium, metal nanoparticles encapsulated in the carbon matrix or other composites can be produced by condensation of vapors mixture in the shutting bubbles.

3. For ADLP, nanostructures form simultaneously at several points on the conducting particle surface as a result of microscopic acts of arc discharge similar to those shown in Fig.2, a. These nanostructures are generated from the liquid phase and anode vapors and represent the product exhibiting rather interesting physical and chemical properties.

Conclusions

Based on the analysis of the observations performed in the course of carbon nanostructures synthesis, the model of nanostructures formation by arc discharge in the liquid phase has been proposed.

Presence and absence of deposit on the cathode have been explained.

Acknowledgment

The work has been done within the framework of STCU project 4012.

References

1. Schur D.V., Dubovoy A.G., Zaginaichenko S.Yu., Adejv V.M., Kotko A.V., Bogolepov V.A., Savenko A.F., Zolotarenko A.D. Production of carbon nanostructures by arc synthesis in the liquid phase // Carbon. 2007; 45(6): 1322-1329.

2. Tenne R., Margulis L., Genut M., Hodes G. Pelyhedral and cylindrical structures of tungsten disulphide // Nature 1992; 360:444-446.

3. Chopra N.G., Luyken R.J., Cherrey K., Crespi V.H., Cohen M.L., Louie S.G., Zettl A. Science 1995; 269:966.

4. Hacohen Y.R., Grunbaum E., Tenne R., Sloan J., Hutchison J.L. Cage structures and nanotubes of $NiCl_2$ // Nature 1998; 395:336-337.

5. Cote M., Cohen M.L., Chadi D.J. Theoretical study of the structural and electronic properties of GaSe nanotubes // Phys. Rev. B. 1998; 58:4277-4280.