# PLASMA PYROLYSIS DEVICES FOR NANOCARBONS SYNTHESIS USING DC AND AC ATMOSPHERIC PRESSURE ARC PLASMA TORCHES

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Fine mechanical, optical, chemical, electrical and magnetic properties make such nanocarbons as nanotubes (CNT), fullerenes, endohedrals attractive nanomaterials for a variety of applications. It is known that nanotubes and fullerenes nanocarbons are efficiently produced vaporization of carbon bearing materials followed by the condensation of carbon gas [1]. Due to the very high sublimation temperature of carbon (near 4000 K) a few of thermal plasma techniques (arc and RF discharges, laser excitation plasma) had been demonstrated for the synthesis of gram quantities of these nanostructures (including those of CNT in nonaligned elongated form). The progress in development of nanocarbon materials synthesis was demonstrated by some groups [1, 2] using the DC reactors with plasma pyrolysis of hydrocarbons or others low cost carbon raw materials.

This paper gives some of the results that were obtained under investigation of pyrolysis to synthesize nanocarbons in the plasma reactor with DC or AC plasma torches such as $C_{60}$, $C_{70}$, CNT. Plasma gases are a propane-butane mixture with nitrogen and air stabilization, at torches of the 0.5-100.0 kW power. The used plasma torches were of such types: a DC or AC electric arc, a DC electric arc conjugated with a non-self-maintained discharge [3], AC gliding arcs (one- or three-phase). Also, we have designed such a unit as a DC torch with a magnetic annular arc to generate a high non equilibrium plasma zone into the torch operated with the power up to 100-150 kW.

Using the reactors for electric arc pyrolytic synthesis of nanomaterials from the gas phase (CVD), that has been optimized on the previous stages, we begin to study feasible mechanisms for the generation of nanoparticles (nanotubes, fullerenes) within the plasma pyrolysis reactor (PPR) with a reducing medium, in the presence of metal-containing catalytic particles. This reactor can be equipped with various plasma torches operated at a special automated electric arc unit (see Fig.1).

According to the provisional data plasma arc synthesis in the considered quasi-equilibrium conditions (device pressure ~ 0.1 MPa, average temperature in the reaction zone 1500–4000 K, “volatile” and surface catalysts based on iron group metals, the quenching rate of a carbonaceous gas at condensation of nanoparticles - $10^5$-$10^6$ K/s) permit synthesizing fine carbon products with the contents of the fullerenes phases up to 15–24 mass % and multiwalled CNT up to 3–6 %. The samples synthesized were investigated using IR- and Raman spectroscopy, XRD, chemical extraction, BET method. Plasma reactor media were studied using OE spectroscopy and also gas chromatography methods. Some of the effects were observed for the regimes of PPR (see Fig.2), i.e., energetic number $K_{EN}$ dependences on the fraction of such nanocarbon precursors in the gas phase as unsaturated hydrocarbons ($C_2H_2$, $C_2H_4$, $C_3H_6$ with $sp^2$- or sp-hybridization in the molecules and with the $\pi$-bonds) into the C-H-N-plasma reaction zone.

The next stage of the work will deal with specific physical-chemical investigations of the products of plasma pyrolysis synthesis of carbon nanomaterials with the purpose to optimize the operating condition of the process. For a high yield of fullerene and CNT–nanostructures in the products of synthesis to be provided, we plan to use in PPR special impacts that activate non-equilibrium mechanisms of condensation (electromagnetic fields with the intensity $>10^3$ V/m or with the induction > 1.0 Tesla, i.e., generated by such plasma torches as AC gliding arcs and the DC torch with a magnetic annular arc) and also in plasma the products of synthesis and the partial oxidation reaction between hydrocarbons and air that is rich in CO (usable for a growth of single walled CNT).

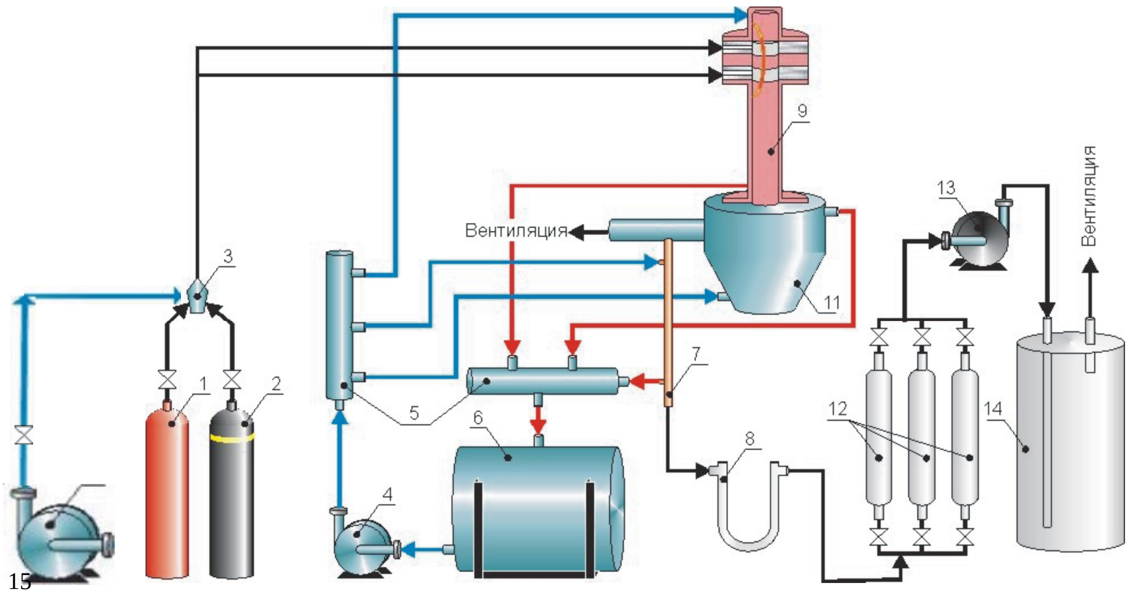


Fig. 1. Schematic of the lab-scale electric arc unit for nanocarbons synthesis operating with PPR based on various plasma torches to generate ($N_2$-$O_2$-($C_3H_8$+$C_4H_{10}$))–system plasmas.
1 – gas cylinder with propane-butane, 2 – gas cylinder with nitrogen, 3 – gas mixer, 4-6 – system of water cooling of PPR, 7 – gas probe, 8 – net filter for trapping of soot with nanocarbons, 9 – plasma torch, 11 – quenching-absorption device, 12-14 – system for gas sampling for chromatography analysis, 15 – air compressor

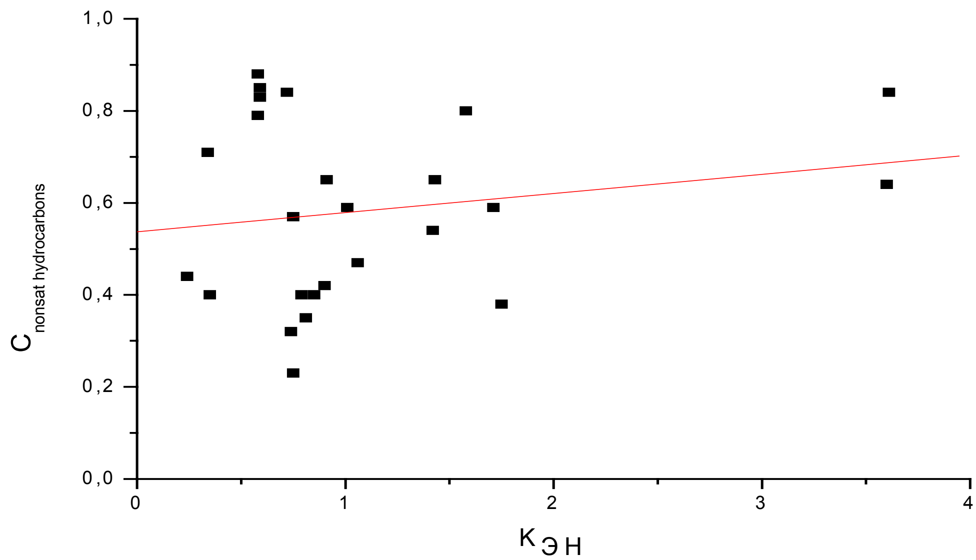


Fig. 2. Mole fraction of unsaturated hydrocarbons ($C_2H_2$, $C_2H_4$, $C_3H_6$) to the sum of all hydrocarbons into the reaction zone of the pyrolysis reactor based on DC and AC plasma torches vs. Suris' energy number of the nanocarbon synthesis process. Plasma gas in PPR is propane-butane with $N_2$

**References**


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