PRODUCTION OF NANOSTRUTURE MATERIALS IN THE SOLAR FURNACES

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Introduction

Three high temperature processes were developed for the synthesis of fullerenes and nanotubes: laser ablation, electric arc and solar energy. The experiments with using the cheap ecological clean source of heating were continued in different variations.

Results and Discussion

Historically initial method for obtaining of carbon vapor at solar furnace is heating the graphite rod [1]. About 2 mg/h of carbon soot containing fullerenes were obtained using a small parabolic mirror (36.5 cm diameter). Recently there is demonstrated [2] that a solar reactor placed at the focus of the 1 MW solar furnace, and used the full power of the facility, can produce 80 – 150 g/h of carbon soot.

Fig.1 shows schematic of the experimental set up [3-7]. The main subsystems are: the reactor, the gas circulation system, the filter, and the measurement and acquisition system. The reactor was a water-cooled metallic tube closed by a hemispherical quartz window in front face and connected to the filter backwards. The target rod was placed inside graphite tube insulated by graphite felt. The carbon and catalysts mixture vaporised at the front face where the concentrated solar energy was incident. The buffer gas (Ar or He)

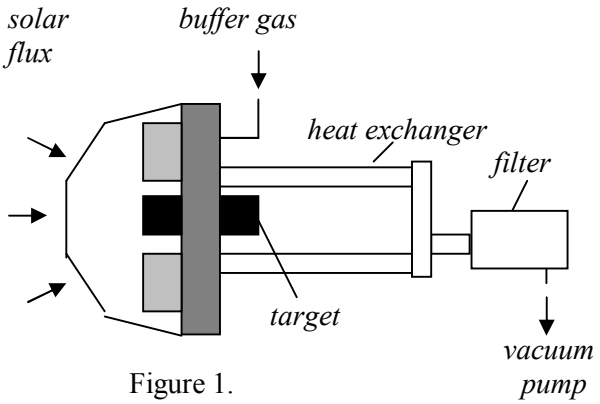

Figure 1.

entered around the perimeter of the quartz window and swept its interior surface in order to prevent condensation of the carbon and catalysts vapours. The mixture (buffer gas + carbon and catalysts vapours) was then entrained and pulled between the target and the graphite tube to the back of the reactor. A water-cooled heat exchanger cooled the gas mixture before it entered a bag filter.

For standard conditions, the produced carbon material collected on the heat exchanger and in the filter was in the range 2– 7 g/h. The SWNT diameter is in the range 1.2 – 1.6 nm with Ni/Co as catalyst.

The produced carbon soot containing fullerenes and nanotubes was collected in three locations: inside the reactor (mainly in the graphite tube after the target), on the heat exchanger and in the filter. Apparatus [8] with moving soot collector was developed for utilization of the synthesis products without stop of the process.

The relaxation of the requirement to use conductive graphite rods opens the possibility to use less expensive forms of graphite, including mineral graphite powders. The conception of direct volumetric absorption of solar energy in a gas-solid suspension offers the advantages of high heat and mass transfers based on short diffusion path length and large surface area [9].

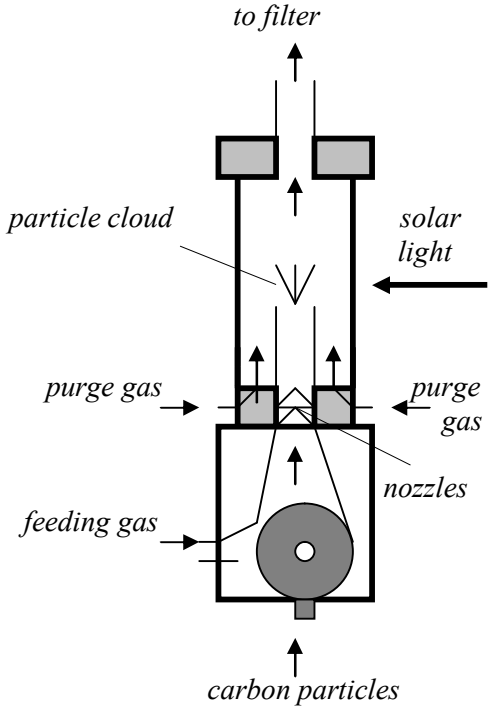

Figure 2.

This reactor (see the Fig.2) is configured around a secondary solar concentrator designed to deliver a solar flux of well over 1500 W/cm^2 at a distance

of 1.25 cm from the secondary concentrator's exit. A 2.5 cm diameter quartz tube mates to the exit end of the secondary concentrator. This tube serves the reaction chamber for carbon vaporization. A purge gas, delivered by annular tubes sweeps the inside of the quartz tube to keep it free from the carbonaceous deposits in locations incident with the entering light beam. Annular tubes, made of tantalum, can serve as heat shields to reduce radiative losses from the system. Carbon powders are fed up from the bottom of the reactor by vibrating, feedthrough system that directs the fluid to the focus of the beam. Soot is collected at the exit of the reactor in a filter.

Equilibrium temperatures in the particles cloud reached 2700 K and the maximum temperature was achieved in period of 4 ms or less for the conditions used in these experiments. Concentrated solar energy can be used as the clean source of high-temperature process heat, avoiding the emission of pollutants while upgrading the calorific value of the products. The decomposition of hydrocarbons is a high-temperature, endothermic process. These reactions proceed at temperatures in the 800-1000 K range when conducted at atmospheric pressure [10].

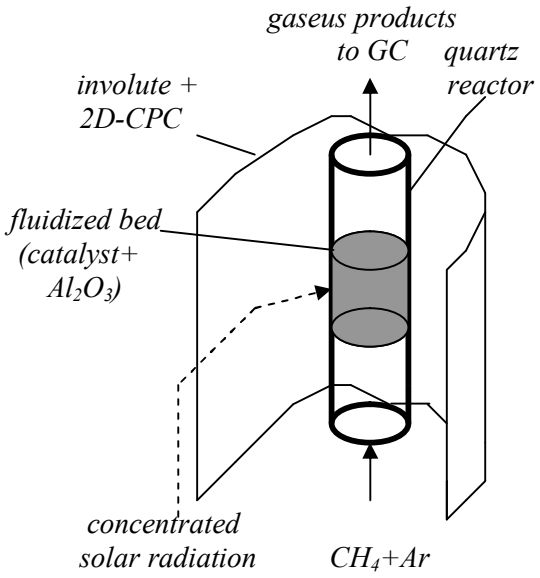

Figure 3.

The solar receiver-reactor system (Fig.3) consisted of a 2 cm-diameter quartz tube containing a fluidized bed of Ni catalyst and Al_2O_3 grains. A secondary reflector, composed of a 2D-CPC (compound parabolic concentrator) coupled to an involute, provided uniform irradiation on the tubular reactor. With this arrangement, the catalytic particles were directly exposed to the incoming high-flux solar beam. The fluidized bed was solar-heated at 850K under a flow of argon and isothermally subjected to a reacting CH_4-Ar gas flow. The outlet gas composition showed 40% chemical conversion of CH_4 to H_2 in a single pass of a 0.6 seconds through the 5 cm bed-height. The carbon obtained consisted of 1 to 2 granules being built by randomly interlaced filaments, including fibers and hollow nanotubes of approx. 30 nm diameter.

Conclusion

The solar production of fullerenes and nanotubes has the advantage of being able to use carbon source in a form of electrically conducting graphite rods as well in another forms, and uses a cost effective energy source rather than electric arc. These factors plus the ability of the solar approach to be able to separate the vaporisation and annealing zones are strong arguments in favor of the solar approach. It seems difficult to obtain great temperature with the small furnace but the possible use of the 1000 kW furnace may provide a solution to the problem of the fullerenes and nanotubes production in needed scale.

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