International Journal of Sciences

Research Article Volume 4 – August 2015 (08)

Synthesis of Carbon Nanoparticles from Polystyrene Wastes

Davood Kaviani[1], Payam Pirmohamadi[2], Majid Saghi[3], Behzad Padidaran[4], Mohammad Hosein Bigtan[5]

[1]Department of chemistry, Science and research branch, Islamic Azad University, Tehran, Iran
[2, 3, 5]Department of chemistry, Arak branch, Islamic Azad University, Arak, Iran
[4]Eeducation, Maneh and Samalqan, North Khorasan, Iran.

Abstract: There are various methods for the synthesis of carbon nanoparticles. Each laboratory uses one of them depending on its abilities and available tools. Adding nanoparticles, especially Nano carbons, to some materials changes their behaviours. For example, adding carbon to iron matrix leads to an increase in its compressive strength and adding carbon to plastics results in a remarkable increase in their thermal resistance. Therefore, synthesis of such compounds from the wastes is a good achievement. The purpose of this study is the synthesis of carbon nanoparticles from the wastes (disposable containers made of polystyrene) using the designed reactor and heat system. In the used reactor, as high pressures and temperatures above 700 ºC are used along with appropriate catalysts for different periods, all of the materials lose their macro structures and fragment into Nano-size particles. Each of the mentioned conditions is optimized with each other and type of initial materials. The effects of different parameters such as time, catalyst quantities, and the ration of polystyrene to catalyst available on the obtained particle sizes have been investigated. Time and catalyst ratio are the fundamental parameters in this method. The carbon nanoparticles that we have extracted from disposable containers also helps the environment and reduces the recycling costs of polystyrene wastes.

Keywords: Carbon nanoparticles, synthesis, polystyrene waste, disposable containers

1. Introduction

Plastic polymers make up a considerable portion of the volume of wastes produced across the world. In 2004, about 20 million tons of plastic wastes were produced in Europe (1). For years, researchers have been looking for various ways to overcome the problems of such large quantities of wastes. On the other hand, carbon nanotubes (CNTs) are materials with extraordinary physical and chemical properties which often have energy and resource intensive production processes (2). Carbon nanotubes are also used in the production of electric appliances that magnetic field emitters (3). In recent years, some researchers have suggested the idea of using such wastes as the carbonaceous feed of carbon nanoparticle production.

To this end, this paper deals with the extraction of carbon nanoparticles from polystyrene wastes such as disposable containers. For this purpose, an experimental procedure has been set up. It aims to reach nano-scale particles using the heat method (by adjusting the temperature). Iron and nickel were used as catalysts. Two inert gas including argon and nitrogen were used in the reactor. In this study, the effects of several parameters on the sizes of the obtained carbon nanoparticles are investigated including the effects of time, temperature, pressure, catalyst, and polystyrene wastes.

2. Materials and methods

A solution with a solubility of 6.04 g $Fe(NO_3)_2$ in distilled water was prepared. In addition, a solution of 0.25 molar $Ni(NO_3)_2$ and Al_2O_3 were prepared in weights of 7.27 g and 2.55 g, respectively.

The used reactor has two gas inlets made of titanium and one gas outlet at the end connected to a pressure indicator. This reactor can operate at high pressures. Its internal pressure can reach 5 bar. The reactor is located within a furnace. The temperature of the furnace is adjusted up to 900 ºC. Argon and nitrogen were used in the reactor as the atmosphere.

The pH of the solutions was measured by Lab-827 pH meter equipped with a synthetic glass electrode.

Published at: http://www.ijsciences.com/pub/issue/2015-08/
DOI: 10.18483/ijSci.797; Online ISSN: 2305-3925; Print ISSN: 2410-4477

Davood Kaviani (Correspondence)
davood.kaviani@gmail.com
+98-935-0640578

VGT-1730QTD ultrasonic bath made in ULTRA company was used for the homogenisation of the prepared solutions and dispersion and prevention of formation of colloidal particles.

2.1. Catalyst preparation

To prepare the used catalyst, 0.25 molar aqueous solutions of $Fe(NO_3)_2$ and $Ni(NO_3)_2$ were prepared. The pH of this solution was fixed at 9 by adding 1 molar NaOH droplets. The prepared solution was placed in an oven of 125 ºC for 300 minutes to become dry. The precipitates were then washed. Finally, the obtained precipitate became dry in the environment and powdered in a mortar so that its particles become completely homogeneous and uniform. The obtained solid powder was then filtered by a 120 mesh sieve. Fig.1 shows the prepared catalyst.

Fig. 1: The prepared catalyst.

2.2. Sample preparation

First of all, the wastes must be collected. In this study, the wastes used are polystyrene disposable containers such as paper cup, disposable water bottles, etc. The wastes were fragmented by scissors into strip shape pieces so that we can put them in the quartz tube into which the materials are poured. The quartz tube placed inside the reactor is 60 cm long and 2.5 cm in diameter. It can tolerate high temperatures without any change or destruction in its structure.

The catalyst was poured into the quartz tube to be spread all over the tube. The polystyrene strip slices were then put on it such that they spread in all over the materials. The important note is that the polystyrene amount must be more than the catalyst. In fact, at the start of the synthesis process, the polystyrene began to burn and supplied the carbon source. The temperature was adjusted by the controller to reach the chosen temperature without any more temperature tolerance. The outlet valve of the reactor was open in order to prevent oxdation. After compete exit of the air from the reactor, the outlet valve was closed and the inlet valve was open for gas entry. The created pressure inside the reactor must be controlled during the process. This is done in different times, temperatures, pressures, and polystyrene-catalyst ratios. This causes the compounds miss their macro structures and becomes nanoparticles. The obtained nanoparticles were collected after each sampling and a little amount of them were placed in a test tube and its volume was increased to 5 mL and 0.01 mL surfactant was added to it. It was then placed in the ultrasonic device for 30 minutes to be mixed and the particles became separated. The prepared solution was then checked under the light microscope to see that whether the colony sample is created or not and how the articles lie beside each other. If the sample particles lie beside each other regularly, they are measured approximately and the best sample is prepared for easurement by the electronic microscope.

3. Results and discussion

In this study, we are going to synthesize carbon nanoparticles from disposable wastes. The heat method was applied via the designed reactor. The used catalyst was a combination of Ni and Fe on an aluminium oxide basis

The carbon nanoparticles are synthesized by chemical precipitation method in catalytic vapor phase (CCVD) in the presence of Ni and Fe catalysts on an aluminium oxide basis.

The sampling was begun from 600 ºC to 900 ºC and the effects of all temperatures on the particle sizes were investigated. 850 ºC was selected as the fixed temperature. At 900 ºC, the quartz tube lost its initial state. Fig. 2 shows the effect of temperature on particle size.

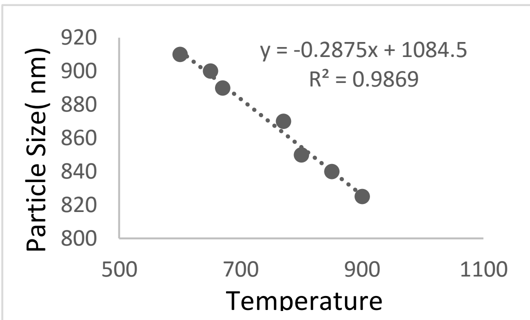


Fig. 2: The effect of temperature on particle size.

Fig. 3 shows the investigated effect of time of the particle size.

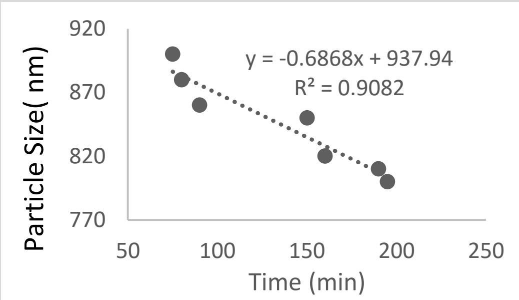


Fig. 3: The effect of time on particle size.

As shown in Fig. 4, the pressure was selected between 1 to 5 bar. The effect of the pressure on particle size was investigated and finally 4 bar was set as the fixed pressure. The quartz tube lost its initial state at pressures higher than 4 bar.

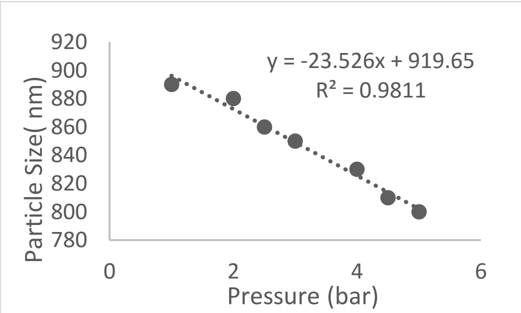
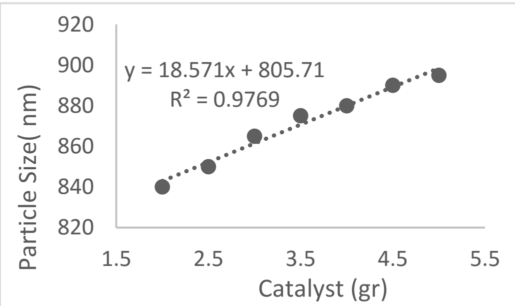


Fig. 4: The effect of pressure on particle size.

The effect of the catalyst amount on particle size is

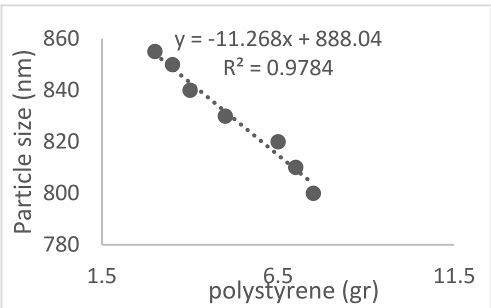


also demonstrated in Fig. 5.

Fig. 5: The effect of the catalyst on particle size.

Different amounts of polystyrene were used in the experiment. The effect of polystyrene content on the particle size is illustrated in Fig. 6.

Fig. 6: The effect of polystyrene on particle size.



Since in this study two inert gases including nitrogen and argon have been applied and time, amount of polystyrene wastes and catalyst are used as the variable parameters, the three mentioned variables have been determined separately for the best case of the inert gases. The best case is when the particle sizes are the finest and there is no aggregation.

3.1. The effect of time on nitrogen samples

To determine the optimum time for nitrogen, the sampling was started from 3 hours to 9 hours. As illustrated in Fig. 7, an increase in heating time leads to a decrease in particle size. According to the energy consumption, 9 hours time is enough for the particles to reach nano-sizes (it is the optimum time for the inert gas).

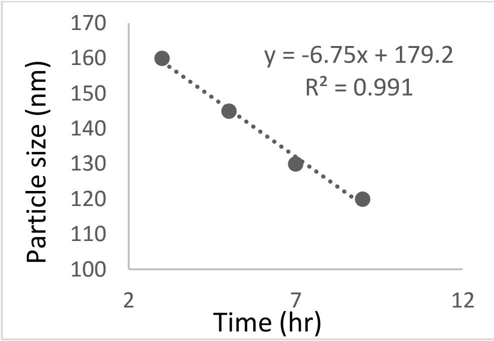


Fig. 7: The effect of time on particle size for nitrogen.

3.1. The effect of the catalyst content on nitrogen samples

To determine the optimum catalyst content for nitrogen, different amounts of the catalyst were used and their effects on the particle size were investigated. Fig. 8 demonstrates the effect of catalyst content on particle size. As the catalyst content is reduced, the particle size is also reduced.

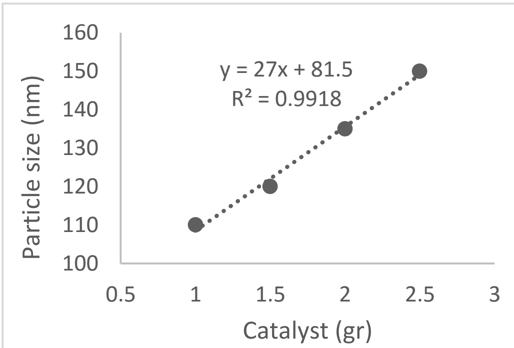


Fig. 8: The effect of catalyst content on particle size for nitrogen.

3.2. The effect of the polystyrene content on nitrogen samples

To achieve the optimum polystyrene content for nitrogen, different quantities of polystyrene were used and its effect on particle size were investigated. As shown in Fig. 9, an increase in polystyrene content results in a decrease in the particle size. This proves that the amounts of the wastes must be increased to achieve more carbon. As can be seen in Fig. 9, the particle size is smaller in the sample that has 10 g polystyrene (the optimum effect of polystyrene content).

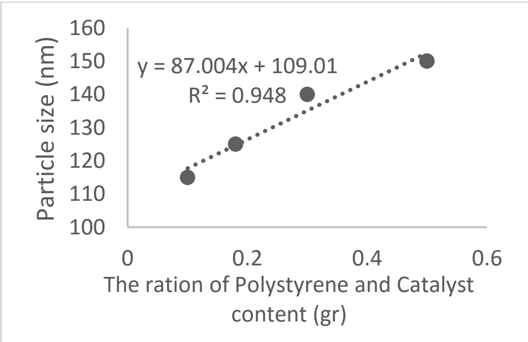


Fig. 9: The effect of polystyrene-catalyst content ratio on particle size for nitrogen.

3.3. The effect of time on argon samples

To achieve the optimum time for argon, the sampling was begun from 3 hours to 9 hours and the effect of time on particle size were investigated. The time effect of argon gave smaller particle sizes that that of nitrogen. As can be seen Fig. 10, similar to nitrogen, as the heating time for each sample increases, the particle size decreases. According to the energy consumption, 9 hours time is enough for the particles to reach the optimum size for the argon case.

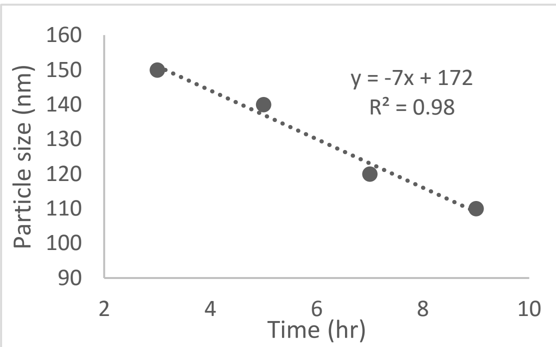


Fig. 10: The effect of time on particle size for argon.

3.4. The effect of the catalyst content on argon samples

To determine the optimum catalyst content for argon, different amounts of the catalyst were used and their effects on the particle size were investigated. Fig. 11 shows the effect of catalyst content on particle size. As the catalyst content is reduced, the particle size also decreases.

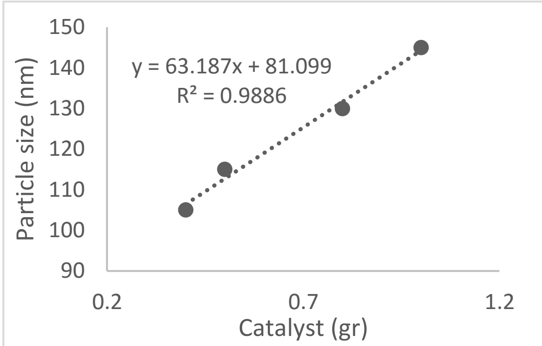


Fig. 11: The effect of the catalyst content on particle size for argon.

3.5. The effect of the polystyrene content on argon samples

To achieve the optimum polystyrene content for argon, different quantities of polystyrene were used and its effect on particle size were studied. As shown in Fig. 12, an increase in polystyrene content results in a decrease in the particle size. This proves that the amounts of the wastes must be increased to achieve more carbon.

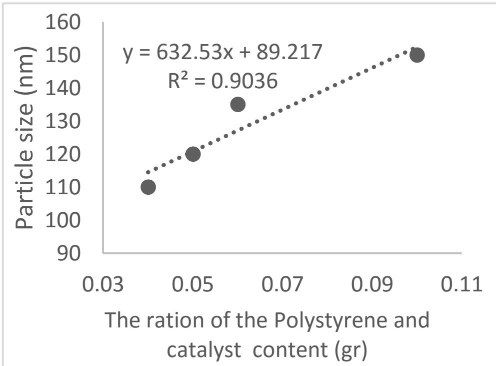


Fig. 12: The effect of polystyrene-catalyst content ratio on particle size for argon.

3.6.The effect of the catalyst

The results show that when the catalyst is used the obtained particle sizes are smaller that when no catalyst in used. In fact, the catalyst reduced the energy of bond breakage. As argon is a more inert gas, the particle obtained in argon case were finer than those in nitrogen case.

4. Conclusion

Various processes have been presented for the production of carbon nanoparticles from wastes. The increasing problem of waste streams, coupled with the potential benefits and profits coming from carbon nanoparticles has made the possibility of producing these high value products from the seemingly useless waste stream attractive. The findings of literature show that such an endeavor is achievable through a large variety of reactor types and process set-ups.

In this study, an experimental procedure was set up to synthesize carbon nanoparticles from polystyrene wastes such as disposable containers. Two gases, nitrogen and argon, were used in the experiments.

According to the samples taken and achieving the optimum conditions for argon and nitrogen samples and the particle size measured by electronic and light microscopes, we can conclude that the particle sizes for argon case, which is more inert than nitrogen, are smaller.

As nanoparticles behave differently from the masses of the same material, we could extract valuable materials called carbon nanoparticles from polystyrene wastes such as disposable containers. As adding nanoparticles to the matrix of other materials changes their behaviour completely, it is useful to synthesize these materials and submit them to the researchers who want to investigate the effects of these particles for other materials. The reactor used in this research can be used to synthesize other nanoparticles. However, it is clear that the conditions must be changed for each nanoparticle type apart from carbon. It should also be noted that the work done in this study helps the environment and decreases the recycling costs of polystyrene wastes such as disposable containers.

5. References

1. APME, **2004**, *Good Practices Guide on Waste Plastics Recycling: a Guide by and for Local and Regional Authorities*, Association of Plastics Manufacturers in Europe, Brussels
2. A. Bazargan, G. McKay, *Chemical Engineering Journal*. **2012**, 195-196, 377-391.
3. R. Saito, M. Fujita, G. Dresselhaus, M.S. Dresselhaus, *Phys. Rev*. **1992**, 46, 1804.