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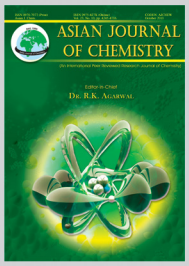

Effects of Synthesis Reaction Temperature, Deposition Time and Catalyst on Yield of Carbon Nanotubes

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Fluidized bed chemical vapour deposition (FBCVD) has been introduced promising method for carbon nanotubes (CNTs) synthesis because of its large scale, low cost and high yield production. However, there is no clear relation between synthesis parameters and carbon nanotubes growth. Therefore, more data investigations are required for FBCVD synthesis of carbon nanotubes. This research intend to investigate the effects of some synthesis parameters namely reaction temperature, catalyst loading and deposition time on FBCVD growth of carbon nanotubes. In present study, carbon nanotubes were synthesized through decomposition of acetone over a prepared catalyst, iron and molybdenum supported on alumina. After each run the product was characterized using scanning electron microscopy, transmission electron microscopy, thermo gravimetric analysis and energy dispersive X-ray spectroscopy. Besides that the effects of parameters on carbon deposition yield were statistically studied using analysis of variance (ANOVA). The results demonstrated that the ideal reaction temperature was about 750 ºC, by increasing to 950 ºC more amorphous carbon was observed due to deactivation of catalyst at high temperature. It was also observed that by increasing the deposition time, the yield of carbon nanotubes had decreased and by increasing the catalyst loading the yield and quality of carbon nanotubes had increased.

Key Words: Synthesis Carbon nanotube, Fluidized bed, Chemical vapour deposition, Carbon nanotubes.

INTRODUCTION

In recent years, many techniques have been used to produce carbon nanotubes. The chemical vapour deposition in fluidized bed appears a promising method for carbon nanotubes (CNTs) synthesis because of large scale, low cost and high yield production. Low cost is important in commercial use, so this method is economically good for carbon nanotubes production[1]. Fluidized bed chemical vapour deposition (FBCVD) is a method through which we can control growth condition and synthesize a large quantity of carbon nanotubes. Also, in a fluidized bed reactor, because the heat and mass transfer is done well, uniform temperatures within the bed and rapid gas-solid interactions are allowed. In addition, continuous operation is possible[2-6]. There are still many problems such as synthesis parameters that require more research. See *et al.*[7] reported that there is no clear relation between synthesis parameters (reaction temperature, deposition time, catalyst loading) and carbon nanotubes growth. Therefore, many studies are needed to control FBCVD synthesis of carbon nanotubes. Large scale and low cost in production of carbon nanotubes still needs further investigation. This research describes the synthesis of carbon nanotubes through decomposition of acetone over the prepared catalyst Fe-Mo/AL_2O_3 in a fluidized bed reactor. Our research is a parametric study investigating the effects of reaction temperature, catalyst loading and deposition time on carbon nanotubes growth. Scanning electron microscope, transmission electron microscopy and thermogravimetric analysis were the analytical equipments used in this study to analyze and characterize carbon nanotubes.

EXPERIMENTAL

There are two steps in FBCVD technique for synthesis of carbon nanotube: catalyst preparation and actual reaction.

Catalyst preparation: Catalysts are usually prepared on a substrate, in this study Al_2O_3 as a substrate and Fe-Mo as a catalyst were used. The right amount of alumina powder was added to a solution of iron nitrate [$Fe(NO_3)_3 \cdot 9H_2O$] and $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$ ammonium molybdate. The weight ratio of iron to molybdenum to alumina[8] Fe:MO:Al_2O_3 is 9:1:5.

Carbon nanotubes synthesis: The experimental apparatus for nanotubes growth is presented in Fig. 1. The main body of the reactor is a vertical 316 stainless steel cylinder. Its dimensions

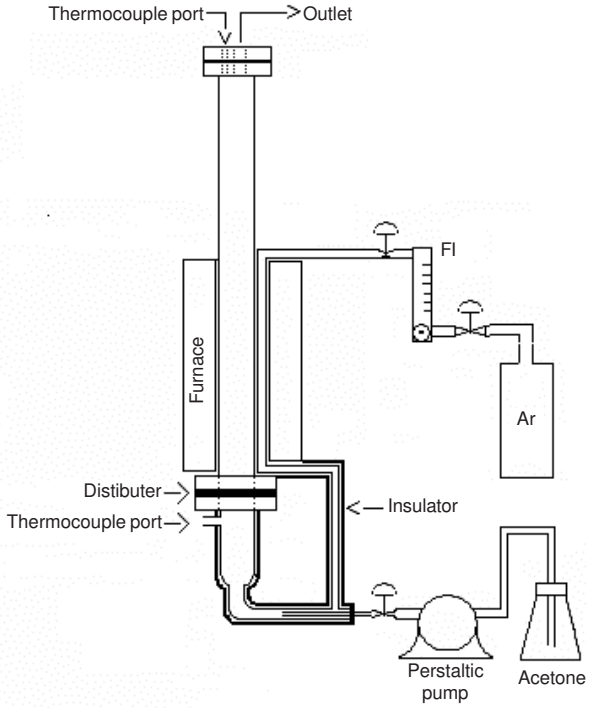

Fig. 1. Schematic of fluidized bed for carbon nanotube synthesis [Ref. 10]

are 53 mm internal diameter and 1000 mm in height enclosed by an electrical furnace, the gas distributor is a stainless. The gas distributor also is the floor, which supports the weight of the solids before they are suspended in a fluid flow. In this experiments, catalyst was placed into the reactor and argon gas with 1.4 L/min ratio was introduced into the bottom vessel of the reactor and then passes through the gas distributor and finally flows out into the atmosphere. When the fluidized-bed reached the desired temperature, acetone vapour was supplied by the argon flow that was preheated with using the main body of furnace. Therefore, acetone vapour was injected by the flow of argon into the reactor. Reaction occurs within the catalyst particles which are the sites of growing carbon nanotube. Reaction occurs within the catalyst particles which are the location of growing carbon nanotube. Both the catalyst and carbon nanotube were smoothly fluidized until desired duration time (30, 40 and 50 min) in the reactor. As a result the acetone was decomposed over the catalyst to form carbon nanotubes. At the end of each run, the electric furnace was turned off and argon stream was flowed through the reactor while it cooled down to room temperature. After reaction, the morphology and microstructure of the carbon nanotubes were observed in their state using SEM. The exact amount of carbon deposit formed during the reaction is determined by weighing the catalyst before and after reaction. The yield of deposited carbon is obtained from the total weight of the catalyst after the reaction by subtracting the initial weight of the catalyst before reaction. Process carbon yield based on the amount of deposited carbon during the reaction is obtained from the following formula:

$$\text{Carbon yield (\%)} = \left[\frac{(m_{tot} - m_{cat}}{m_{cat}}\right] \times 100$$

where m_{cat} is the initial amount of the catalyst before reaction) and m_{tot} is the total weight of the product after reaction[9].

Statistical analysis: One-way analysis of variance (ANOVA) was used to determine the difference between samples, using SPSS software. Duncan test was used to carry out the difference of means between pairs. And Hsu's test was used to determine the best level of sample with $p < 0.05$.

RESULTS AND DISCUSSION

The experimental results of synthesized carbon nanotubes by fluidized bed chemical vapour deposition (FBCVD) method at different reaction temperature, deposition time and catalyst loading are discussed in this chapter. We carried out systematic studies on investigating the effects of three influential parameters and their interactions, on the resulting carbon yield and carbon nanotubes yield.

Effect of synthesis parameters on carbon nanotubes growth: In this section carbon nanotubes were synthesized using FBCVD and effects of important process parameters (deposition time, catalyst loading and reaction temperature) on FBCVD synthesis of carbon nanotubes were investigated. Results from each run were carefully studied based on SEM and TGA observations.

Deposition time: The effect of deposition time was investigated on carbon and carbon nanotubes yield in this part of experiments. It was shown that deposition time plays an important role in carbon nanotubes growth[11,12]. There is an optimum deposition time that beyond this, nucleation becomes more difficult and deactivation of the catalytic nanoparticles starts to occur continuously. Still there are no clear relations for prediction of optimum time of chemical vapour deposition[12]. The values for all parameters, including carbon source flow rate, temperature, carrier gas flow rate and mass of catalyst, was fixed in this set of runs. Accordingly, 5 g of Fe_Mo/Al_2O_3 as a catalyst was loaded in the reactor and furnace temperature was set at 750 °C. Acetone flow rate of 1.5 mL/min and carrier gas (argon) with flow rate of 1.4 L/min were applied. Using these conditions, three different runs were conducted with deposition time of 30, 40 and 50 min.

Fig. 2 demonstrates the effect of deposition time on carbon yield. The significant effect of deposition time on carbon yield is evident. However, based on the information presented in Table-1 (Fig. 2), there is linear trend between reaction rate and deposition time and an increase was observed in carbon yield with increasing of deposition time. Since the catalyst activation requires more time[2], 70 % carbon yield was formed when deposition time was 0.5 h. The carbon yield reaches a maximum 98.19 % carbon yield on 40 min and 99.5 % carbon yield on 50 min deposition time.

TABLE-1
EFFECT OF DEPOSITION TIME ON THE CARBON YIELD

Deposition time (min)	30	40	50
Product weight (g)	8.5	9.91	9.97
Carbon yield (%)	70	98.19	99.5

Qualitative characterization of the carbon deposits formed over the metal particles in different deposition time by the FBCVD process was performed by scanning electron micro-

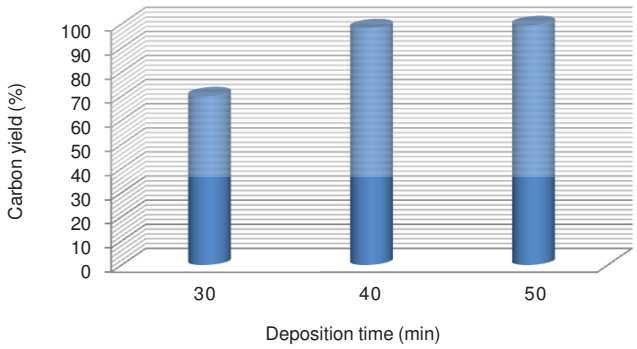

Fig. 2. Effect of deposition time on carbon yield

scope (SEM). SEM images of deposited carbon synthesized in the fixed condition of 5 g catalyst at 750 °C whereas deposition time were different, 30, 40 and 50 min, are displayed in Figs. 3-5, respectively. It can be observed that there are good qualities of carbon nanotube at 40 min deposition time. Beyond that the carbon nanotubes decreases with increasing of deposition time, this observation can be attributed to catalyst deactivation that the metal nanoparticles availability is limited[13], as a result, a decrease was observed in the rate of nanotubes growth. Most carbon in the production is amorphous carbon and uncatalyzed acetone.

It is observed that there are several significant trends regarding carbon nanotubes quality. The SEM images indicate that the trend toward carbon nanotubes formation under 30 and 50 min duration time is almost low. It shows that the product was included amorphous carbon and carbon fiber when deposition time was 0.5 h. Since that the catalyst doesn't have

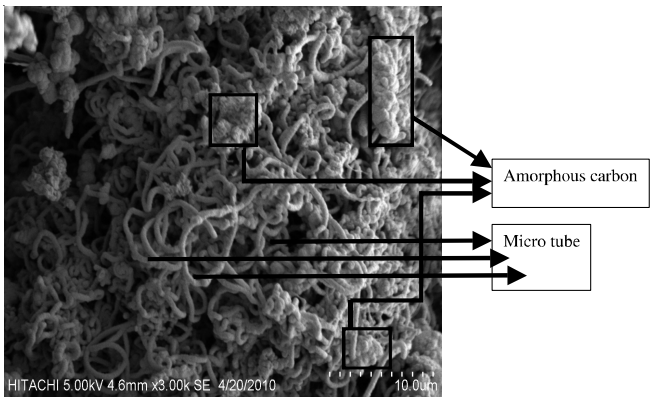

Fig. 3. SEM image of carbon nanotubes synthesized with 30 min

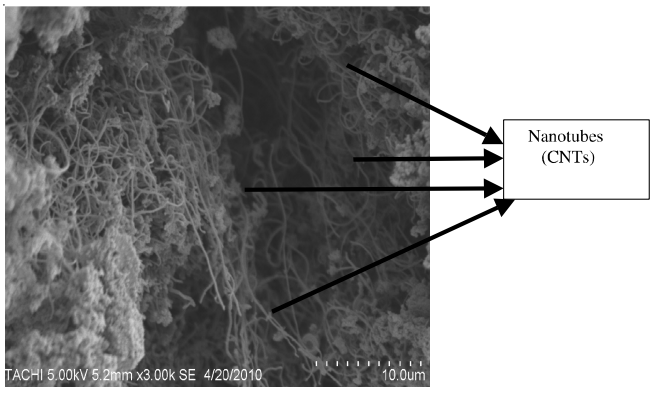

Fig. 4. SEM image of carbon nanotubes Synthesized with 40 min

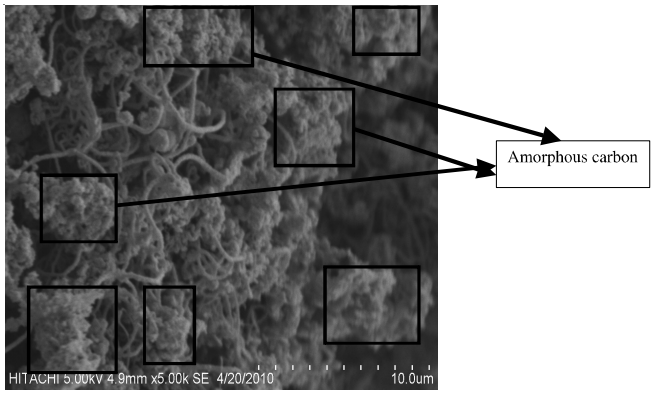

Fig. 5. SEM image of carbon nanotubes Synthesized with 50 min

enough time for activation and needs more time before the optimum time so, synthesized carbon nanotubes is little. Beyond the optimum time we have deactivated catalyst, so very little carbon nanotubes were synthesized. The SEM images indicate that the trend toward carbon nanotubes formation under 40 min duration time is almost high, only small traces of amorphous carbon are observed on the outer surface of some of the nanotubes.

Table-2 summarizes the results obtained for effect of deposition time on carbon yield from the analysis of variance (ANOVA) at a 95 % confidence interval ($p < 0.05$) in SPSS software. These results indicate that the deposition time has a significant effect on the weight and carbon yield. A p-value (0.0001) < 0.05 shows a statistically significant effect. The mean values of two replication of each run for the three time levels, indicate that as the time level increased (from 30-50 min), so varied carbon yield as follows (0.5 h: M = 70; 40 min:M = 98.19; 50 min: M = 99.5). This result was shown the overall difference in the carbon yield between three levels. The standard deviation is a value that tells us how closely all the various data point are clustered around the mean in a set of data. A large standard deviation indicates that the data points are far from the mean and a small standard deviation indicates that they are clustered strongly around the mean. In this set we have small standard deviation so; the data points are clustered closely around the mean.

TABLE-2
ANOVA RESULT FOR EFFECT OF DEPOSITION TIME ON CARBON YIELD

	Mean	Std. deviation	p-Value
Model	–	–	0.0001
30 min	70.00	0.7011	–
40 min	98.19	0.7015	–
50 min	98.50	0.7021	–

*A p-value < 0.05 shows a statistically significant effect.

Thermogravimetric plots were used to differentiate carbon yield from carbon nanotube yield. The TGA test was carried out with 50 mL/min sweep of air from 30-1000 ºC by heating rate of 10 ºC/min. See *et al.*[7] have reported that the oxidative temperature range for carbon nanotubes were between 420-620 ºC. Previous workers[7,14,15] have reported that oxidative temperature was around 330 ºC for amorphous carbon. The TGA graphs are as shown in Fig. 6. In this figure, it can be

seen that the graph at 40 min has more weight loss (low residual mass) than other samples and the oxidization temperature is between 500-600 ºC. This result indicate that the trend toward carbon nanotubes formation under 30 and 50 min duration time is almost low. The amount of residual mass after reaction in TGA is included of catalyst particles (iron, molybdenum) with oxygen. The EDX graph is as shown in Fig. 7. The EDX graph of synthesized with Fe_Mo/Al_2O_3 in 40 min deposition time at 750 ºC reaction temperature revealed that large amount of carbon surrounded by iron particles.

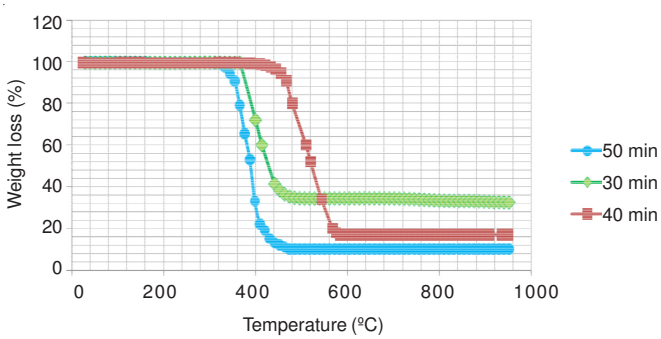

Fig. 6. TGA graph of samples

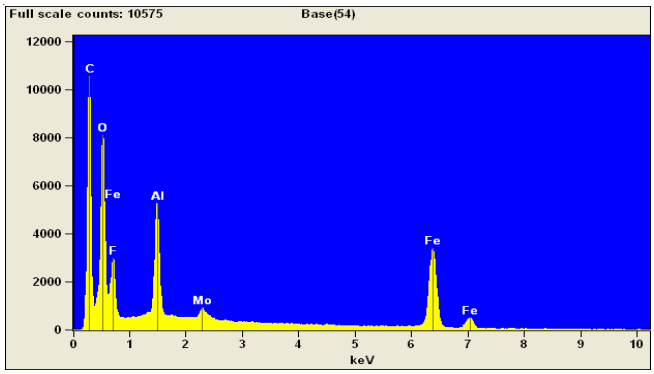

Fig. 7. EDX graph of carbon nanotubes synthesized with 40 min at 850 ºC

Catalyst loading: Amount of catalyst is an important factor in FBCVD synthesis of carbon nanotubes. Since the amount of catalyst loading to the bed height indicates the quality of fluidization, the amount of catalyst loading in the reactor has an effect on carbon nanotubes formation and other fluidization condition[12].

In this set of experiments, three different amount of catalyst (5, 10 and 15 g) was employed. Other operating conditions were: synthesis temperature of 750 ºC, 40 min deposition time, acetone as a carbon source with rate of 1.5 mL/min, carrier gas (argon) with rate of 1.4 L/min and Fe-Mo/Al_2O_3 as a catalyst. Table-3 presents the results of the amount of carbon yield.

TABLE-3
EFFECT OF CATALYST LOADING ON THE CARBON YIELD

Catalyst loading (g)	5	10	15
Weight (g)	9.91	15.5	19.54

To make the comparison more understandable, Fig. 8 demonstrates the effect of catalyst loading on carbon yield. The significant effect of catalyst loading on carbon yield is evident. However, based on the information presented in Table-3 (Fig. 8), there is a roughly linear relationship between reaction rate and catalyst loading. As a result, a decrease was observed in carbon yield with increasing of catalyst loading.

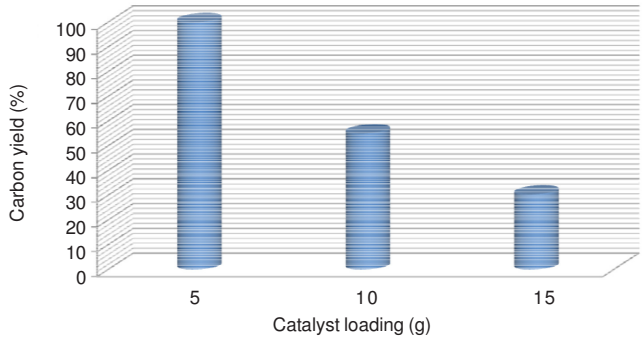

Fig. 8. Effect of catalyst loading on carbon yield

These results show that there is overall difference in the carbon yield between the three catalyst levels. Qualitative characterization of the carbon deposits formed over the metal particles in different deposition time by the FBCVD process was performed by scanning electron microscope (SEM). SEM images of deposited carbon synthesized in the fixed condition of 750 ºC (reaction temperature and 40 min deposition time are whereas catalyst loading were different, 5, 10 and 15 g, are displayed in Figs. 9-11, respectively.

It is observed that there are several significant linear trends regarding carbon nanotubes quality. The SEM image indicates that the trend toward carbon nanotubes formation is decreasing from 5-15 g catalysts loading. However, it is concluded that

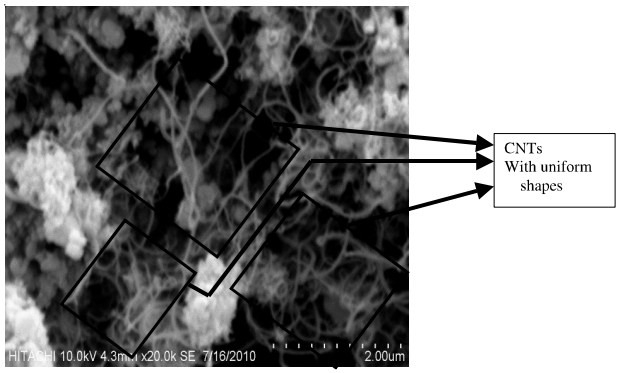

Fig. 9. SEM image of carbon nanotubes synthesized with 5 g at 750 °C

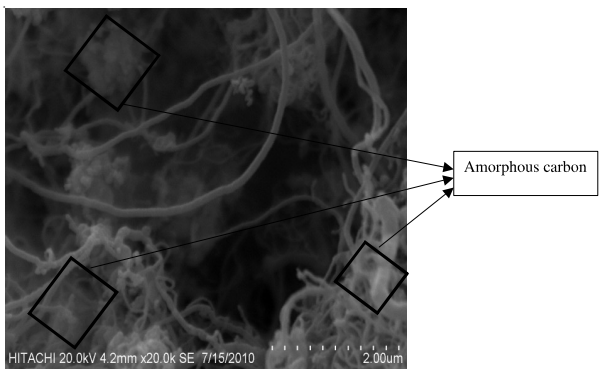

Fig. 10. SEM image of carbon nanotubes synthesized with 10 g at 750 ºC

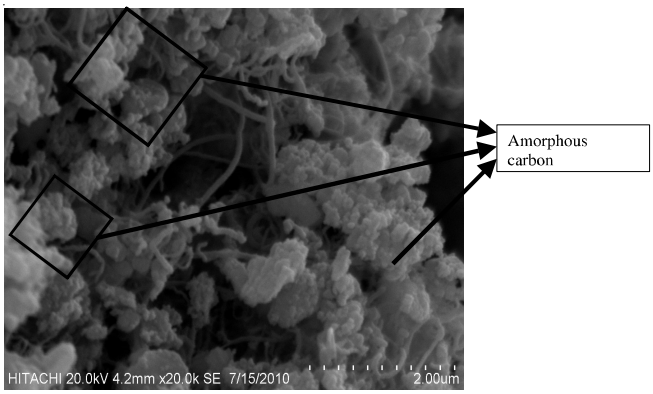

Fig. 11. SEM image of carbon nanotubes synthesized with 15 g at 750 ºC

large amount of catalyst need to high flow rate of gas and more space for better homogeneous condition so this study observed weak fluidization quality at large amount of catalyst. Subsequently, in small amount of catalyst loading the fluidized bed has enough space and more contact surface between catalyst-carbon source furthermore sufficient flow rate of gas so the images shown better quality of carbon nanotubes and more carbon yield[16].

Table-4 summarizes the results obtained for effect of catalyst loading on carbon yield from the analysis of variance (ANOVA) at a 95 % confidence interval ($p < 0.05$) in SPSS software. Based on the results of the one way ANOVA the catalyst loading that was used in this study, has the effect on the both (weight and carbon yields) significantly. (A p-value < 0.05 shows a statistically significant effect). The mean values of two replication of each run for the 3 time levels indicates that as the catalyst level increased (from 5-15 g), so varied carbon yield as follows (5 g: M = 98.19; 10 g: M = 55; 15 g: M = 30.33). These results was shown that the overall difference in the carbon yield between three levels. The standard deviation is a value that shows various data point are clustered around the mean in a set of data. A large standard deviation indicates that the data points are far from the mean and a small standard deviation indicates that they are clustered strongly around the mean. In this set we have small standard deviation thus the data points are clustered closely around the mean.

TABLE-4
ANOVA RESULT FOR EFFECT OF CATALYST LOADING ON CARBON YIELD

	Mean	Std. deviation	p-Value
Model	–	–	0.0001
5 g	98.19	0.07111	–
10 g	55.00	0.70711	–
15 g	30.33	0.12568	–

*A p-value < .05 shows a statistically significant effect.

To differentiate carbon yield from carbon nanotube the yield obtained in TGA was used. The TGA was carried out with 50 mL/min sweep of air from 30-1000 ºC by heating rate of 10 ºC/min. See *et al.*[7] have reported that the oxidative temperature range for carbon nanotubes were between 420-620 ºC. Previous authors[7,14,15] have reported that oxidative temperature was around 330 ºC for amorphous carbon.

The TGA graphs are shown in Fig. 12. Graphs in Fig. 12 shows that for 10 and 15 g we can see that the oxidization temperature is less than 500 ºC, it shows that there are many amorphous carbon in the samples and for 5 g catalyst loading has more weight loss and the oxidization temperature is between 500-600 ºC. This result indicates that the trend toward carbon nanotubes formation is decreasing from 5-15 g catalysts loading. The amount of residual mass after reaction in TGA is included of catalyst particles (iron, molybdenum) with oxygen. The EDX graph of carbon nanotube synthesized with 5 g at 750 ºC revealed that large amount of carbon surrounded by iron particles (Fig. 13). All mentioned observations obviously show the different behaviours of the catalytic particles of different diameters.

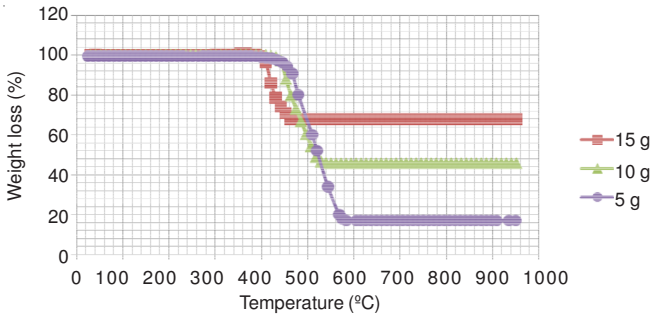

Fig. 12. TGA graph of samples

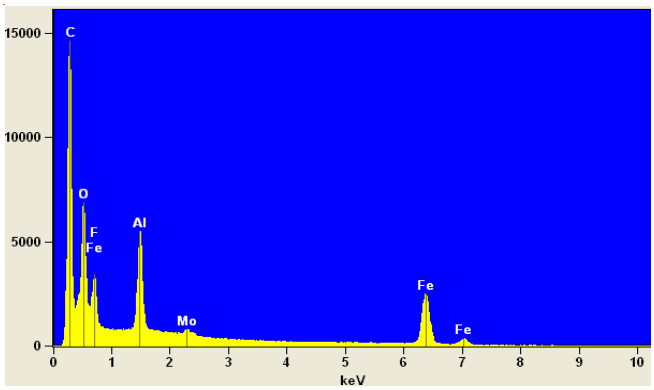

Fig. 13. EDX graph of carbon nanotubes Synthesized with 5 g at 750 ºC

Reaction temperature: Temperature is well known parameter in synthesis of carbon nanotubes. It was found that the starting reaction temperature for FBCVD is 550 ºC. It was reported that no carbon nanotubes were produced[17] below 550 ºC and for maximum temperature the conclusions are different[2,17-19].

Five different temperatures (T = 550, 650, 750, 850 and 950 ºC) were examined for carbon nanotubes growth in FBCVD under following fixed conditions: deposition time 40 min and 5 g catalyst (Fe-Mo/Al_2O_3), acetone as a carbon source with rate of 1.5 mL/min and one carrier gas (argon) with rate of 1.4 L/min. Table-5 indicates the amount of carbon yield using different reaction temperatures.

TABLE-5
EFFECT OF TEMPERATURE ON CARBON YIELD

Temperature (ºC)	550	650	750	850	950
Weight (g)	7.5	8.9	9.91	8.7	9.90
Carbon yield (%)	50	78	98.19	74	98.06

To make the comparison more understandable, Fig. 13 demonstrates the effect of reaction temperature on carbon yield. The significant effect of reaction temperature on carbon yield is evident. However, based on the information presented in Table-5 (Fig. 14), there is no linear trend between reaction rate and reaction temperature.

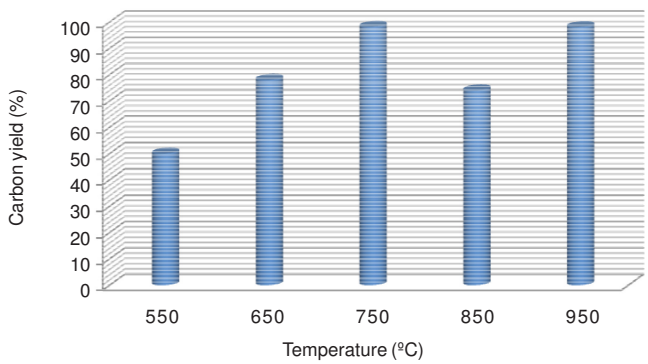

Fig. 14. Effect of reaction temperature on carbon yield

Based on the results of the experiments presented in Table-5 and Fig. 14, the carbon yield rate at 550 ºC reaction temperature is 50 %, at 650 ºC is 78 % and for 750 ºC is 98.19 %. There is linear trend between reaction rate and reaction temperature from 550-750 ºC and the carbon yield rate increased to 98.19 % with the increase of synthesis temperature from 550-750 ºC. Therefore, at the low temperature, the low decomposition rate of acetone and very little of active catalytic sites led to the low carbon yield rate. Beyond 750 ºC some parasitic phenomena occur which are responsible for deactivation of the catalyst.

When the reaction temperature is more than 850 ºC, the deposit is included of encapsulated iron particles. Supported catalyst at high temperature partial to sintering so, larger particle sizes was obtained. Similarly, an increase of the deposited carbon yield was reported by Venegoni *et al.*[2] and Morancais *et al.*[19] in high temperature after deactivation catalyst. Based on the above result, it can be concluded that the reaction temperatures at 750 and 950 ºC is good for carbon yield and 750 ºC is favorable for high purity in the synthesis of carbon nanotubes.

Qualitative characterization of the carbon deposits formed over the metal particles in different deposition time by the FBCVD process was performed by scanning electron microscope. SEM images of deposited carbon synthesized in the fixed condition of 5 g catalyst in 40 min by different temperature from 550-950 ºC are displayed in Figs. 15-19, respectively. It is observed that there are several significant linear trends regarding carbon nanotubes quality.

Fig. 14 and SEM images (Fig. 15-19) revealed that there is linear trend between reaction rate and reaction temperature from 550-750 ºC and the carbon yield rate increased with the increase of synthesis temperature from 550-750 ºC. At 550 ºC there is small significant decomposition of carbon nanotube because the transition of carbon atoms into the catalyst is low. Beyond 550-750 ºC the amount of carbon yield continuously increases, the deposit includes of carbon nanotubes plus some encapsulated iron particles. The SEM image indicates that the trend toward carbon nanotubes formation beyond 750 ºC reaction

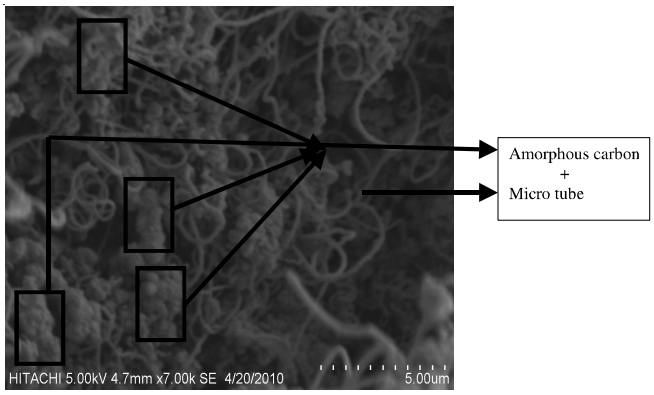

Fig. 15. SEM image of carbon nanotubes synthesized at 550 °C

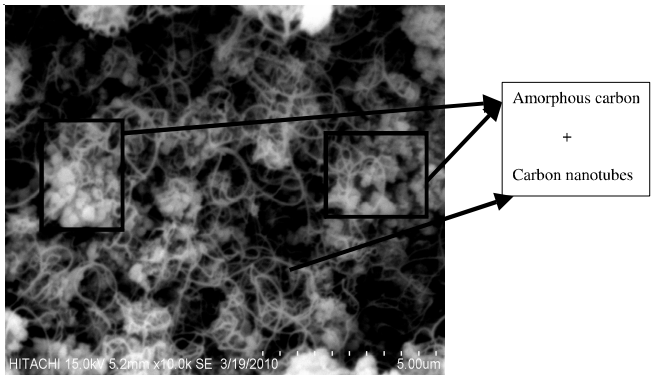

Fig. 16. SEM image of carbon nanotubes synthesized at 650 °C

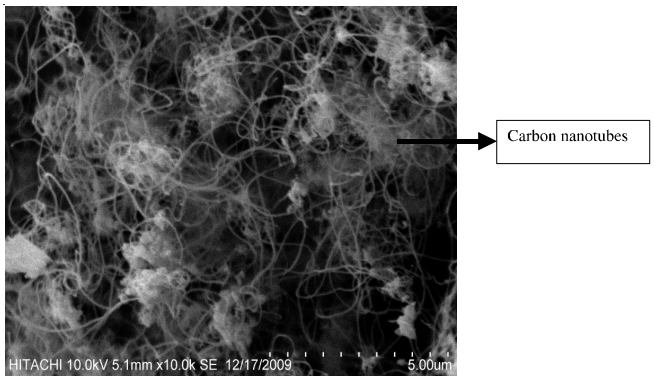

Fig. 17. SEM image of carbon nanotubes synthesized at 750 °C

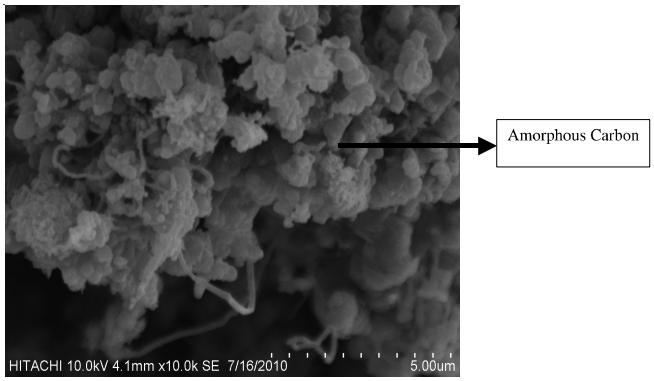

Fig. 18. SEM image of carbon nanotubes synthesized at 850 °C

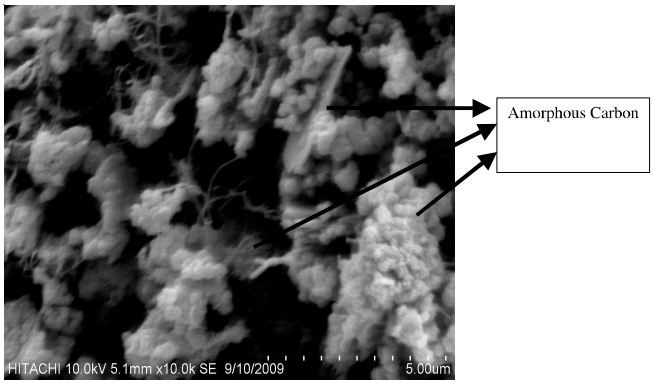

Fig. 19. SEM image of carbon nanotubes synthesized at 950 °C

temperature is decreasing. At 850 ºC we observed the presence of significant amount of encapsulated iron nanoparticles in the samples. Venegoni *et al.*[2] reported that in high temperature the supported catalyst are subjected to sintering the encapsulated. So that larger iron particle sizes are obtained that this large iron particle formed are not active for carbon nanotube growth so after 750 ºC strong decrease of the carbon yield is accrued. At 950 ºC we have uncatalyzed acetone decomposition plus many encapsulated iron particles[2,19].

Table-6 summarizes the results obtained for effect of reaction temperature on carbon yield from the analysis of variance (ANOVA) at a 95 % confidence interval ($p < 0.05$) in SPSS software. Based on the results of the one way ANOVA the reaction temperature that was used in this study, has the effect on the both (weight and carbon yields) significantly. (A p-value < 0.05 shows a statistically significant effect).

TABLE-6
ANOVA RESULT FOR EFFECT OF TEMPERATURE ON CARBON YIELD

	Mean	Std. deviation	p-Value
Model	–	–	0.0001
550 ºC	50.00	0.35350	–
650 ºC	78.00	0.70711	–
750 ºC	98.19	0.70711	–
850 ºC	74.00	0.56560	–
950 ºC	98.06	0.63640	–

*A p-value < 0.05 shows a statistically significant effect.

The mean values of two replication of each run for the five different temperatures indicates that since the temperature levels increased (from 550-950 ºC), so the carbon yield are increased from (950 ºC: M = 98.06; 750 ºC: M = 98.19; 650 ºC: M = 78; 550 ºC: M = 50; 850 ºC: M = 74). This result shows that the yield of carbon related to the temperature and there are overall differences in the carbon yield between the five levels. The standard deviation is a value that shows various data point are clustered around the mean in a set of data. A large standard deviation indicates that the data points are far from the mean and a small standard deviation indicates that they are clustered strongly around the mean. In this set, we have small standard deviation so; the data points are clustered closely around the mean.

To differentiate carbon yield from carbon nanotube, the yield obtained in TGA was used. The TGA was carried out with 50 mL/min sweep of air from 30-1000 ºC by heating rate of 10 ºC/min. See *et al.*[7] have reported that the oxidative temperature range for carbon nanotubes were between 420-620 ºC. Previous workers[7,14,15] have reported that oxidative temperature was around 330 ºC for amorphous carbon.

Fig. 20 shows the TGA graphs of synthesized carbon nanotubes at 40 min deposition time and 5 g catalysts loading. It can be seen the amount of oxidization temperature at 750 ºC is between 420-620 ºC so, this result indicates that the trend toward carbon nanotubes formation from 550-750 ºC reaction temperature is increasing. The TGA graph of reaction temperature at 950 ºC, illustrate that the oxidization temperature is less than 420 ºC it concluded that we have more amorphous carbon because the amorphous carbon usually started to burn in temperature of less than 420 ºC. This conclusion is consistent with the observation from SEM. To differentiate carbon yield from carbon nanotube yield using TGA. The amount of residual mass after reaction in TGA is included of catalyst particles (iron, molybdenum) with oxygen. The EDX graph of carbon nanotube synthesized with 5 g at 750 ºC revealed that large amount of carbon surrounded by iron particles (Fig. 21). All mentioned observations obviously show the different behaviours of the catalytic particles of different diameters.

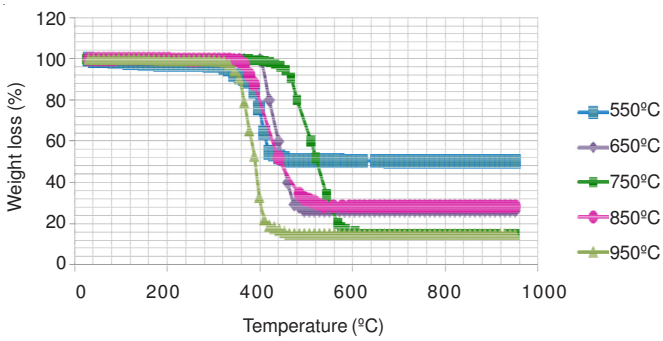

Fig. 20. TGA graph of all the samples in this set of experiments

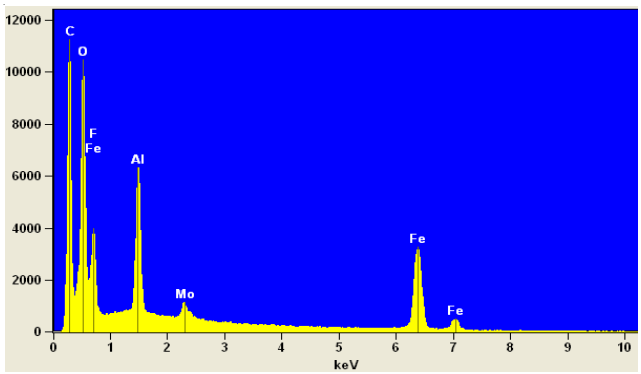

Fig. 21. EDX graph of carbon nanotubes synthesized with 5 g at 750 ºC

Conclusion

Present work was done in the fluidized-bed reactor with good heat and mass transfer coefficients that allows uniform temperatures within the bed and rapid gas-solid interactions. Also in this fluidized bed reactor, before the introducing acetone into the reactor, liquid form of acetone was transformed to its vapour by the argon flow. That argon gas was preheated with using the main body of furnace. Therefore, acetone vapour was injected by the flow of argon introduced

into reactor. So, these unique properties of fluidized bed make low cost and large scale synthetic production. Present work demonstrates the effects of synthesis temperature, deposition time and catalyst loading on carbon and carbon nanotubes yield in FBCVD. Carbon nanotubes were synthesized on a Fe-Mo bi-metallic catalyst system supported on Al_2O_3. The product was analyzed by SEM, TGA and EDX. The results demonstrated that the ideal reaction temperature was about 750 ºC, by increasing to 950 ºC more amorphous carbon was observed due to deactivation of catalyst at high temperature. The best amount of catalyst loading and deposition time in carbon nanotubes synthesized were about, 5 g and 40 min, respectively. It was also observed that by increasing the deposition time, the yield of carbon nanotubes had decreased and by increasing the catalyst loading the yield and quality of carbon nanotubes had increased.

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