SYNTHESIS OF CARBON NANOPARTICLES FROM ACTIVATED CARBON USING CO_2 LASER ABLATION

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ABSTRACT

In this work, carbon nanoparticles were synthesized from activated carbon by using the continuous CO_2 laser ablation at atmospheric pressure. The obtained carbon nanoparticles were characterized by scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). The influences of the laser power and ablation time on the particle size were investigated. The results show that the spherical carbon particles were produced with the particle size between 136–2880 nm.

KEYWORDS: *CO_2 laser; Carbon nanoparticles; Activated carbon*

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INTRODUCTION

Carbon nanomaterials are the most popular field for researchers because of their unique properties such as excellent electrical conductivity, good corrosion resistance and enhanced chemical compatibility [1, 2]. They have been used in many applications such as polymer composites, catalysis supports, oil and gas absorbents and hydrogen storage [3–7].

Various methods such as arc discharge, chemical vapor deposition and laser ablation have been used for synthesis carbon nanostructures [8–10]. For laser ablation, the pulsed laser is generally used but it is expensive laser mechanism. The continuous wave CO_2 laser, on the other hand, is much lower in its cost than the pulsed laser. Therefore, this latter technique is possible alternative use of laser for the synthesis of carbon nanomaterials.

In this work, carbon nanoparticles were synthesized by the continuous wave CO_2 laser ablation and using activated carbon as the target. The properties of the synthesized nanoparticles were investigated by means of scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) analysis.

MATERIALS AND METHODS

Carbon nanoparticles were synthesized at atmospheric pressure by using continuous CO_2 laser ablation. The experimental setup is illustrated in Fig. 1. The CO_2 laser (Reci) is the continuous wavelength type with the maximum power of 80 W. The laser beam has a 3 mm diameter with the typical wavelength of 10.6 μm. The laser tube was supplied by CO_2 laser power supply (Jinan Zhenyu, model MYJG-80W). To control the laser power the current of power supply was adjusted. The power meter (Yongli, model HLP-200) was used to measure the laser power output. The target material used in this experiment is the activated carbon which can be purchased from typical pharmacy (Fig. 2).

In this work, the influences of laser power and ablation time on the properties of nanoparticles were investigated. In the experiment, the laser power was varied at 10 W, 20 W and 30 W with fixed ablation time at 15 second. In order to study effect of the ablation time, the target was irradiated by the 20 W laser power with the variation of time duration at 5, 10 and 15 seconds.

The morphology and elements characterization of the synthesized nanoparticles were observed by SEM (JEOL model JSM-5410LV) and EDS (OXFORD), respectively.

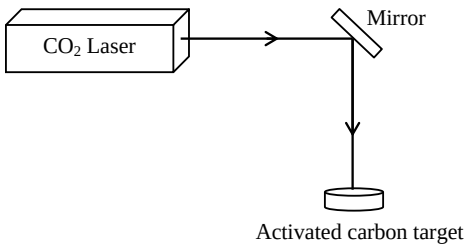


Fig. 1 Diagram of the experimental setup.

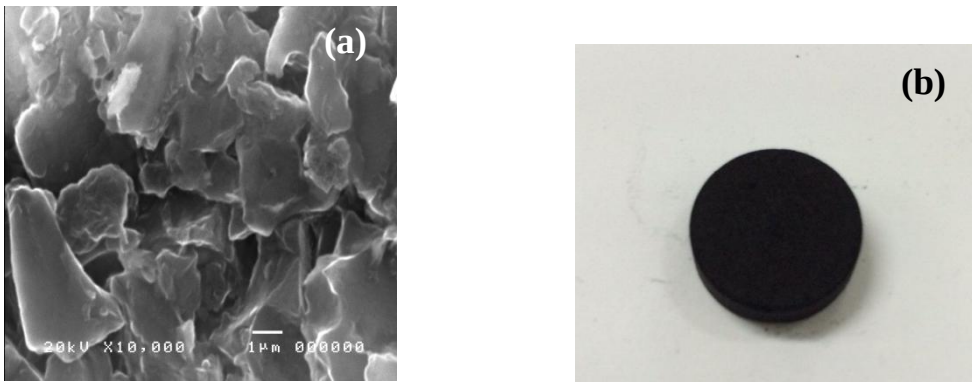


Fig. 2 (a) SEM image of initial activated carbon target. (b) Photograph of the activated carbon target.

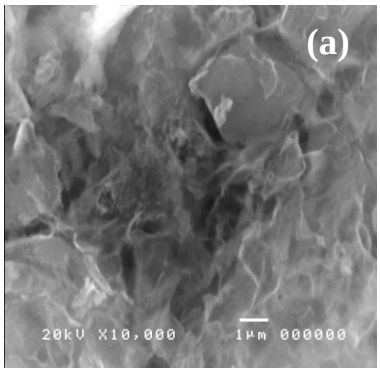
RESULTS AND DISCUSSION

During the ablation process, the target surface was found to be melted when the target was irradiated by the laser beam. When the laser radiation was stopped, the temperature in the melting area was decreased after which the particles with spherical shape were formed. The formation of particles into the spherical shape is due to the fact that the sphere has the least surface tension compared to the other shapes with the same volume. The resulting parameters of synthesized carbon nanoparticles at different conditions are shown in Table 1.

Table 1 Experimental conditions and results

Laser power (W)	Ablation time (s)	Particles size (nm)			
		Maximum	Minimum	Average	Standard deviation
10	15	no particles formation			-
20	15	1680	144	401	286
30	15	2880	280	1213	752
20	5	728	136	302	131
20	10	1280	136	336	236

The synthesized carbon particles from varying laser power at the equal ablation time (15 second) are shown in Fig. 3. There was no particle formation at the 10 W laser power because the power was not high enough to melt the target surface. When the laser with 20 W was applied, the sphere particles in the order of nanometer were created. The average particles size was about 401 nm. Finally, for the 30 W, the experiment showed larger sphere particles compared to those obtained from the 20 W laser power. The average size of particles was 1213 nm. The results revealed that, the average particles size was increased with the increasing of laser power.



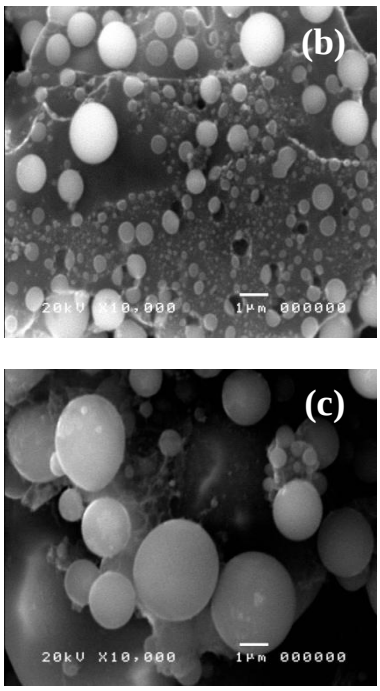
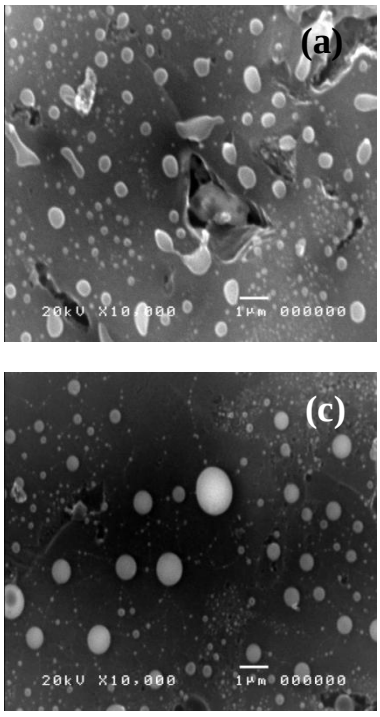


Fig. 3 SEM images of carbon nanoparticles which were synthesized at different laser power (a) 10 W, (b) 20 W and (c) 30 W.



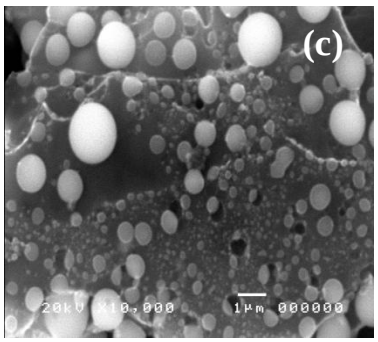


Fig. 4 SEM images of carbon nanoparticles which were synthesized at ablation time of (a) 5 second, (b) 10 second and (c) 15 second.

Fig.4 shows the obtained carbon particles at different ablation times of 5, 10 and 15 second with the fixed 20W laser power. The results show that for the shortest ablation time (5 second) the small particles were created. For the longer ablation time (10 and 15 second), the larger particles were formed. The particles sizes were increased as the ablation time was extended. The long ablation time produces the large melting target volume which also creates the large particle sizes. The average particle sizes are 302 nm, 336 nm and 401 nm for the ablation time of 5s, 10s and 15s, respectively.

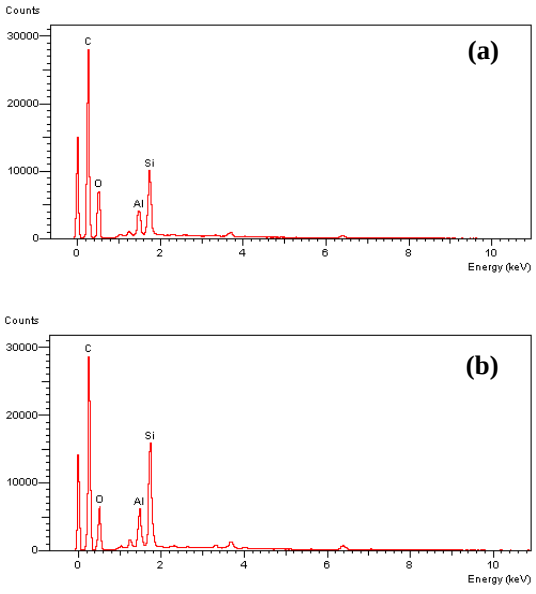


Fig. 5 EDS pattern of (a) activated carbon target, (b) carbon nanoparticles.

In order to characterize the elements of the studied samples, the EDS measurements were performed. The results are presented in Fig.5. The sample that was synthesized at 20 W laser power and ablation time of 20 second was chosen for the EDS analysis. The EDS spectra showed the most intense peaks of carbon (60.74%), oxygen (30.27%), aluminium (2.4%) and silicon (6.57%) from the synthesized nanoparticles which is very close to the EDS result from the activated carbon target which was composed of carbon (59.14%), oxygen (34.36%), aluminium (1.84%) and silicon (4.66%).

CONCLUSION

This work proposes a simple and low cost method to synthesize carbon nanoparticles from activated carbon by using CO_2 laser ablation in the atmospheric pressure. The advantage of this method is short time preparation and it does not need the vacuum system. The prepared carbon particles from this method are dry particles which is convenient for the applications in powder form. Moreover, the cost of continuous wave CO_2 laser is lower than the pulse laser. The average particle size obtained in this experiment is in the range of 302 – 1213 nm, depending on the laser power and time ablation. The small and uniform sphere particles can be obtained from the appropriate laser power and time ablation.

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