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Elimination Effect of Formaldehyde, Acetaldehyde and Total Volatile Organic Compounds from Car Felts using Nano-carbon Materials

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Abstract : We proposed the new nano-carbon ball (NCB) materials for eliminating the total volatile organic compounds(TVOCs) from the felt which is built in the car. The concentrations of acetaldehyde and formaldehyde of the original felts were varied upon the different production lots. Acetaldehyde in the felt can be eliminated to target level(0.2 ㎍) after introducing 0.5 wt% of NCB into the felt. Detector tube method for analyzing formaldehyde gas was more accurate than HPLC method. Formaldehyde can be eliminated to target level (64 ppb) after introducing 0.5 wt% of NCB into the felt. We also found that TVOC can be reduced to target level (0.32 ㎍) after introducing 2.0 wt% of NCB. Upon introducing small amounts of NCB into the felt, it was possible that the level of formaldehyde, acetaldehyde and TVOC formed from the felts can be reduced to the target level. We also suggest the effective analyzing method of TVOCs.

Keywords : nano-carbon material, aldehyde, acetaldehyde, TVOC, elimination

1. Introduction

One of the most formidable challenges posed by the increasingly severe regulations on air pollution in many countries is the search for efficient and economical materials for volatile organic compounds(VOCs). The most popular material for VOC control is the adsorption of activated carbon[1,2]. In spite of economical activated carbon has several disadvantages, such as, pore irregularity and hygroscopic property. Hence, much effort has been focused at finding alternative materials.

In 1992, a novel M41S (mesoporous molecular sieve family) was discovered[3]. MCM-41S possesses a high surface area and large pore volume with highly ordered and hexagonally packed pores. Since the pioneering reports by Japanese scientists[4], surfactant templated mesostructured materials have attracted much attention because of

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their emerging applications in catalysis, adsorption, sensors, and separations[5,6]. Polyethylene oxide (PEO) nonionic surfactants or block copolymers have been studied extensively as structure-directing agents in the synthesis of highly ordered mesostructured materials[7]. Fabrication of mesoporous materials with controllable morphologies has been one of the main subjects in this rapidly developing research field. Mesoporous materials in the form of films, monoliths, spheres, fibers, rodlike powders, and crystals have been obtained in block copolymer templating systems[8-14]. It is important to design the morphology of mesoporous materials as well as the mesostructure for desired applications. For example, mesoporous films may be used in membrane separation and gas sensing. For the particles, mesoporous spheres may be utilized in high-performance liquid chromatography as a stationary phase, while rodlike SBA-15 (Santa Barbara-15) materials possess bioimmobilization abilities for lysozymes much improved over that of conventional SBA-15 materials[15]. Many of such new porous materials, particularly ordered microporous, mesoporous and macroporous materials, respectively, are often prepared by template replication[16-18].

In the previous paper, we reported the method of synthesis of nano-carbon ball(NCB) and its possibility of applications[19]. In the present paper, the elimination capacity of NCB which was put into the automotive felt, was measured.

2. Materials and methods

2.1. Materials

NCB was kindly provided from Ecopro(Ohchang, Chungbuk, Korea). The detailed synthesis procedure was reported elsewhere[18]. Felt was provided from Feltech(Nagoya, Japan) and commercial Tedlar bags were purchased from Fisher Scientific(SKC Inc. No.:23205, USA). Theses bags had dimensions of 12 in. by 12.5 in. and were made from 2 mm thick Tedlar film with a normal capacity of 5 L. Tedlar is widely used in a variety of applications because it is generally regarded as having very little tendency to adsorb organic compounds.

2.2. HPLC analysis of acetaldehyde and formaldehyde gas

The weight of the felt was adjusted to 20 g(4 g = about 8 cm x 10 cm size = 1 TP). Five TPs(test piece) were used for the analysis. Felt samples were treated as follows: 5 L Tedlar bags were prepared for analysis; silicon chip and clamp were connected into the bag and pure nitrogen gas was filled into the bag; nitrogen gas was blown out from the bag; nitrogen gas washing process was repeated twice; small part of the Tedlar bag was cut off using scissors; then test piece was put in the bag; 4 L of pure nitrogen gas was filled into the bag; Test piece in the bag was set in dry oven and kept at 65 ℃ for 2 hours. After heat treatment, the Tedlar bag was connected into DNPH cartridge; the gas in the bag was pumped out to the cartridge by ADPEC pump (flow rate, 100 mL/min) for 40 minutes; acetaldehyde and formaldehyde in the cartridge were eluted by acetnitrile (10 mL) and analyzed by High Performance Liquid Chromatography (HPLC); and HPLC was used for the analysis of acetaldehyde and formaldehyde. The HPLC experimental conditions are shown in Table 1.

2.3. Analysis of acetaldehyde and formaldehyde gas using detector tube method

Since the formaldehyde is unstable and its concentration in the felt is lower by ppb level, we analysed acetaldehyde and formaldehyde using detector tube method.

Table 1. Analysing Conditions of HPLC

HPLC	Waters 600
Column	Alltech C_{18}, 250 ㎜× 4.6 ㎜, 5 ㎛ particles
Eluent	Acetonitrile/Water
Flow rate	1.0 mL/min
Elution	60: 40 (Acetonitrile : water) for 10 min, 100 % acetonitrile for 10 min
Injection volume	50 mL
Detector	UV @ 360㎚, photodiode array detector

Table 2. Analysing Conditions of GC-MS

GC-MS	HP5890
Column	UA-5 (60m X 0.25mm, 1.0㎛)
Flow rate	1.2 mL/min
Heat treatment (Temp.)	280 ℃
Detector	FID

Based on our experience, the accuracy was dependent on the sample treatment technique. The detector tube method was designed to analyze certain chemicals by the reaction with a special reagent filled in a thin glass tube. When air containing formaldehyde passes through the tube, the reagent will change its color in reaction to it. The color intensity is proportional to the formaldehyde concentration in the air. Therefore, we can get the concentration by comparing the color intensity with a previously prepared color chart. The detector tube method permits a simple, quick, and economical analysis at the working sites. We have increased the repeatability of the analysis of formaldehyde by this detector tube method.

The weight of the felt was adjusted to 20 g(4 g = about 8 cm x 10 cm size = 1 TP). Samples were treated as follows. At first, 1 L glass chamber was prepared for the analysis; test piece (felt) was put into the glass chamber, and the chamber was heated to 65 ℃ for 2 hours in the dry oven. After heat treatment, the chamber was cooled to room temperature (20 ℃) about 30 minutes. Finally, formaldehyde concentration was analyzed by Gastec Detecting Tube No.91LL.

2.4. GC-MS method for analysing the total Volatile Organic Compounds (TVOC)

The weight of the felt was adjusted to 4 g (4 g = 8 cm x 10 cm size = 1TP). Samples were treated as follows. Glass chamber and stainless chamber were prepared for the analysis. Pure nitrogen inlet line was connected to a side of the chamber. The other side of the chamber was the outlet and this was connected to Tenax-TA column. Mass flow controller was also connected to the inlet side of the chamber. Test piece (felt) was put into the glass chamber. Pure Nitrogen gas was introduced into the chamber. The chamber was heated to 65 ℃ for 2 hours in the dry oven. After heat treatment, all the gases adsorbed into Tenax-TA column were analyzed by GC-MS. The GC-MS experimental conditions are shown in Table 2.

3. Results and Discussion

3.1. Elimination effect of acetaldehyde and formaldehyde after introducing NCB into felt using HPLC analysis

In Fig. 1 we plotted the level of acetaldehyde and acetaldehyde of test pieces of a felt. The concentrations of acetaldehyde in the test piece varied from 0.66 μg to 1.42 μg as shown in Table 3. The average concentration was 1.075 μg/5TP. Upon the experimental results, the concentrations of acetaldehyde and formaldehyde of the original felts varied depending on the samples produced. Formaldehyde concentration of the felt samples can not be accurately estimated since the concentration was too low to be analyzed properly. The experimental error was too large to detect the gas using HPLC method.

Table 4 and Fig. 2 shows the results of NCB effects when NCB is introduced into the felt. Concentration of acetaldehyde and formaldehyde reduced as the amounts of NCB increased. Acetaldehyde in the felt can be eliminated to target level (0.2μg) after

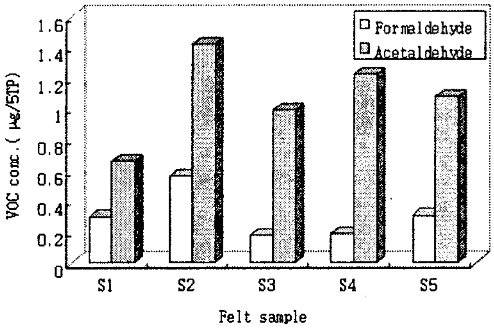

Fig. 1. Average formaldehyde and acetaldehyde level of felts.

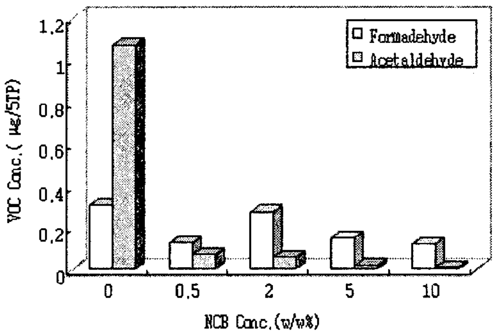

Fig. 2. Elimination effect of formaldehyde and acetaldehyde after introducing NCB into felt.

Table 3. Average Formaldehyde and Acetaldehyde Level of Felts

Felt	Felt weight(g)	Formaldehyde(mg/5TP)	Acetaldehyde(mg/5TP)
S1	20 ± 0.02	0.3	0.66
S2	20 ± 0.02	0.57	1.42
S3	20 ± 0.02	0.18	0.99
S4	20 ± 0.02	0.19	1.23
S5	20 ± 0.02	0.31	1.08

Table 4. Elimination Effect of Formaldehyde and Acetaldehyde after Introducing NCB into Felt

Sample	Felt Weight(g)	Formaldehyde (μg/5TP)	Acetaldehyde (μg/5TP)
Felt without NCB	20 ± 0.02	0.31	1.075
Felt + NCB 0.5 wt%	20 ± 0.02	0.13	0.07
Felt + NCB 2.0 wt%	20 ± 0.02	0.28	0.06
Felt + NCB 5.0 wt%	20 ± 0.02	0.15	0.02
Felt + NCB 10.0 wt%	20 ± 0.02	0.12	0.01

introducing NCB with 0.5 wt%. The accuracy of formaldehyde analysis by Tedlar bag method seems not to be enough to be discussed because of the instability of formaldehyde.

3.2. Elimination effect of acetaldehyde and formaldehyde after introducing NCB into felt using detector tube method

Table 5 and Fig. 3 shows the results of formaldehyde concentration of felt. The experimental error was reduced as compared with HPLC method. The concentrations of formaldehyde in the test piece varied from 200 ppb to 340 ppb. NCB was introduced into the felt for reducing the VOC. The results were shown in Table 6 and Fig. 4. Formaldehyde can be eliminated to level (64 ppb) after introducing NCB with 0.5 wt%.

Table 5. Average Formaldehyde Level of the Felt Analysing by Detector Tube Method

Felt	Felt Weight (g)	Detected conc. (ppb)
S6	20 ± 0.02	200
S7	20 ± 0.02	340
S8	20 ± 0.02	320

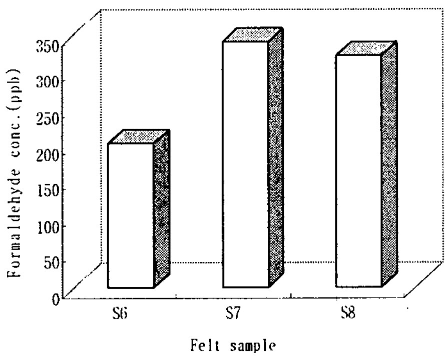

Fig. 3. Average formaldehyde level of the felt analysing by detector tube method.

Table 6. Elimination Effect of Formaldehyde after Introducing NCB into Felt

Sample	Felt Weight(g)	Detected conc.(ppb)
Felt without NCB	20 ± 0.02	340
Felt + NCB 0.5 wt%	20 ± 0.02	70
Felt + NCB 1.0 wt%	20 ± 0.02	30
Felt + NCB 2.0 wt%	20 ± 0.02	0

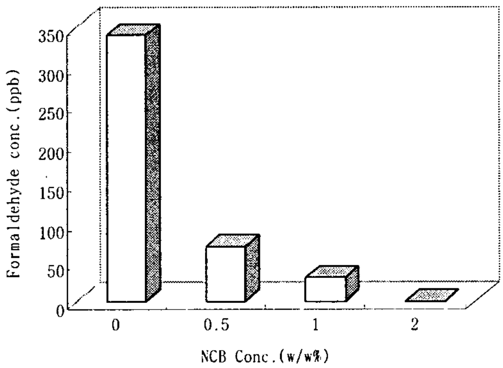

Fig. 4. Elimination effect of formaldehyde after introducing NCB into felt.

3.3. Elimination effect of total volatile organic compounds (TVOC) after introducing NCB into felt using GC-MS Method

For analyzing the TVOC, two kinds of collecting chambers were tested. TVOC levels of felt in the glass chamber and the stainless chamber were 8.00 ㎍ and 8.49 ㎍, respectively as shown in Table 7 and Fig. 5. Glass chamber system has been used for further analysis. In Table 8 and Fig. 6, the reducing effects of TVOC were shown as introducing NCB. TVOC can be reduced to below 0.32 ㎍ per 1TP after introducing NCB with 2.0 wt%.

Detector tube and GC-MS method for analyzing formaldehyde gas was more accurate than HPLC method. From the above the results, detector tube and GC-MS method can be used for analyzing TVOCs.

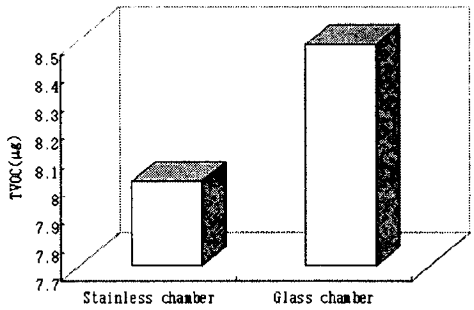

Fig. 5. Average TVOC level of the felt analysing by GC-MS.

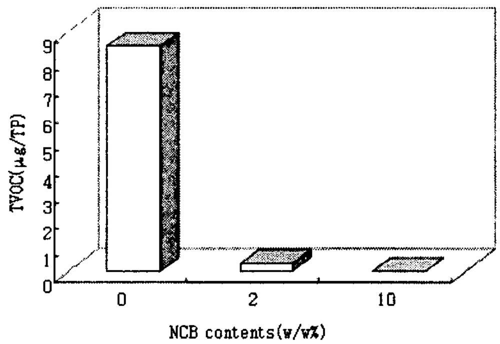

Fig. 6. Elimination effect of TVOC after introducing NCB into felt.

4. Conclusions

We proposed the new nano-carbon ball (NCB) materials for eliminating the total volatile organic compounds(TVOCs) from the felt which is built in the car. The concentrations of acetaldehyde and formaldehyde of the original felts varied according to the different production lots. Acetaldehyde in the felt can be eliminated to target level(0.2 μg) after introducing 0.5 wt% of NCB into the felt. Detector tube method for analyzing formaldehyde gas was more accurate than HPLC method. Formaldehyde can be eliminated to the target level (64 ppb) after introducing 0.5 wt% of NCB into the felt. We also found out that TVOC can be reduced to target level (0.32 μg) after introducing 2.0 wt% of NCB. Upon introducing small amounts of NCB into the felt, it was possible that the level of formaldehyde, acetaldehyde and TVOC formed from the felts can be reduced to the target level. We also suggest the effective analyzing method of TVOCs.

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Table 7. Average TVOC Level of the Felt Analysing by GC-MS

	Felt weight(g)	TVOC (mg/TP)
Stainless chamber	4 ± 0.01	8.00
Glass chamber	4 ± 0.01	8.49

Table 8. Elimination Effect of TVOC after Introducing NCB into Felt

Felt	Felt weight(g)	TVOC(mg/TP)	Test Method
Felt without NCB	4 ± 0.01	8.490	Glass chamber
Felt + NCB 2 wt%	4 ± 0.01	0.300	Glass chamber
Felt + NCB 10 wt%	4 ± 0.01	0.002	Glass chamber

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