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Research Article

Synthesis and Characterization of Carbon Papers

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Abstract : Porous carbons are promising for various applications from sensors to CO2 capture. This work aims to report a facile approach to synthesizing porous carbons by using cheap and sustainable materials. Porous carbons are also treated to tune the chemical and physical structure. SEM images, FTIR spectra, Raman spectra, and XRD patterns are examined to characterize the porous carbons. The treated carbon fibers showed a highly disordered structure with a large interlayer spacing. Results show that porous carbons could be applicable for different applications.

Keywords : Carbons, Filter, Structure, Characterization

1 Introduction

With the development of the technology, material scientists explore new materials for the emerging fields. Carbon materials have been widely investigated owing to their advantages. A large surface area, high robustness, high and tunable porosity, high electrical conductivity, exceptional flexibility, and easy recyclability have made carbon materials promising for many applications [1, 2, 3]. Cai et al. [2] used carbon fiber-based cloth for water decontamination and reported effective purification. Cheng et al. [4] reported efficient oxygen electrocatalysis by using carbon fibers. Shi et al. [5] reported high-performance supercapacitor electrodes by using carbon cloth. Ma et al. [6] synthesized porous carbon fibers and porous carbons with fibrous structures and showed promising results in CO_2 capture. Li et al. [7] designed a carbon-based electrochemical sensor. Yang et al. [8] prepared carbon biosensors.

Heteroatom doping including nitrogen doping is an effective strategy to increase the properties of carbon materials. Many studies reported enhanced performance after doping for various applications including but not limited to supercapacitors, adsorbents, batteries, and electrocatalysis. Nitrogen doping could tailor their electron-donor properties and provide extra active sites for pseudocapacitive interaction, thus improving supercapacitors' capacitance. Moreover, doping also changes the crystal structure and thus electrical conductivity [6, 9, 10, 11, 12]. Very few studies reported N-doped carbons by using melamine. Ozturk et al used carbon black and melamine to synthesize N-doped carbons and investigated the effect of N doping at different temperatures [13]. Tjandra et al. used graphene oxide and melamine foam [14].

Considering global warming and climate change, reducing the usage of petroleum-based materials is crucial. Moreover, there is a huge demand for low-cost and sustainable precursors for carbon materials [15, 16]. Many biomass has been used as a carbon source however cellulose is one of the most abundant in the earth [17]. In this study, cellulose paper was used as a carbon source, and free-standing carbon paper was synthesized via calcination. Melamine was used as a nitrogen source and the as-prepared carbon paper was characterized by using SEM, FTIR, XRD, and Raman spectroscopy.

2 Experimental Methods

Cellulose filter paper was used as a carbon precursor. Melamine was purchased from Merck and used as a nitrogen source. Calcination was applied in the nitrogen atmosphere at 800 ^{o}C for 2 h. Melamine was dissolved in water and applied to cellulose filter papers to tune the chemical composition as well. The free-standing carbon papers were obtained after calcination and several structural characterization techniques were used to study the porous carbon materials.

Scanning electron microscopy with EDX equipment was used to study the morphology and elemental composition of the prepared samples. Fourier transform infrared spectroscopy, Raman spectroscopy, and XRD analysis were also employed to study the chemical composition of the samples.

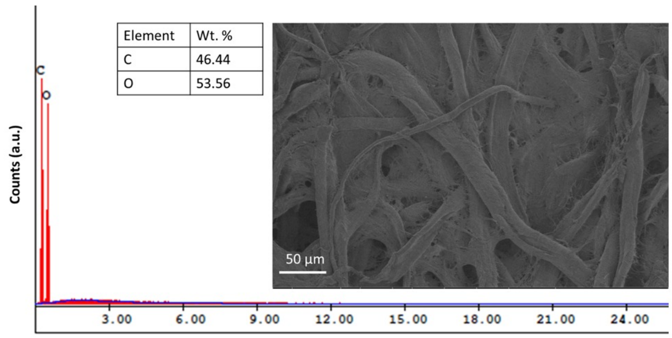

Figure 1: SEM image of the filter paper with the EDX spectra

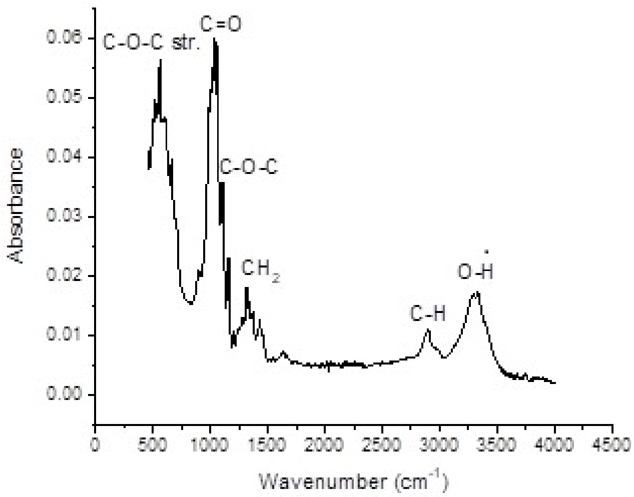

Figure 2: FTIR spectrum of the filter paper

3 Results and Discussion

Figure 1 shows the SEM image of the filter paper with the EDX spectra. A highly fibrous structure is observed which is beneficial for many applications including filtration and sensors. EDX spectra also confirm the chemical structure of cellulose.

FTIR spectrum of the filter paper is shown in Figure 2. A broad peak between 3500 and 3200 cm^{-1} corresponds to stretching vibrations of O-H presented in cellulose. The peaks approximately at 2900 and 1020 cm^{-1} are attributed to C-H and C-O stretching, respectively. The peak around 1730 cm^{-1} corresponds to C=O stretching vibrations. The peak at 1312 cm^{-1} corresponds to C-H_2 rocking vibration while the peak at 1158 cm^{-1} is ascribed to the C-O-C asymmetric valence vibration. The peak approximately at 660 cm^{-1} is attributed to C-O-C stretching related to glycosidic linkage between glucose units in cellulose [15, 18].

After successfully characterizing the structure of the cellulose filter paper, the calcination was applied to synthesize carbon paper. Figure 3 displays the SEM images of carbon paper and melamine-treated carbon papers. The fibrous structure is preserved after calcination at high temperatures and a highly porous structure was observed. Conductive and porous carbon structures are promising for sensors, supercapacitors, and filters [5, 19]. High porosity leads to rapid mass transport of species, a larger amount of electrolyte infiltration of electrolyte onto the electrode, proper electrode-electrolyte interfaces, large surface area, many active catalytic sites, continuous electron transport pathways, shorter distances for mass and ion transport, many available active surfaces, and free spaces to accommodate changes in volume [17].

The SEM image of melamine-treated carbon paper was also seen in Figure 3. Melamine treatment did not change the morphology significantly. Moreover, EDX spectra reveal that melamine-treated carbon papers have nitrogen atoms in the structure. Nitrogen in the carbon structures improves the physical and chemical properties and thus improves the performance for many applications [20].

Figure 4 shows the FTIR spectra of the carbon and treated carbon papers. The peak at around 1600 cm^{-1} corresponds to the C=C/N=C stretching vibration indicating the presence of a sp^2 hybridized honeycomb lattice, and the peak at around 1446 cm^{-1} is ascribed to the characteristic C-N stretching vibrations [21]. The results indicate that nitrogen-containing functional groups are introduced efficiently which is proved by EDX spectra, Raman analysis, and XRD pattern as well.

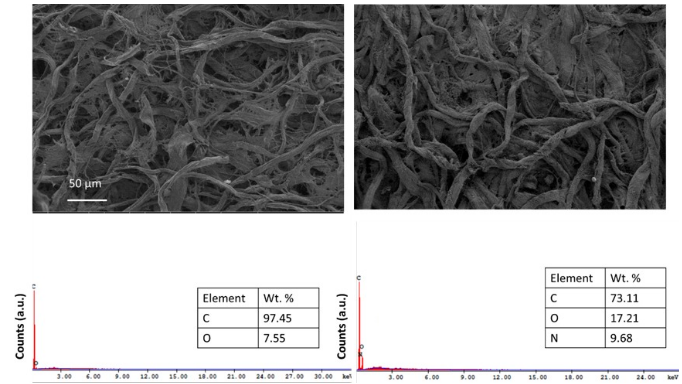

Figure 3: SEM images of the carbon paper and the treated carbon paper with the EDX spectra

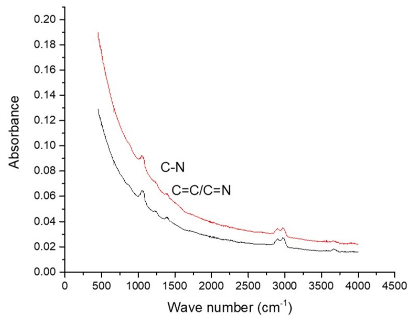

Figure 4: FTIR spectra of the carbon paper and the treated carbon paper

Raman spectra of the carbon and treated carbon are seen in Figure 5. Two peaks of D band (1366 cm^{-1}) and G band (1610 cm^{-1}) suggest that carbon paper and treated carbon paper are graphitic dominating material with disordered structure. The intensity ratio of D and G bands (I_D/I_G) is used to evaluate the degree of the disorder [10]. The intensity ratio of the D and G bands is calculated to be 0.8 and 1.0, respectively, for the carbon and treated carbon papers, indicating that melamine treatment increased the degree of disorder which is beneficial for many applications. Increased disorder level was also reported as a result of N doping by Chen et al. [22]. The increase in intensity of the D band could be ascribed to the increase of surface defects [23, 24] as a result of melamine treatment which is consistent with the EDX spectra of the treated carbon paper.

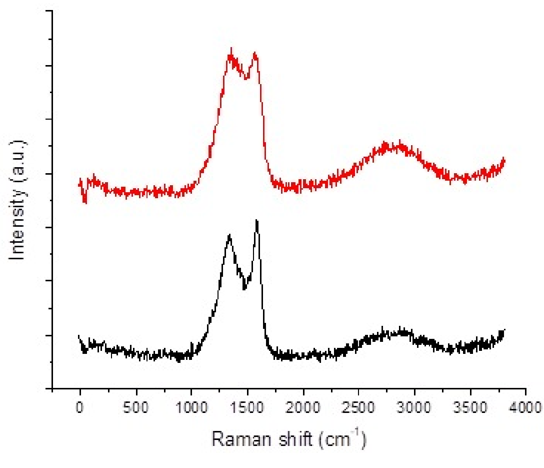

Figure 5: XRD pattern of the carbon paper and the treated carbon paper

4 Conclusion

In summary, porous carbons were synthesized by using calcination and melamine treatment. The prepared materials were characterized by using SEM, Raman spectroscopy, XRD, and FTIR analysis. The effect of the treatment on the chemical structure was shown. The degree of disorder increased after the treatment. This study shows that the chemical structure and physical properties of carbons could be easily tuned via simple and low-cost treatment to improve performance for specific applications.

Competing of Interest

The authors declare that they have no competing interests.

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