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Nanoporous Activated Carbons Derived from Peach Stones

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Abstract: In this work, nanoporous activated carbons from Peach Stone powder was achieved using phosphoric acid as an activating agent and carbonization has been conducted at temperatures ranging from 400°C to 700°C using Nitrogen as inert gas in a tubular furnace, to understand the effect of the adsorption capacity with variation in temperature. Evaluation of microporosity of each of these specimens was performed by Iodine Number technique, of which the results showed a maximum amount of micropores in the carbon at the carbonization temperature of 500°C. The morphology of the carbon samples at two extreme temperatures of 400°C and 700°C was studied using FE-SEM images, which demonstrated large amount of nanoporous in the carbon surfaces at the higher temperature. Raman Spectroscopy outcomes delineate the similar amorphous nature of the carbonaceous specimen at these temperatures with both G band and D band. These results indicate a potential to develop a good adsorbent material applicable for water purification.

Key words: Activated carbon, peach stones, Raman spectroscopy, iodine number, cyclic voltammetry

1. Introduction

Preparation of Activated Carbon mainly involves two steps; carbonization and activation; resulting in a wide range of processed amorphous carbon based materials with microcrystalline structure, resulting highly developed inter-particulate surface area [1]. By increasing the surface area, highly functional carbon materials can be developed which will have advance properties. These activated carbons have wide range of applications, from energy storage to water purification. Derivation of activated carbon can be from a wide range of sources but emphasis is usually given to the use of waste products. Peach (*Prunus persica*) seeds are used in this research for the production of carbon. These seeds are available in plenty in Nepal but rarely utilized to the extent of being marketable. Peach stones are agricultural by-products that are currently of no economic value, and have a hard lignocellulosic material shell that gives them the potential to be used as raw materials for production of granular activated carbon [4].Various methods of activation can be achieved to enhance the physical properties and performance of the carbon. This paper presents the idea of developing chemically activated carbons from peach stones and studies the properties. Activation is done using phosphoric acid as an activating agent at various temperatures ranging from 400° C to 700° C. Characterization has been done by Iodine number, Scanning Electron Microscope (SEM) image and Raman Spectroscopy.

2. Experimental

2.1 Materials

Peach Stones collected from the market were washed, dried and powdered using a mortar, pestle and an electric grinder. Nitrogen gas of Ultra High Pure (UHP) has been used and the chemicals used were of analytical grade.

2.2 Preparation of Activated Carbon

50% concentration phosphoric acid was added to Peach Stone powder of size 300 μm and stirred continuously till the right consistency of the material was achieved. This mixture was then kept in oven with temperature maintained at 100°C for 24 hours. The charcoal was then powdered and carbonized in a tubular furnace at 400° C in inert atmosphere using UHP nitrogen. The activated carbon thus obtained was then washed and filtered. Finally, the sample was sieved and activated carbon size 106 μm (P-4) was preceded for characterization. Similarly the activated carbons were also prepared at temperature 500°C, 600°C and 700°C represented by P-5, P-6 and P-7.

Fig. 1: Experimental Setup for Preparation of Activated Carbon in a Tube Furnace

2.3 Determination of Iodine Number

Iodine Number indicates the presence of microporous structures in the activated carbon. In many activated carbons the iodine number (expressed as milligrams of iodine per gram of carbon) is close to the Brunauer-Emmett-Teller (BET) surface area [3]. The Iodine Number can be calculated as.

$$\text{Iodine number } \left(\frac{\text{mg}}{\text{g}}\right) = \text{C} \times \text{Conversion factor} \quad (1)$$

where C is the difference between Blank Reading and Volume of hypo solution consumed by adsorption of hypo solution by activated carbon. The Conversion Factor is determined from the equation (2) as:

$$\text{Conversion factor} = \frac{\text{Equivalent weight of Iodine} \times \text{Normality of Iodine} \times 10}{\text{Weight of Activated carbon} \times \text{Blank reading}} \quad (2)$$

3. Results and Discussion

3.1 Iodine Number

These iodine number values of the activated carbon sample do indicate increase in the micropore content from 400°C to 500°C. However, the iodine number values decrease after the 500°C threshold when the temperature is increased, signifying that the highest number of micropores in phosphoric acid activated carbon derived from peach stones can be obtained at the carbonization temperature of 500°C.

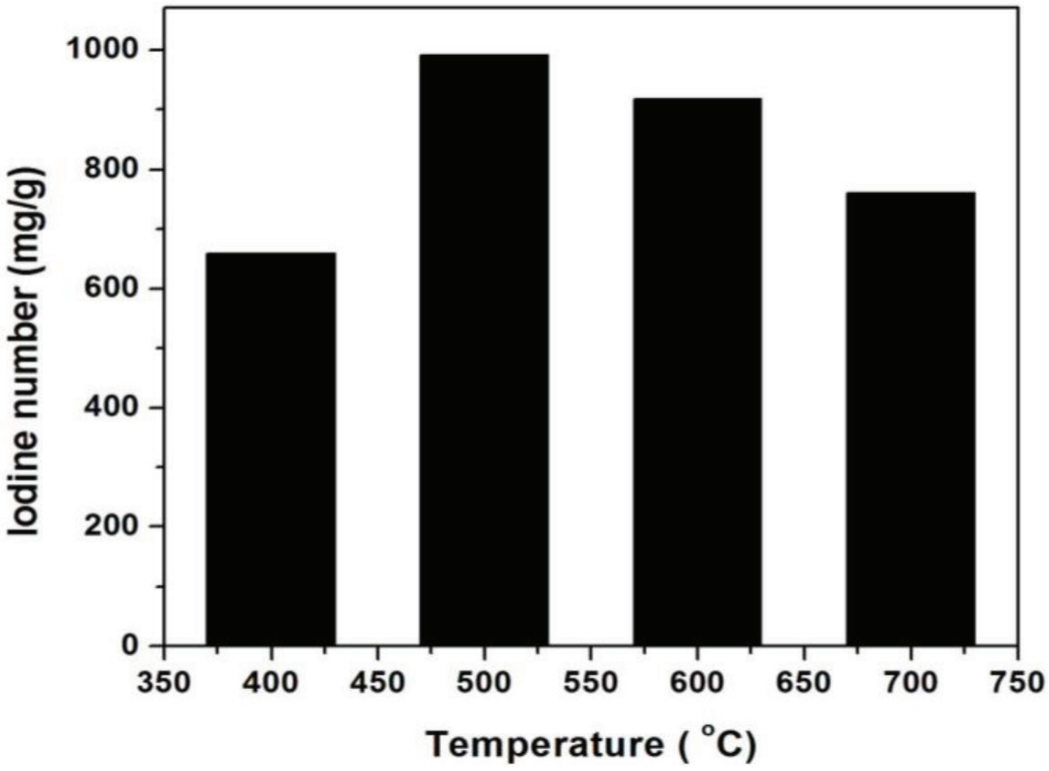

Fig. 2: Iodine number of Activated carbons

The iodine number of the activated carbon samples increases micropores from 400°C to 500°C as shown in Fig. 2. However, the iodine number decreases after 500°C signifying that the highest number of micropores in phosphoric acid activated carbon derived from peach stones can be obtained at the carbonization temperature of 500°C .The decrease in Iodine number after 500°C may be due to the deformation of micropores.

3.2 Scanning Electron Microscopic images

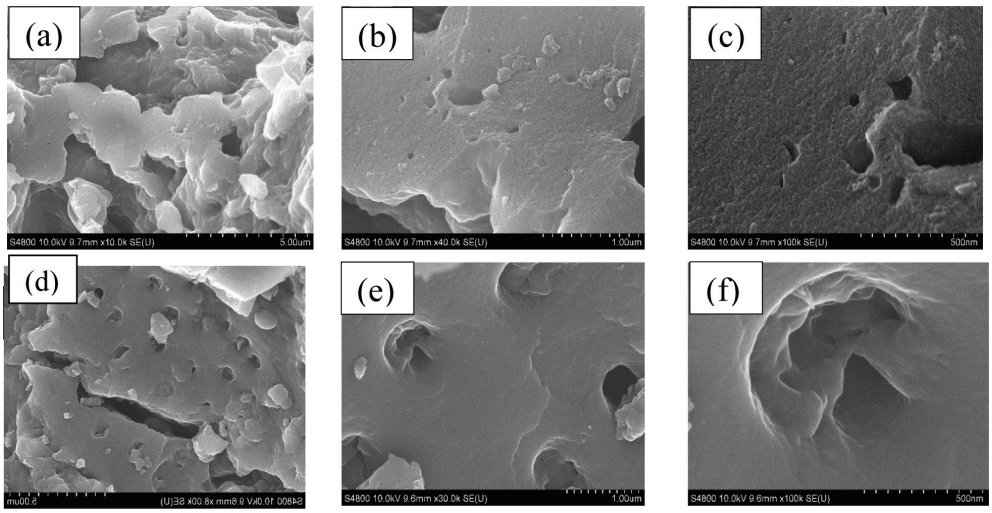

Fig. 3: FE-SEM images of P-4 Activated Carbon (a) 10K (b) 40K (c) 100K; FE-SEM Images of P-7 Activated Carbon (d) 8K (e) 30K (f) 100K

Field Emission Scanning Electron Microscope (FE-SEM) provides ultra-high resolution imaging at low accelerating voltages and small working distances [2]. Fig. 3 shows the morphological structures of the carbon samples activated at 400°C and 700°C. Observation of the images at relatively close magnifications of both samples illustrates a large development of nanopores with increase in the carbonization temperatures.

3.3 Raman Spectroscopy

Raman Spectroscopy is extremely useful in characterization of carbonaceous materials, owing to the fact that the vibration spectra of solid compounds are much simpler than the IR spectra and are characteristic to complexes existing in the material [6]. Raman Spectroscopy has the capability to distinguish very minor changes to the morphological structure making it a invaluable tool in the characterization of carbon nanomaterials.

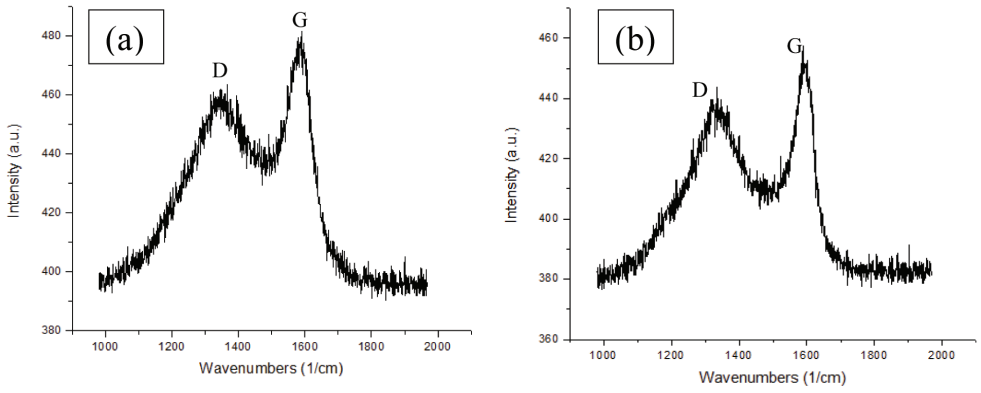

Fig. 4: Raman Spectroscopy of (a) P-4 Activated Carbon (b) P-7 Activated Carbon

The spectrum of these activated carbons display bands which shows reduction in molecular symmetry resulting in more Raman bands being active. For both samples, the Raman Spectra appear in two frequency domains, 1300 to 1650 cm^{-1}, corresponding to G and D bands, which is characteristic to carbonaceous compounds [6]. The band around 1580 cm^{-1} is known as the G band and the prominent band around 1350 cm^{-1} is known as D band. The D band is also known as disorder or defect band and in relation to the intensity of the G band indicates the quality of the carbon nano-material. The graph also identifies a large vibrational frequency of atoms and illustrates the sensitivity of Raman spectroscopy to the differences in molecular morphology, corresponding to the amorphous nature of the carbon compounds.

3.4 Cyclic Voltammetry (CV)

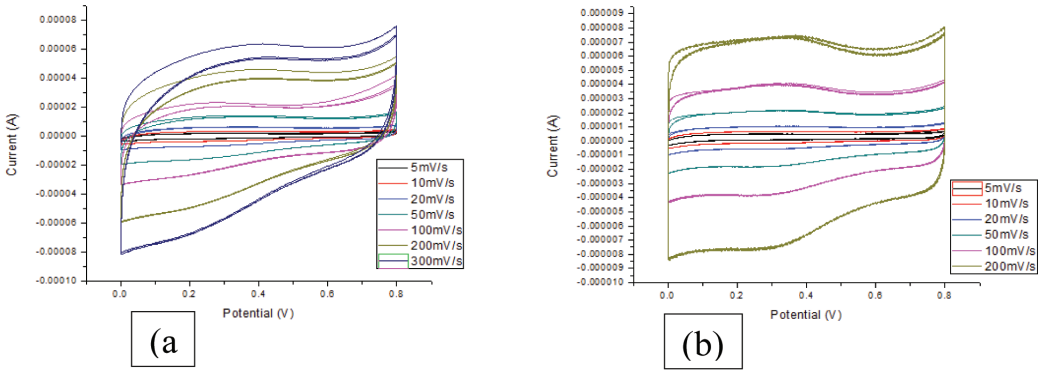

Fig. 5: Cyclic Voltammetry of (a) P-4 Activated Carbon (b) P-7 Activated Carbon

CV was carried out at scan rate of 5, 10, 20, 50, 100, and 200 mV/s between the potential range of 0 to 0.8 V. At lower scan rates a symmetrical shape is obtained about the zero current line indicating a fast reversible charge/discharge non-redux behavior as well as the consistency of adsorption and desorption of the carbon material corresponding to the symmetry at higher scan rate [5].

4. Conclusion

Activated carbon was successfully prepared from peach stones by activation with phosphoric acid and carbonization at various temperatures. Microporosity of the carbon specimen increases from P-4 to P-5, at which it is maximum, after which it decreases at a gradual rate with increase in temperature, as signified by the Iodine number. Raman Spectroscopy results illustrate the amorphous nature of the carbonaceous material. However, study of the FE-SEM results at the temperatures of 400^{o}C and 700^{o}C show a drastic increase in the nanopores of the material. Observing the FE-SEM results along with the CV graphs, the potential of adsorption capacity seems to be on the higher side with increase in the carbonization temperature for the activated carbon sample, which has the potential to be used as an adsorbent for removal of heavy metals, dyes and purification of water.

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