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A short review on preparation and application of carbon foam

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Abstract. This paper reviews about the preparation and various application of carbon foam. Some of the major preparation methods were discussed. By these processes pore size, density, porosity specific area were been controlled. Carbon foam material prepared from various methodology act to be very active material and helps in various application such as electrode, thermal energy savers, adsorbent and other microwave activities.

1. Introduction

Carbon materials are the new kind of materials provided with the wide range of pore structure because of its size, amount of pores and their surface morphologies¹. These materials usually have higher surface area and concentration of their micropores. It was attracted by the researchers to make development in these material². Currently, mesopores also plays role in developing the individual functions such as electrode, in recovering heavy oil, and biomedical liquid sorption^{3,4}. There are different morphologies in these structures. Some include granular, spherical, fibrous, tubular, platelet structures. Carbon foam has cell structure and have peculiar properties such as macropores, large surface area, high thermal stability, very light in weight, high electrical conductivities and hydrophobic in nature etc. Electrical and thermal properties may change relatively by controlling and changing their structure to amorphous. They also have nanotexture in case of bulky structure. Mainly in carbon foams, cell structure plays important role by controlling the structure and texture in the wall of macropores present in the carbon foam. This give a greater tolerance rate by controlling their bulk properties than the other carbon materials.

In carbon foam, it can be said that the macropore present in it usually surrounded by the wall which can be called as cell. The wall has two parts such as strut and cell wall. In the walls of the carbon foam both micropores and macropores are present, where macropores are said to be smaller than the other cells. In another way, carbon foam can be defined as the materials which has open cell structure where the cells are interconnected with each other through the adjoining cells called as window. In order to enhance their functions different kinds of materials can be interrupted in formation of carbon foam. In this present study, different methods of preparation were discussed by attracting how the structure is being controlled and different applications which played by the carbon foam are focused.

2. Groundwork of carbon foam

The preparation of carbon foam carries out several methods, five different methods of preparation of carbon foam were discussed below.



2.1 *Agitating the air*

The agitating procedure involve in the outcome of carbon foam. It involve in two processes. The first one is the pyrolysis under pressure and second by adding some chemical blowing agents. Previously, it was noted that the saturation made by decomposing gases in the closed vessel pursue by swift reduction in pressure where it mainly found on the pitches⁵⁻⁷. The pitches were heated in an autoclave above its softening point at constant rate for long time. During this process of heating the pressure was controlled by adding the inert gases or by built-up the pressure. Then it is cooled down to the room temperature where pressure is released. The foam which is in green colour was produced which stabilize in dry air and put in carbonization at 1000°C⁸. Meanwhile, it can be called as stabilization process. Since heat treatment is performed for long time taking foam morphology is not necessary. Similarly, high electrical and thermal conductivity found in carbon foam.

2.2. *Patterned carbonization*

Patterned carbonization is said to be the promising technique where the pore structure is being controlled by creating the pore in form of micropores, macropores and mesopores. There will be no loss by means of oxidation though particular losses can occur in the pore structure which can be controlled by activating them to produce the activated carbon. Carbon material which bears the honey comb structure have open cell structure. Most of them usually made by the polyurethane carbonization after the impregnation of epoxy resin or phenol. Their cell size and fraction can be controlled in the open cells. To improve their thermal and electrical properties it can be performed by the electroplating method⁸⁻¹². PU foams also helps in preparing the carbon foam by adding furfuryl alcohol in which 30% mass followed by 1000°C carbonization. Also, melamine foam also helps in preparation of carbon foam by adding the amic acid and get carbonized at 1000°C. In some cases the ester type PU foams were immersed in the dimethylacteamide by heating the mixture at 60°C for evaporating solvent and carbonized at 1000°C to get carbon foam^{13,14}. The converted carbon foam made to dip in the water slurry of petroleum pitch. Then it is dried by heating at 450oC under N₂ gas to form “interparticular bonded” structure. Then carbonized at 1000°C. The mesophase pitch was made to combne with the PU foam as water slurry to get stabilize in air at 350°C.

2.3. *Exfoliated graphite*

The residue compounds from the intercalated H₂SO₄ along with graphite flakes was used in producing the exfoliated graphite¹⁵. This can be used as gaskets when those graphite sheets are compressed. Due to compression the graphite sheets were used as a mold with their compacts. These were usually prepared by the graphite flakes at 500-800°C in air for 2mins to form the greater density^{16,17}. Depending on the thermal conductivity density will be increasing rapidly. Since it passes their energy in the cell wall. The density decreases with increase in the volume along with the temperature¹⁸. Rapid change will be found by changing these parameters and exploiting these flakes with the worm like particles which contain ellipsoids typed pores inside them.

2.4 *Congregation of graphene nano-sheets*

One of the new foam of foam is said to be the graphene foam where it usually consists of flexible graphene nano-sheets which were interconnected with the pore network¹⁹. The hydrophilic graphene results from oxidation, intercalation and exfoliation of graphite. These were used widely as a precursor to form the graphene foams. One method is the hydro-thermal reduction by alternate freezing and drying. Some graphene foam leads in π - π interaction²⁰. These usually forms three dimensional network in porous nature. It will eliminate the energy which was consumed during the carbonization process. These foams with pore structure can also be prepared using the droplets of water from the air²¹. Similarly, if these foam have honey comb structure which straight cell were prepared by introducing ice into it as a template.

2.5 Other methods

The formation of carbon foam results from different method. The formation of foam by interlinking the aerogel with the polymer after the process of carbonization at 800°C²². Sucrose also be one of material which helps in preparation of foam in the aqueous medium by placing in hot air oven for 24hrs at 110°C²³. Similarly, thermo effect of activated carbon in the aqueous solution of sucrose gives the carbon foam with the smaller cell size, high compressive strength and greater density²⁴. They can also be prepared by the hollow carbon and phenolic sphere with phenolic resin and alcohol carbonization²⁵. The wall of the carbon foam membrane bears ultra-low density which was prepared by the laser deposition. This had adopted for increase in thickness with the deposition of carbon foam.

3. Varied application of carbon foam

Carbon foam plays various role as electrode- it store the thermal energy and enhance the thermal property, adsorption experiment- oil, gas as a molecular sieve.

3.1 Electrode

Since 1977, reticulated vitreous carbon has been used as an electrode. It bears high porosity around 97%, low resistance to liquid flow, resistance to corrosion, higher resistance to temperature and rigid structure. This carbon has honey comb structure and used in various applications. It was used as an optically-transparent electrode that helps in electrochemical measurements also in corrosive solutions²⁵. The microgram and sub-microgram, coulombic and amperometric modes to detect nanograms, epinephrine and ascorbic acid, hydroquinone and catechol are the varied application as an electrode²⁶. It also helps in monitoring the solutions acidity as it has response in pH change in flowing streams²⁷. Act as electrolysis along ferrocyanide²⁸. The toxic pollutant from the industrial waste can be removed along H₂O₂ by acting as an electrochemical cell and has implemented in removing the formaldehyde at higher rate²⁹. These foams also used as an electrode for the electrochemical cell to store the energy. Lithium ion batteries are said to be the rechargeable cells used as anode with the propylene carbonate as an electrolyte solution³⁰. The efficiency in coulombic cell is about 60% over 20-30cycles. The capacity decreases gradually with the cycling. It was deposited on the electrode on the foam from the pitch of mesophase phase using the silica. It shows the greater performance as the electrode for the generation of supercapacitor.

The rechargeable batteries plays more vital role in redox coupling where the electrochemical reactions followed. Reticulated vitreous carbon foam electrode were studied with the V⁴⁺/V⁵⁺ in the H₂SO₄ utilizing the cyclic-disc and rotating disc voltammetry³¹. Dethroning the zinc ion on the reticulated vitreous carbon electrode were studied in the Zn-Zn cells and Zn-Br cells with an electrolyte of NaCl, KBr aqueous solution³². Some foam performed superior performance in supercapacitors, gravimetric capacitance and as an electrolyte³³. The nanoparticles onto the carbon foam also plays commercial role in the carbon supported nanofoams when carbonized at 100°C³⁴.

3.2 Storage for thermal energy

The latent heat storage phase materials were proposed with the change in materials. The solid and liquid phase make changes in the volume and are more practical also smaller than the gas-solid and gas liquid phase changes. The particles used for this thermal energy saving are known to be phase change materials. They generally divided into two major groups, as organic and inorganic compounds. Below 100°C, organic compounds involve in various benefits such as corrosive resistance, individual nucleation and to melt congruently³⁵. The graphite foam act as a thermal enhancer that contain organic material as it has high thermal conductivity. This also mainly due to lower density, chemical inertness, lower thermal coefficient. At higher temperatures inorganic salts plays good role as it bears lower thermal conductivity. This creates serious problem than the organic salts³⁶. The composite of metal foam were compared with the graphite foam. These composite metals heated from 30-70°C and cooled down quickly. The paraffin foam with the graphite foam shows the greater heat exchange with air also energy storage get reduced. The inherent heat of the composite elements is proportional to the fraction

of mass in the composite³⁷. Also, other composite can be prepared consuming the wood alloy with the graphite foam. The thermal energy saving uses the extent of latent heat in the solid-liquid phase to change the material that changes their attention towards their relation with the energy saving³⁸.

3.3 Adsorption

It was known that carbon foam has open cell structure and greater specific area can be easily activated using the activation agents. These agents helps in increasing the pores present in the outer surface of the cells. Adsorption studies the water vapor were studied on the carbon foam which was prepared from the polyurethane foams³⁹. Adsorption of vapor that generated from water could be accelerated at very low pressure. It can also be performed by additional flow of nitrogen gas at 40°C⁴⁰. Reticulated carbon foam was prepared by carbonization at 950°C using sucrose. Calcination process also helps in preparing carbo foam using the sodium chloranilate dihydrate. It adsorb the CO₂ and shows low adsorption capacity. It also act to be good recycle agent at lower temperature⁴¹. Fine TiO₂ particles also involve in producing foam acts as good adsorbent in the hydrothermal condition. These foam usually have very low density compared with other foam. They used in adsorbing the methanol where it has higher desorption enthalpy and thermal stability. Some carbon foam also said to be flexible as such as melamine foam⁴². They said to be super hydrophobicity and also has good sorption properties that involve in adsorption of liquids, beneze, dimethylsulfoxide, hexane etc. The porosity range is greater than the normal foam when it comes to be composite combination⁴³. It act as a selective adsorbent effectively by separating oil from water through the capillary and hydrophobicity actions. Subjecting the foam to the oil water mixture, oil quickly get stick over the foam within few seconds. Similarly, they play vital role in adsorbing dyes. They readily relate the surface area and charge while the performance of oil adsorption directly depend on the surface area⁴⁴. The oils were adsorbed on the surface of carbon foam to reclaim by the extrusion mechanically and also be recycled effectively.

Conclusion

Different applications of carbon foam were reviewed here mainly due to specular properties such as high electrical and thermal conductivity, size, porosity nature, light in weight etc.,. The composite material of carbon foam plays effective role to store the latent heat. Researchers mainly seemed with carbon foam as to improve the thermal conductivity. Though, carbon foam doesn't play much attention towards the size of the cell as the volume changes from phase to phase as solid-liquid and liquid-gaseous. The size of the cell strongly depend on their preparation methods which they quietly different from other precursor. They also helps in storing energy as the electrochemically active elements such as lithium ion rechargeable batteries. It act to have high thermal and electrical conductivities. Also, they reduce the internal resistance and enhance the dissipation from the devices. Since, its strong in mechanical properties it helps in volume expansion and shrinkage due to the charge cycle. Taking all these aspects carbon foam helps in gas molecule adsorption as CO₂, H₂O etc. The pores present in the wall of cell in the structure carbonization conditions and their thickness. They also have an advantage as it has both mesopores and micropores in the cells. Thus carbon foam seems to be promising and effective role support in many applications.

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