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Synthesis of recycled polyethylene terephthalate hybrid aerogels (r-PET) with Multi-wale carbon nanotubes (MWCNT)

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Abstract

In this research, the synthesis of hybrid aerogel based on polyvinyl alcohol (PVA) with recycled polyethylene terephthalate (r-PET) fibers and multi-walled carbon nanotubes (MWCNT) by the atmospheric drying method using glutaraldehyde (GA) cross linker and initiator hydrochloric acid prepared. The resulting samples were evaluated by Thermogravimetric Analysis and Differential Thermal Analysis (TG-DTA) and optical microscopy methods. The effect of multi-walled carbon nanotubes on the absorption of distilled water was investigated and determined. The results showed that increasing the denier and increasing the length of the fibers decreased the porosity of the aerogel (r-PRT), and the addition of carbon nanotubes increased the porosity of the aerogel. The prepared aerogels are very light and very porous materials that can have a wide range of applications such as sound and, heat insulation, and filtering due to the flexibility that is due to the effect of hybridization with (r-PET). The production of (r-PET) hybrid aerogel is an alternative method for recycling (PET) plastic waste, which also helps to reduce environmental pollution.

Keywords: aerogel, polyethylene terephthalate, carbon nanotubes, fibers

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1. Introduction

Polyethylene terephthalate (PET) is a linear thermoplastic polyester that was produced by step-growth polymerization, from the reaction between terephthalic acid (TPA) and mono ethylene glycol (MEG). That is used in most countries to produce polyester fibers (70%), bottle resin (22%), film (6%), and engineering polyester resins (2%). In Iran, this polymer is mainly used to produce beverage bottles. The high resistance of these polymers against breakage and gas penetration, as well as their low weight and low price compared to other packaging materials such as glass and metal, increase the production of bottles of this polymer, which increases the volume of these bottles in the municipal waste stream. Due to the high resistance of polyethylene terephthalate to biological agents until then, these wastes are considered biodegradable [1]. Polyethylene terephthalate is most widely used in the production of synthetic fibers, which accounts for the third largest volume of polymer production after polyethylene and polypropylene. Polyester fibers are widely used in the textile industry and automobile tires [6]. Nearly 6,300 million tons of plastic waste were generated in 2015, of which only 9% were recycled, and the rest were spilled in landfills, rivers, and oceans. If this trend continues, about 12,000 million tons of plastic waste will be released into the environment by 2050, endangering the lives of marine life. [2]. Aerogels contain nanoparticles that are located in a three-dimensional network with a high degree of porosity. These holes have different diameters, varying from a few nanometers to a few micrometers. Porosity makes up most of the volume of aerogels [3]. Normally, to prepare aerogels, first, their precursor, which is called hydrogel (wet gel), must be prepared [4]. The optical properties of aerogels depend on their production conditions. These materials are saw as yellow in the light and blue in the dark. Different methods of solvent removal, removal of water or moisture from the aerogel structure, and reaction conditions are among the main and effective parameters in the optical properties of aerogels [5]. In this research, a sample of recycled polyethylene terephthalate hybrid aerogel with multi-walled carbon nanotubes was synthesized and another sample without carbon nanotubes was prepared. The thermal stability, surface morphology, and the effect of adding multi-walled carbon nanotubes on the absorption rate of this aerogel (r-PET) have been investigated.

2. Materials and methods

2.1 Preparation of materials

R-PET, fibers were prepared by the Polymer Sazan Company. Hydrochloric acid (HCl) (37%), glutaraldehyde (GA) (25%), and polyvinyl alcohol (PVA) from Sigma Aldrich, as well as sodium hydroxide (NaOH) and ethanol from Merck Company, Multi-walled carbon nanotubes (MWCNTs) prepared by the Petroleum Industry Research Institute, were used in this study. Also, all solutions were prepared with deionized water [7].

2.2 Methods

Initially, r-PET fibers were immersed in a four-weight percent sodium hydroxide solution and placed in an oven at 80 degrees Celsius for one hour to place the carboxyl and hydroxyl groups on the surface. The fibers are then rinsed with deionized water to remove the sodium hydroxide. A solution consisting of PVA, glutar aldehyde, and multi-walled carbon nanotubes is made, and added to the fiber content. Its pH is controlled by HCl. The solution is sonicated in an ultrasonic bath for 15 minutes to homogenize and remove bubbles. It is then placed in an oven at 80 degrees Celsius for 3 hours to complete the reaction. The resulting gel is then placed at room temperature for 48 hours to dry completely.

3. Results and Discussion

R-PET aerogels are obtained from hydrogen bonds formed between polyvinyl alcohol (PVA), staple fibers, and bond from glutaraldehyde (GA) [8, 9]. Glutar aldehyde as a catalyst improves the interaction between r-PET and PVA fibers[10]. As the weight percentage of fibers increases, the density of the aerogel increases. This reduces the pore size and porosity of the aerogel. This means that increasing the concentration of fibers increases its weight percentage per unit volume, which increases the density. As the increase of the R-pet fiber's length, the density of the aerogel increases, and, as a result, the porosity of the aerogel decreases. Also, with increasing the Denier (increasing diameter to length ratio) of the r-PET fiber, density increases, and porosity decreases.

Figure (1) shows the surface image of the aerogel of recycled polyethylene terephthalate fibers. As it is clear in the figure, recycled polyethylene terephthalate fibers have a porous and non-woven structure, and the length of the fibers is in the range of (12-42mm). According to the morphology of r-PET aerogel, it shows that the fibers are intertwined and have micrometer Holes. And still, the pores created by r-PET fibers are clearly visible in the figure. It can be seen that the fibers did not allow the hydrogel, which was dried in Environmental drying, to turn into zero gel.

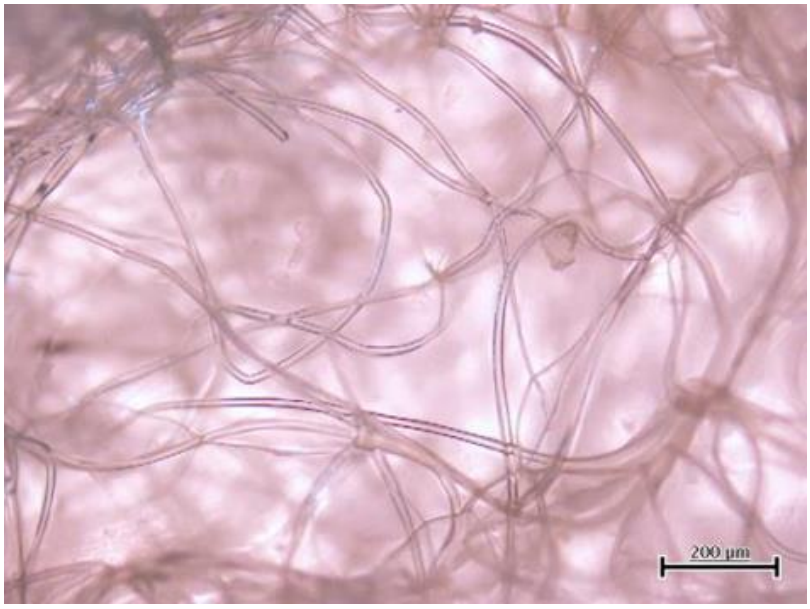


Figure. 1 Optical microscope image. Recycled polyethylene terephthalate hybrid aerogel (r-PET)

In the temperature range of 50 to 100 °C, there was a change in mass in the TG diagram, which was caused by the evaporation of a small amount of ethanol remaining in the sample, which can also be seen in the differential thermal analysis DTA (Differential thermal analysis) diagram. Caused a downward slope. In the range of 200 to 300 °C, it can be seen that the Thermal gravimetric TG diagram has a downward slope, which is the change in the mass of the sample due to the decomposition of PVA, and the DTA diagram shows the endothermic. And the endothermic reaction means the decomposition of materials due to heat. The greatest change occurred in the region of 400–500 °C, which is evident in both graphs, which show the breakdown of r-PET fibers, showing the process of heat absorption. Because in the DTA diagram, the peak is towards the bottom, which shows that it is an endothermic process, and the TG chart also shows a sharp decrease in weight, which is also the temperature range of sample decomposition. This shows that r-PET aerogel with multi-walled carbon nanotubes has more thermal stability than silica aerogel. As silica aerogel tends to lose weight at 200 °C[11].

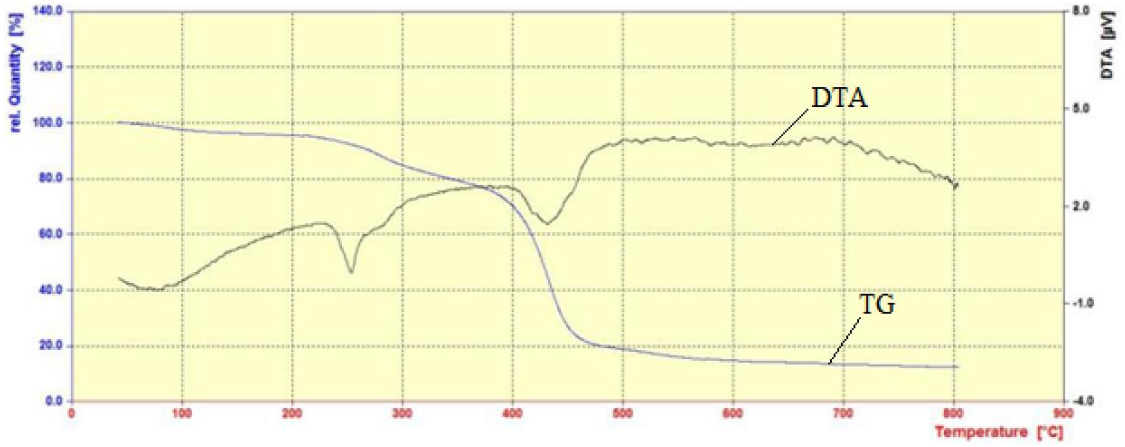


Figure. 2 Image Thermal gravimetric-differential thermal analysis (TG-DTA). Recycled polyethylene terephthalate hybrid aerogel (r-PET)

Table 1 shows the effect of adding multi-walled carbon nanotubes (MWCNT) on the adsorption rate of r-PET aerogel. With the additional of nanoparticles, the amount of adsorption increases due to the increases in the effective surface of the aerogel and the increase in porosity. The meaning of this increase in water absorption is the increase in porosity and permeability of r-PET aerogel with the hybridization of multi-walled carbon nanotubes.

Table. 1 Effect of adding multi-walled carbon nanotubes (MWCNT) on the amount of r-PET aerogel adsorption.

Material	The amount of water absorbed in one gram of material
R-PET hybrid aerogel in the absence of carbon nanotubes	6.57
R-PET hybrid aerogel containing carbon nanotubes	7.75

4. Conclusions

Environmentally Compatible r-PET aerogel was prepared using recycled PET fibers and an environmental drying process and then investigated the effect of r-PET fiber concentration, fiber denier, and fiber length on the morphology and porosity of r-PET aerogel. The results of the surface morphology examination clearly show that the recycled PET fibers prevent the hydrogel volume from shrinking extensively, and do not allow it to turn into a xerogel when it dries in the environment. The effect of adding multi-walled carbon nanotubes (MWCNT) on the adsorption rate of r-PET aerogel was also evaluated. The results showed that r-PET aerogel has low density, high porosity, and high flexibility.

Because the increase of multi-walled carbon nanotubes (MWCNT) shows a considerable percentage of water absorption compared to the sample without carbon nanotubes. Therefore, it is suitable for Applications such as heat insulation, sound insulation, and absorber.

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Authors Profile



ROZBEH BARAKZAI was born in 1989 and have master's degree in chemical engineering and polymerization Technology & Nano Technology from Iran. He have published many research articles. Also he have membership of research committee and scientific board of KPU.

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