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Study of Properties of Polyethylene Glycol and Its Glass Fibers Composites under UV-Rad for Oils Filtration Applications

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Abstract

Abstract

This study determines the effects of UV radiation and heat treatment on many flow and mechanical parameters of PEG 4000, including flow time and viscosity (specific, reduced, relative, and intrinsic). Solubility time and shore D hardness are among the mechanical characteristics. By adjusting the concentrations of solutions in the range (0.01–0.03) g/ml of heating and non-heating PEG powders, and examining the polymer's solubility at the same time, the flow characteristics of the polymer are explored. Random glass fiber reinforcement in the range of 0.1–0.4 wt has also been studied to indicate the effect on shore hardness. After exposing the produced plates to ultraviolet light, the efficacy of the plates in purifying the oil from contaminants was investigated. The results show that increasing the concentration increases all types of viscosity and flow time, with the exception of intrinsic viscosity, which decreases as concentrations increase. Other parameters decrease after the first UV ray and heat treatment, but increase as the time of UV ray treatment increases. Furthermore, increasing the weight ratio of glass fibers from 0.1 to 0.4 wt lowered shore hardness, whereas increasing the weight ratio at the same previous range increased it after UV rad. While solubility data refers to increasing polymer weight and radiation help increase solubility time. The filtration efficacy of the small particles of the produced filters increased after the overlapping plates were exposed to UV radiation, owing to the smaller pore diameters.

Keywords: PEG, flow time, Shore D. UV rad.

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دراسة خواص البولي أثيلين كلايكول ومتراكباته مع الياف الزجاج تحت تأثير الأشعة الفوق بنفسجية لتطبيقات ترشيح الزيوت

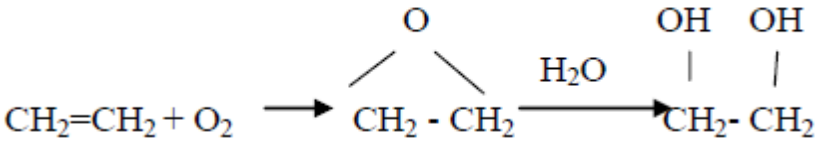
الخلاصة:

تهدف هذه الدراسة الى معرفة تاثير الأشعة فوق البنفسجية والمعالجة الحرارية على العديد من عوامل التدفق والخواص الميكانيكية للبولي اثيلين كلايكول - 4000، بما في ذلك زمن الانسياب واللزوجة (الذاتية، والمختزلة، والنسبية، والجوهرية). وايضا زمن الانحلال في الماء للبولي اثيلين كلايكول المشعع وغير المشعع، كما تشمل دراسة تاثير الاشعاع على صلادة شور كمؤشر للخصائص الميكانيكية للبولي اثيلين كلايكول ومتراكباته مع الياف الزجاج بنسب وزنية محتلفة تتراوح بين 0.1 – 4.0 نسبة وزنية. تم اخذ تراكيز المحاليل في النطاق (0.03-0.01) غم / مل من مساحيق PEG المشععة وغير المشععة، وفحص قابلية ذوبان البوليمر في نفس الوقت. أظهرت النتائج أن زيادة التركيز يزيد من جميع أنواع اللزوجة ووقت التدفق، باستثناء اللزوجة الجوهرية التي تقل كلما زادت التركيزات، ايضا اظهرت النتائج نقصان اللزوجة مع تسخين المحاليل عند درجة حرارية 40 درجة مئوية. علاوة على ذلك، أدت زيادة النسبة الوزنية لالياف الزجاج من 0.1 إلى 0.4 نسبة وزنية إلى تقليل صلادة شور، بينما أدت زيادة نسبة الوزن في نفس النطاق السابق إلى زيادتها بعد التشعيع بالأشعة فوق البنفسجية. بينما تشير بيانات الذوبان إلى زيادة وزن البوليمر والإشعاع يساعد في زيادة وقت الذوبان.

اثبتت نتائج حساب كفاءة الفلتر المتراكب المحضر ان كفاءة ترشيح الزيت من الجسيمات والاتربة العالقة فيه تزداد بعد التعريض للاشعة فوق البنفسجية، حيث تنقص الدقائق المارة خلال الفلتر ذات الحجوم الكبيرة، ويسمح للدقائق الصغيرة ذات اقل من 2 مايكرومتر بالمرور، ويمكن تقليل تلك الدقائق المارة بتغيير ظروف صناعة الفلتر او من الممكن زيادتها باستمرار التعريض للاشعة الفوق بنفسجية التي تعمل على تقليل حجوم المسامات وزيادة الترابطات العرضية للبوليمير.

1. Introduction

Polyethylene glycol is a resin created during the petroleum thermal cracking process by oxidizing ethylene to ethylene oxide and then adding water to it according to the processes below [1]



PEG 4000 is a linear polymer whose atoms are linked by single linear chains [2]. It dissolves in water and ethanol, has a melting point of 54-58 C) [3], and has a density of 1.1-1.2 g/cm^3. It comes in the shape of a white solid with a mild odor and a low vapor pressure. The vapor pressure drops as the molecular weight increases, and it is characterized by being stable under typical use and storage settings. PEG 4000 is a viscosity modifier and moisturizer in cosmetics and the paper industry, as well as a rubber lubricant and packaging material. It has great solubility and heat stability. Because of its susceptibility to dissolution and the formation of free radicals, which leads to the formation of cross-links, which in turn leads to the conversion of the

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polymer from a transparent to an opaque state due to the formation of crystalline regions, polyethylene glycol is highly affected by radiation, particularly UV radiation of short wavelength and high energy [4, 5]. Other properties such as viscosity, density, and flow time are affected when exposed to radiation or heating at a certain temperature because these materials bear part of the stress applied to them by radiation or heating [6], and other properties such as hardness, toughness, and fracture toughness are affected when exposed to radiation or heating at a certain temperature because these materials bear part of the stress applied to them by radiation or heating at a certain temperature because these materials bear part of the stress applied to them by radiation Finding an appropriate substance to defend against hazardous high-energy radiation, such as UV rays, and adjusting the molecular weight of the material employed to manage the conditions of its use. The relative viscosity was computed using the equation (1).

$$\eta_{rel} = \frac{t_s}{t_o} \quad \ldots(1)$$

η_{rel}; Relative viscosity

t_s; Time for the solution to descend

t_o; Time for the solution to solvent

The equation 2 was used to compute the specific viscosity (η_{sp}):

η_{rel} - 1 ….(2) η_{sp} =

Equation 3 was used to compute the reduced viscosity (η_{red}):

$$\eta_{red} = \frac{\eta sp}{c} \quad \ldots(3)$$

C; concentration of solution.

Composite materials are made up of two phases of materials: the first is a matrix that requires the addition of the second phase, known as reinforcement, to improve some of its properties [7-10]. A matrix can be made of polymer, ceramic, or metal. Polymer-based composites are useful for a number of applications due to their light weight and ease of processing [11] Reinforcement materials can be used as fibers, particles, laminated and hybrid reinforcement, and nanomaterials [12-17]. All mechanical properties of polymeric materials, such as impact resistance, hardness, toughness, tensile strength, and Young's modulus, are improved when they are formed into composites [18-24]. The ability of a material to resist deformation is tested by a standard test that measures the resistance of the surface to indentation. The shape or kind of indent, the size, and the amount of load applied are the most often utilized hardness tests [25-27].

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The purpose of this study is to investigate how various mechanical and flow properties of PEG 4000 and its composite reinforced with glass fibers are affected by UV radiation and heat treatment before employing it for oil filtering.

2. Experimental Part

2.1 Materials and Method

The hydrophilic glass fibers mat with 0.7 m pore size, 47 mm diameter, and solid powder form of PEG 4000 with formula [H(OCH2CH2)nOH] were utilized to make the samples for this study. It was purchased from the Sigma-Aldrich company.

The concentrations of solutions were made by dissolving certain weights of polyethylene glycol (1, 2, 3 g) in (100 ml) of distilled water to test various sorts of viscosity and flow-time tests of these concentrations, which involved (0.01, 0.02, and 0.03 g/ml) respectively. The same prior weights were taken and melted in a metal mold at a temperature of 55°C by an electric furnace for 15 minutes and left to complete the melting process, then the molten was poured into a plastic mold and left to re-solidify for another 15 minutes, (the hand casting layup method was used to prepare the samples [28]. The annealed samples were then dissolved in 100 mL of distilled water to achieve the same concentrations as the last one. Shore hardness samples were made in the same way that heating samples were made. Random glass fiber reinforcement samples were made by melting a 2g polymer and varying weights of glass fibers given in the values (0.1, 0.2, 0.3, and 0.4) wt., and mixing the weight percentages of the glass fibers with the molten by stirring. After that, the sample was left for 15 minutes to complete the solidification process before being tested. For the aim of testing its dust filtration ability, Helix low viscosity motor oil was combined with dust powder of various particle sizes, The PEG sample was exposed to a UV lamp (Blak-Ray B-100AP) with a 365 nm band pass filter for 6 hours.

2. Tests:

1- Shore hardness was measured using a Shore digital device, which is a digital instrument with a screen and a hardness probe that is pressed down when it comes into touch with the surface to be measured. The hardness is determined using the Iraqi standard ASTM (1973-364).

2- The solubility was determined by dissolving the samples in distilled water and using a digital clock to calculate the dissolution time.

3- The Ostwald viscosity device was used to calculate the viscosity of solutions. It's a U-shaped glass tube with two cylindrical chambers inside. The solution is pumped into the large cylinder,

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which is then pushed through the little cylinder by a compressor. The liquid is then allowed to flow back to the huge cylinder via a capillary tube, where the flow time is determined using two specified spots on the capillary tube in accordance with the Iraqi ASTM (1974-587) [The flow of thermoplastic fuses] specification.

4- The morphology of manufactured composite filters that were exposed to UV, RAD, and free samples were studied using Tescan electro scanning microscopy.

3. Results and Discussions

Figure (1), shows that relative viscosity increased with increasing concentration, reduced after irradiation for the first 24 hours, and then began to increase during the second 48-hour irradiation period. This is due to the polymer's pseudo-elasticity, which is the primary source of decreased Viscosity values as a result of the effect of external stress on them, resulting in the disintegration of polymeric chains.[29] On the other hand, increasing the radiation time to 48 hours resulted in an increase in viscosity values due to the crosslinking process in the polymer and the appearance of the gel, resulting in an increase in the polymer's molecular weight, which is preferred for practical applications requiring high molecular weight. Due to the cohesive forces that diminish as temperature rises, heating resulted in a drop in viscosity [30].

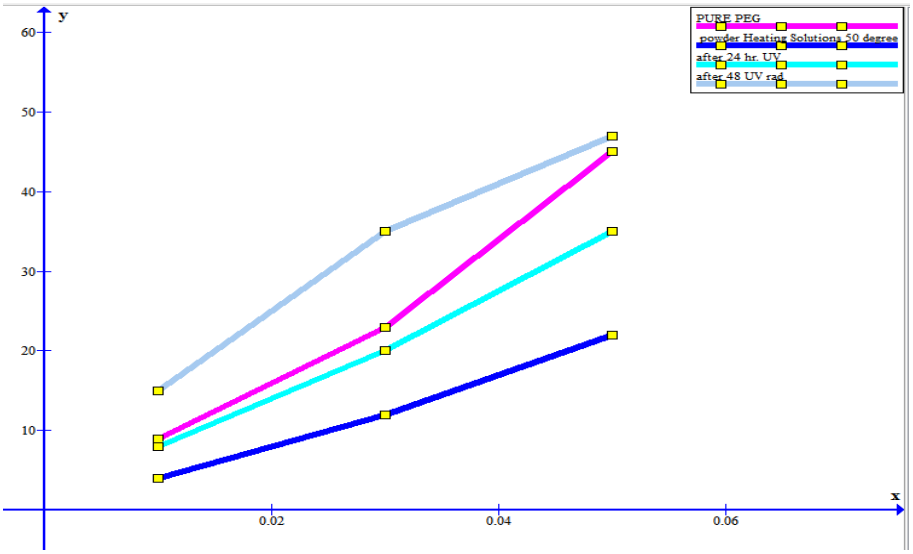

Fig. (1): Relative viscosity versus concentration of PEG under different conditions

Figures (2) and (3) depict the link between reduction and specific viscosity with concentration, respectively, where the same behavior of relative viscosity is observed in terms of increase and decrease in regard to its tight association with relative viscosity [31].

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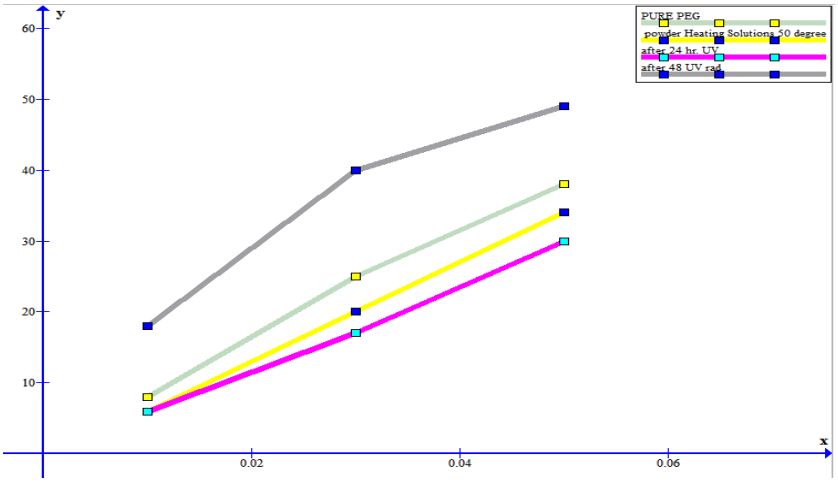

Fig. (2): Specific viscosity versus concentration of PEG under different conditions

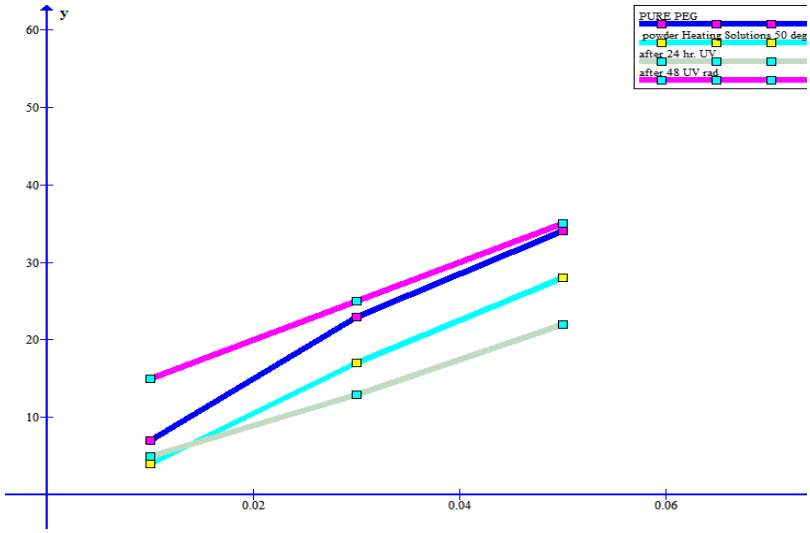

Fig. (3): Reduced viscosity versus concentration of PEG under different conditions

The relationship of intrinsic viscosity with concentration is illustrated in Figure (4), which shows that viscosity decreases with increasing concentration and also decreases with the effect of heating and irradiation for the first 24 hours, while irradiation for the second 24 hours results in an increase in the viscosity value. This is owing to polyethylene glycol's mild viscosity, which increases only slightly with increasing concentration when employed as a viscosity modifier [32].

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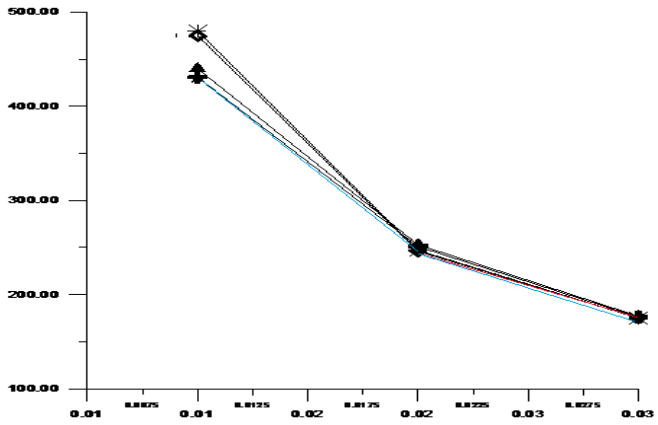

Fig. (4): The relationship between the intrinsic viscosity and concentration of polyethylene glycol under different conditions

Figure (5) depicts the change in flow time with concentration, which increases with increasing concentration and decreases after irradiation for the first 24 hours, as well as after heating, due to a decrease in friction forces between the polymer molecules and the capillary tube on the one hand, and between the polymer molecules on the other. The second session of irradiation, which lasted 48 hours, resulted in an increase in flow time due to an increase in concentration caused by the crosslinking process, which increased the viscosity of the polymer [33].

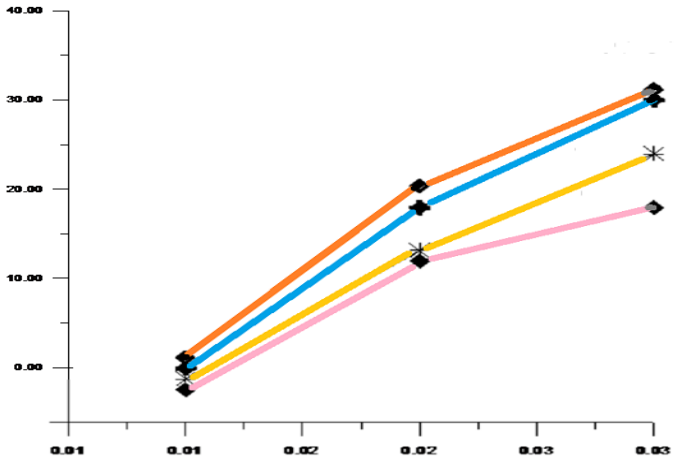

Fig. (5): The relationship between the flow time and concentration of polyethylene glycol under different conditions

The solubility is shown in Figure (6). Due to the shift of the polymer from an amorphous to a crystalline state and the production of cross-linking between its molecules, we detect a decrease in solubility (i.e.) an increase in dissolution time) following heating and re-solidification. In the

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case of the weighted sample (3 g), it's worth noting that Due to its enormous thickness, the sample's solubility has increased greatly (decreasing dissolving time), as the sample retains part of the heat that it loses through the exothermic reaction, resulting in an increase in the sample's solubility. Irradiation, on the other hand, resulted in a decrease in solubility for the same reason as the heating process [34].

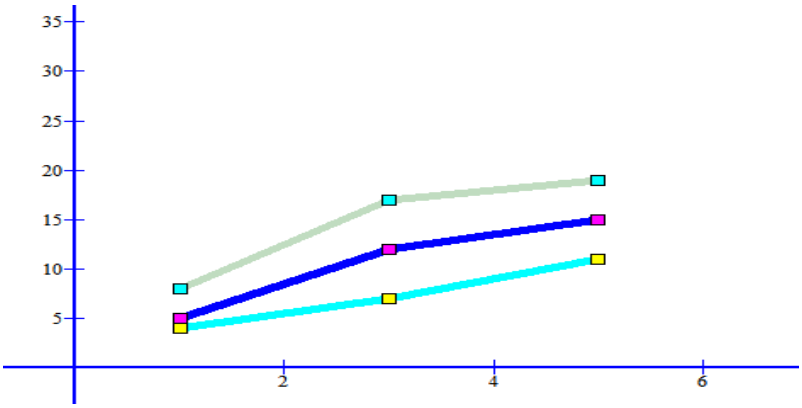

Fig. (6): The relationship between dissolving time and weight of polyethylene glycol under different conditions

The effect of strengthening on the Shore hardness of PEG is seen in Figure (7). Before irradiation with (UV) rays, the Shore D hardness of composites falls as the weight ratio of the fibers increases, owing to a loss in cohesiveness between the matrix and the fibers, which creates voids between the fibers and the matrix. While adding glass fibers to PEG increases durability, because the fibers work to distribute stresses on the composite material between the matrix and the reinforcing material, making it a durable material, and the fibers bear the majority of the applied stress, in addition to giving it a more aesthetically pleasing appearance. The resulting composite material has the ability to stretch before breaking or failing, resulting in a higher strength [35-38] . Due to cavities produced in PEG after adding glass fibers and insufficient adhesion between the matrix and the glass fibers, the Shore D hardness of pure PEG declined as the weight ratio of glass fibers increased. We also note that irradiation increases the value of composites' Shore hardness because the radiation breaks secondary bonds between polymer chains and allows them to rearrange, allowing the polymer to transform from an amorphous to a regular crystalline material, as well as increasing cross-linking and partially filling the cavities between the fibers and matrix. [39].

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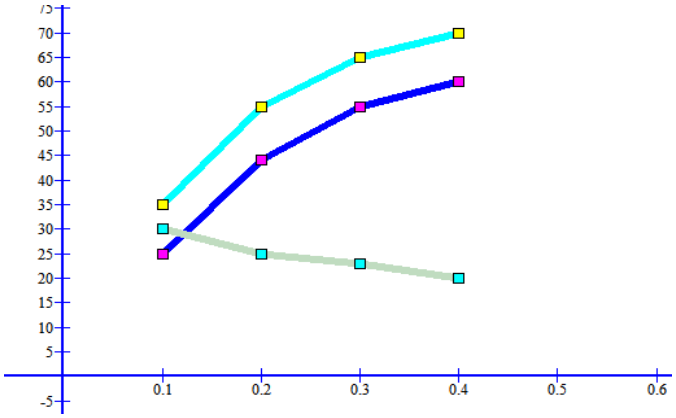

Fig. (7): The relationship between Shore hardness and the weight ratio of glass fibers for PEG composites under different conditions

Thermal analysis and TGA curves for net PEG, PEG+0.6 glass fiber, and PEG + 0.6 glass fibers with 48 hours of UV-RAD are shown in Figure 8 We observe that the thermal degradation of PEG slightly rises with the addition of glass fibers (0.6 wt), and it continues to increase after being exposed to UV-radiation for 48 hours. this is because adding glass fibers prevents polymer chains from moving and it absorbed some heat energy, which later caused the PEG chains to deteriorate. However, the UV-Rad also causes the temperature of thermal decomposition to rise, which may be a result of increased cross-linking between polymer chains as a result of UV-RAD. [40]

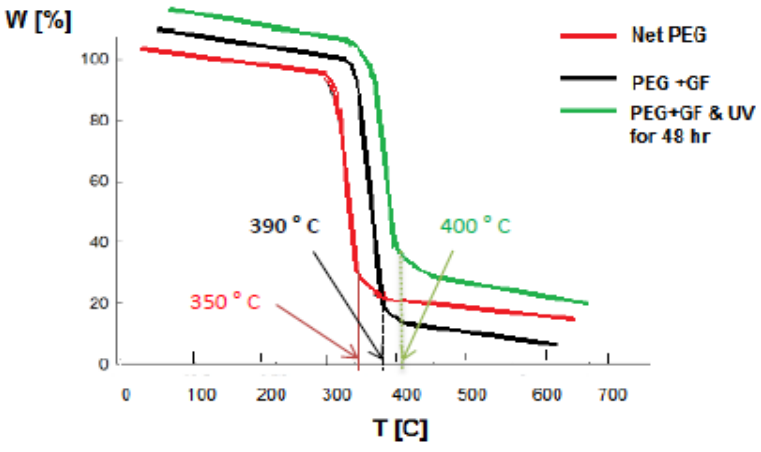

Fig. (8): Thermal analysis by TGA

Scanning electron microscope images of the (0.4) wt. glass fibers) filter used to purify the oil from contaminants and dust are shown in Figures (9A) and (B). Figure a shows the prepared filter without being exposed to ultraviolet rays; we can see that the particles stuck in the filter are

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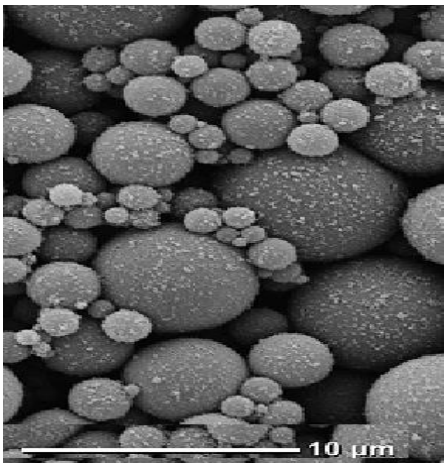
larger than 5 micrometers, implying that the pores inside the filter are 5 to 6 micrometers in diameter, with some small particles stuck in the filter with sizes of 1 to 2 micrometers. Picture B shows that the size of suspended particles passing through the filter is much smaller than that shown in Figure (9A), as particles larger than 2 micrometers did not pass through the filter, indicating a decrease in the diameter of the pores caused by ultraviolet ray exposure, which increased the filter's oil filtration efficiency. [41]



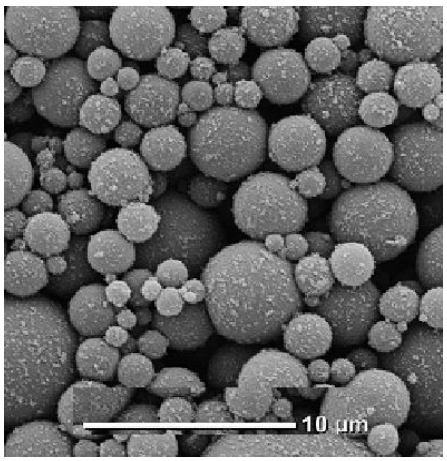


Fig. (9A) **Fig. (9B)**

Fig. (9): SEM images of prepared filters (0.4wt glass fibers) a. without UV RAD b. with UV RAD

4. Conclusions:

The polyethylene glycol 4000 is suitable for the protection of high-energy radiation by the effect of these radiations on the cross-links of the polymer, which is the main reason for making the material more crystallinity and hardwearing, causing the radiation to scatter rather than "permeate," and that irradiation is suitable for obtaining different molecular weights of polyethylene glycol, where irradiation leads to an increase in the molecular weight. This was demonstrated by raising the viscosity of PEG solutions by increasing the concentrations of these solutions. After exposure to ultraviolet rays, the efficiency of oil filtration from suspended particles and dust increases, as large particles passing through the filter decrease and small particles less than 2 micrometers are allowed to pass through, and those passing particles can be reduced by changing the filter industry's conditions, or it can be increased continuously by exposure to ultraviolet rays, which reduces the size of the pores.

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