The effect of inorganic pigment on the tensile properties of polycarbonate irradiated with UV – light

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Abstract

The effect of UV-light on the tensile properties of pure PC has been studied. It was shown that irradiation of PC undergo a drop in the tensile properties of 30 hour of exposure. The results of irradiated samples shows that the addition of ZnO and TiO_2 with different percentages (0.5, 1, 1.5 %) will reduce the Young modulus and ultimate stress of PC/ZnO ,PC/ TiO_2 composites.

Key words

inorganic pigment,

tensile properties,

UV – light

Article info

Received: Sep. 2004

Accepted: Feb. 2005

Published: Dec. 2011

تأثير الصبغات غير العضوية على خصائص الشد للبولي كاربونيت المشعع بالاشعة فوق البنفسجية

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الخلاصة:

تم في هذا البحث دراسة خصائص الشد للبولي كاربونيت المشعع بالاشعة فوق البنفسجية . لوحظ من خلال البحث ان خصائص الشد تتناقص عند تشعيع البولي كاربونيت بزمن تشعيع قدره ٣٠ ساعة. تبين النتائج بانه عند اضافة ثاني اوكسيد التيتانيوم واوكسيد الزنك وبنسب مختلفة (0.5,1 and 1.5%) الى البولي كاربونيت وتشعيع النماذج فان قيم معامل يونك وقيمة الشد القصوى سوف تتناقص .

1. Introduction

The common polymers normally photo degrade are fairly well known, but various aspects of the mechanisms involved remain uncleared. It is important to take into account very significant influence of compounding additives in modifying the chemical pathways, which are pigments, extenders, photostabilizers and thermal stabilizers. Normally all plastics products are manufactured using extrusion, injection molding, or extrusion blowing. The processing of polymers using heat and high shear into useful end products introduces impurities and reaction products that make them susceptible to photodegradation. Because of these complications, the extrapolation of research findings on UV-induced degradation of pure polymer resins to compounded and processed products of the same polymer, is often unreliable. Photo degradation data generated on the actual polymer formulations used in practice, processed in the conventional manner are the most useful for assessment of damage [1].

2. Theoretical Part

2.1 Polymer Degradation

The polymers, used in the building and construction industry, undergo photolytic and photo-oxidative reactions during exposure to solar UV radiation. These contain chromophoric groups, such as carbon-carbon double bonds (C=C) and carbonyl groups (C=O), which are capable of absorbing UV energy. Micro cracking and embrittlement of polymeric substrates are the most serious effects of photo degradation, these effects are often accompanied by extensive deterioration in the mechanical properties of the materials, such as tensile strength, impact strength and elongation, all of which are important parameters in the performance of a building product. It is therefore necessary to be able to predict the performance of building products in specific environments, particularly regarding the expected lifetime of materials. In certain cases, the prediction of the effect of UV radiation on plastics by natural weathering exposure is too slow, particularly where product development is concerned. Therefore, artificial weathering of products is often used to provide information on the effects of UV [2-4].

The rate of photo degradation of polymeric materials is often retarded by the use of UV stabilizers and fillers, such as hindered amine light stabilizers (HALS), carbon black, zinc oxide and titanium dioxide. Although each stabilizer acts by different mechanisms, there are two main methods for stabilizing polymers, namely protection and inhibition. Additives such as carbon black absorb UV radiation and thereby protect the polymer from degradation, whereas TiO_2 and ZnO inhibit the chemical reactions taking place in photo degradation mechanisms, by destroying the radical sources.

2.2 Polycarbonate (PC)

Irradiated polycarbonate polymer with short wavelength UV-B or UV-C radiation, undergo a rearrangement reaction (referred to as a photo-Fries rearrangement). At low oxygen levels this reaction can yield yellow-colored products, but when irradiated at longer wavelengths (including solar visible wavelengths) in the presence of air, it undergo oxidative reactions that result in the formation of other yellow products . However, neither the detailed mechanisms nor the specific compounds responsible for the yellow coloration have been fully identified [5]. However, monochromatic exposure experiments on the wavelength sensitivity of several degradation processes of bis-phenol A polycarbonates have been reported recently [6].

2.3 UV Absorbers

Zinc oxide and Titanium dioxide are photo semiconductors which strongly absorb UV light but permit visible light transmission .

The protection mechanism of UV absorbers is based essentially on absorbing the harmful UV radiation and its dissipation, of heat. Besides having high absorption themselves, these compounds must be very light stable because otherwise, they would be consumed too fast in non-stabilizing secondary reactions [4]. A fundamental disadvantage of UV absorbers is the fact that they need a certain absorption depth (sample thickness) to protect a plastic well. Therefore, UV absorbers provide only limited protection to thin samples, e.g., fibers or films[7].

3.Experimental Part

3.1 Materials

Polycarbonate polymer was used; the fillers were TiO_2 and ZnO.

3.2 Samples preparation

1- polycarbonate polymer was mixed at room temperature with approaprate solvent , Di Chloro Methlyene.

2- A weight amount of the PC polymer was mixed with TiO_2 powder in different percentages (0,0.5,1 and 1.5%), to obtain 5gm of the total weight of homogenized mixture. The same procedure were done for ZnO filler.

3- The prepared sheets were left at room temperature for 24hours.

The samples were shaped according to the ASTM standard for tensile test specimens [7], as shown in fig (1), and for the UV exposure tests.

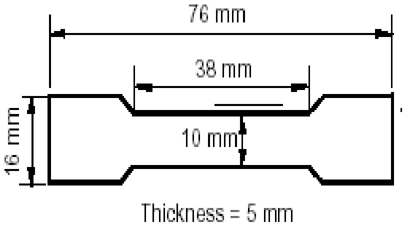

Fig. 1. The dimension of composite sample for tensile testing

3.3 UV Sample irradiation

The samples were irradiated with UV source (OHD – 300 watt) high pressure Hg- lamp of the main emission lines at 254, 290 and 365 nm , the irradiation time was 30 hours .

3.4 Tensile test

Instron testing machine model (Inst. 1122) was used in its tensile mode of full scale 5KN.The values of cross head speed and chart speed were fixed to 0.5 mm/ min and 20 mm/min respectively . The test specimen was positioned vertically with the aid of the grips of the testing machine which were tightened evenly and firmly to prevent any slippage during the tension processes. During loading processes , the load value (force) and displacement were recorded . The processes of elongation of the specimen continued until a rupture of the specimen was observed.

4. Results and Discussion

4.1 Stress- Strain Curve Results

Figure (2) shows the stress – strain curve for pure PC. The irradiation of pc undergo a drop in the tensile properties at 30 hrs of exposure, this is due to the penetration of uv light into the samples and make scissions to the bonds of PC chains and this reflect on the reduction of the mechanical behavior [8] .

Figures (3 and 4) represents the stress- strain curves of PC/ZnO for unradiated and radiated samples respectively. The addition of ZnO to PC (Fig(3)) will reduce the stress and strain as compared to pure PC (Fig(2)) .This is may be due to the creation of new interfaces between PC and the filler (ZnO),so that it could be the starting point for stress concentration and initiation of cracks , and this will reduce the strength and reflect on the strain of the samples .A further drop in stress- strain curves was noticed when the same samples (PC/ZnO)were radiated with uv- light for 30 hours , as it shown in fig 4.

Figures 5 - 6 shows the stress-strain curves of PC/TiO_2 , for unradiated and radiated samples respectively .Comparing these figures with that mentioned previously (Fig 3-4) shows a more reduction in mechanical properties and this reflects the unhomogenity of TiO2 fillers in PC which will effect on the stress – strain curves.

The addition of ZnO and TiO_2 to PC will reduce the young modulus and ultimate stresses as shown in figures 7 - 8 for unradiated samples and figures 9 - 10 for radiated samples respectively .The reductions in young modulus and ultimate stresses are attributed to the distribution of particles ZnO and TiO_2 between the chain of this polymer (PC), since these particles gives more spacing between the fold chains, and the stretch mobility of main chain will be effected . This will reduce the interaction of the applied stress with these specimens , when these chains where stressed , the aggregation of some of these particles in local area will decrease the strength of polymer , because these particles will acts as a weakness points . These weakness points will accumulate a stress around these areas and the crack will propagate causes a failure in the polymers [9-12].

4.2 Morphology Results

Fig (11a) shows the necking on the specimens for pure PC, which means that PC has higher bond strength and these bonds will stretches and make necking until the crack propagated faster. The propagation of the crack in tested specimens depends on the strength of the bond for PC and the distribution percentage of the filler . Fig (11b) shows the effect of addition of ZnO/ or TiO2 up to 1% to PC which were exposed to uv-light make these samples more brittle and the behavior of the cracks propagation will be changed according to the weakness point in specimens . Increasing in percentage of ZnO /or TiO_2 up to (1.5%) will make the crack to propagate faster and the specimen will be separated into two parts, as it shown in fig(11c) .

5. Conclusions

The irradiation at 30 hrs of pc undergo a drop in the tensile properties as compared to pure pc .

The addition of ZnO or TiO_2 to PC will reduces the tensile properties as compared to pure PC.

The ultimate stress for irradiated PC/ZnO composites is higher than that for irradiated PC/ TiO_2 composites.

The Young modulus for PC/ZnO composites is higher than that for PC/TiO_2 composites.

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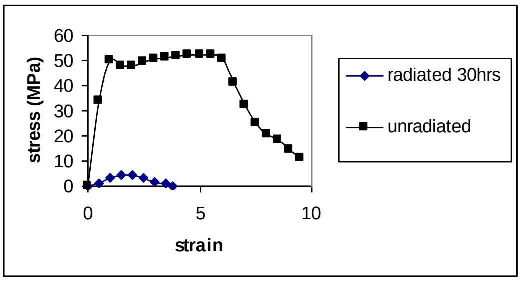
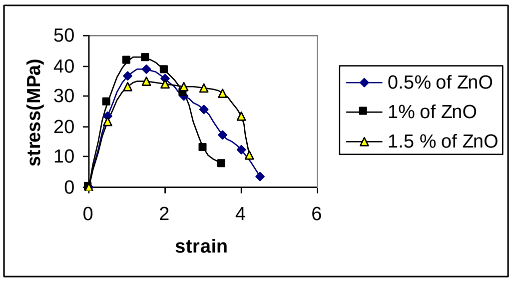
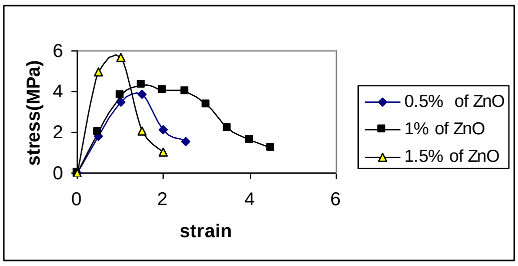


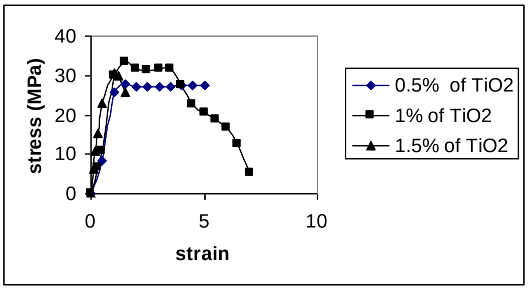
Fig (2): Stress - strain curve for pure PC



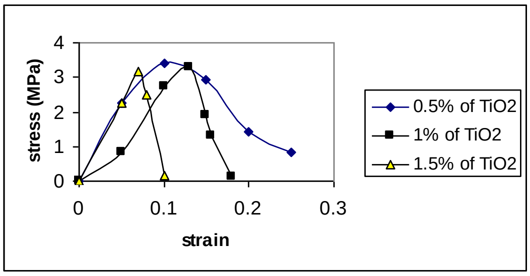
Fig(3) : Stress- strain curve for PC/ZnO of unradiated samples



Fig(4) : Stress- strain curve for PC/ZnO radiated with uv- light for 30 hours



Fig(5) : Stress- strain curve for PC/TiO2 of unradiated samples



Fig(6) : Stress- strain curve for PC/TiO2 radiated with uv- light for 30 hours

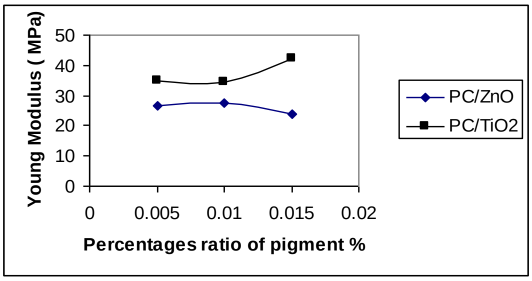


Fig (7): Young modulus of unradiated samples

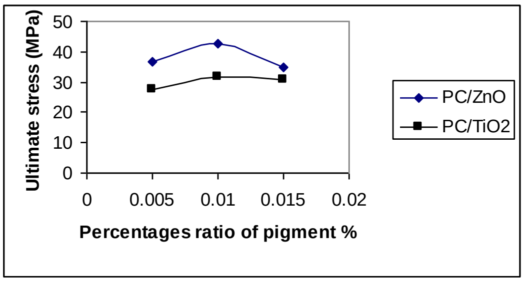


Fig (8) : Ultimate stress of unradiated samples

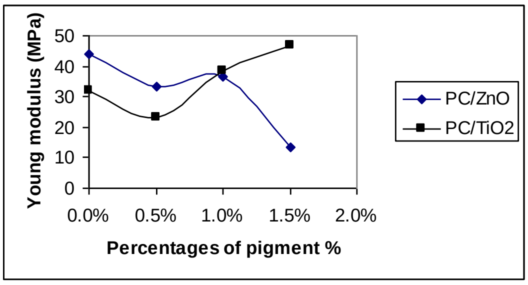


Fig (9) :Young modulus of radiated samples for 30 hours

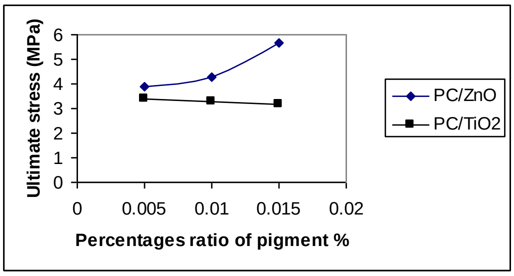


Fig (10) : Ultimate stress of radiated samples for 30 hours