Iraqi Journal of Physics, 2019 *Vol.17, No.41, PP. 7-14*

DOI: 10.20723/ijp.17.41.7-14

Weathering effects on the thermal conductivity of PS/PMMA blends for packaging application

Nahida J. H. and Hadeel Abid Alrahman

Department Applied Science, University of Technology

E-mail: nahidajoumaa61@yahoo.com

Abstract

This work describes the weathering effects (UV-Irradiation, and Rain) on the thermal conductivity of PS, PMMA, PS/PMMA blend for packaging application. The samples were prepared by cast method at different ratios (10, 30, 50, 70, and 90 %wt). It was seen that the thermal conductivity of PMMA (0.145 W/m.K), and for PS(0.095 W/m.K), which increases by PS ratio increase up to 50% PS/PMMA blend then decreased that was attributed to increase in miscibility of the blend involved. By UV-weathering, it was seen that thermal conductivity for PMMA increased with UV-weathering up to (30hr) then decreased, that was attributed to rigidity and defect formation, respectively. For 30%PS/PMMA, there results showed unsystematic decrease in thermal conductivity, which was attributed to unsystematic degradation. By Rain-weathering, thermal conductivity PS, PMMA, and 30 %PS, PMMA, it was seen systematic decreased in PS and 30 % PS/PMMA thermal conductivity; and systematic decrease in PMMA thermal conductivity. That due to the water diffusion in the samples that created some voids, bubbles, and results in decrease in thermal conductivity. This result was attributed to the decrease in adhesive between the components of polymer systems. The results suggested that the samples involved could be used for packaging application.

Key words

PS, PMMA, PS/PMMA blend, UV-weathering, rain-weathering.

Article info.

Received: Jul. 2018
Accepted: Oct. 2018
Published: Jun. 2019

دراسه تاثير التجويه على الخواص الميكانيكيه لخلائط الPS/PMMA لاغراض التعبئه والتغليف

ناهده جمعه حميد و هديل عبد الرحمن

قسم العلوم التطبيقيه، الجامعة التكنولوجية

الخلاصة

يصف هذا العمل تأثيرات التجوية (الأشعة فوق البنفسجية - الإشعاع) على الموصلية الحرارية لمزيج PS، PMMA، PS / PMMA لتطبيق التغليف. تم تحضير العينات من خلال طريقة الصب في نسب مختلفه (10، 30، 50، 70، 90) شوهدت أن الموصلية الحرارية لمادة PMMA (0.145 W/m.K)، و PS(0.095 W/m.K، ازدادت بزياده نسبة PS الى 50 ٪ PS / PMMA ثم انخفضت. والذي يعزى إلى زيادة في اختلاط مزيج المعنية. عن طريق التجوية فوق البنفسجية، لوحظ أن الموصلية الحرارية لمادة PMMA زادت مع التجوية فوق البنفسجية لمدة تصل إلى (30 ساعة) ثم انخفضت، ويعزى ذلك إلى الصلابة وتشكيل الخلل على التوالي بالنسبة الى 30٪ PS / PMMA، أظهرت النتائج انخفاضًا غير منتظم في الموصلية الحرارية، الذي يعزى تدهور غير منهجي. بواسطة المطر التجوية، الموصلية الحرارية PS، PMMA، و 30 ٪ PS، PMMA، فقد شوهد انخفاض منتظم في PS و 30 ٪ PS / PMMA الموصلية الحرارية؛ وانخفاض منتظم في التوصيل الحراري PMMA وذلك بسبب انتشار الماء في العينات التي خلقت بعض الفراغات والفقاعات، ويؤدي إلى انخفاض في التوصيل الحراري. وعزت هذه النتيجة إلى انخفاض في لاصق بين مكونات أنظمة البوليمر. تشير النتائج إلى أن العينات المعنية يمكن استخدامها لتطبيق التغليف.

Introduction

Polymer blends have become very important subject for scientific investigation in recent years because of their growing commercial acceptance, and they can possess unusual combinations of properties [1, 2].

Copolymerization and blending are alternative routes for modifications of properties of polymers. Blending is the less expensive method, but polymer blends have been successfully used in an increasing number of applications in recent years. Such success encourages more attempts to apply this technique to a wider range of problems in polymer- related industries [2].

Polymer materials are made in different varieties, the polymer blends are classified as one of those varieties. Polymer blends are made by physical mixing of two (or more) different polymers [3].

Polymer blends and alloys have got a great interesting due to their essential specifications, which are requested in many applications. These specifications are formulated by contribution of the properties of each component that forms the blend [4].

In general, blends are made by mixing homopolymer or copolymers, which have different chemical structures. The blends may be named as binary, ternary, quaternary depending on the number of polymeric components, which comprise them [5].

These materials generally exhibit a range of properties varying between the properties of their components. Moreover, their properties may be complementary and difficult to be found together in the case of a single component [6]. Polymerization is the process of joining together small molecules by covalent bonds, usually three stages are essential for polymerization; i.e: initiation, propagation, and termination. The number of repeating units in the polymer is called the degree of polymerization [6].

Packaging design and technology requires specified information of a broad range of polymeric properties, these properties involve: mechanical properties, physical properties, thermal characteristics that include the melting temperature, or chemical properties which involve weather resistance and the solubility of a chemical in the polymer which is being utilized for the packaging.

Plastics films must be modified to protect the packaging items against the environmental factors such as: light (particularly UV radiation), (rain, dust, and dirt), temperature, and water vapor. Also must be protected against physical protection (protection of the subject enclosed in the package from shock, vibration, compression) [7].

Thermal conductivity is the rate at which a material conducts thermal energy through itself. It is the quantity of heat that passes through a unit of the material in a unit of time when the temperature variation of two faces is 1 K [8].

Due to thermal energy transports more efficiently along the polymer chain; the thermal conductivity of polymers is highly dependent on polymer chain orientation. Crystalline polymers have higher thermal conductivity than amorphous polymers; this is because of crystalline polymers having highly ordered chain segments.

Amorphous polymers may exhibit anisotropic thermal transport properties, if polymer chains are partially oriented with thermal conductivity along the chains higher than that perpendicular to the chains.

The type and amount of fillers used, size, shape, thermal properties of the filler, and orientation of filler particles in polymer matrix, these factors are important to determine thermal conductivity of filled polymers [9].

Thermal conduction mechanism in polymers is based on agitation or molecular movement across intramolecular or intermolecular bonds. In this context, structural changes that result in a decrease interbond path lengths, or that increase in the effective frequency of contact, increase thermal conductivity. Conversely, factors causing increased disorder or free volume in polymers usually result decreases in thermal conductivity. The presence of crystallinity in polymers results improving in packing of molecules and usually increases the conductivity [10].

Thermal conductivity is measured by using the equation below [11]

$$K\left[\frac{T_{B}-T_{A}}{d_{S}}\right]=e.\left[T_{A}+\frac{2}{r}\left(d_{A}+\frac{1}{4}d_{S}\right)T_{A}+\frac{1}{2r}.d_{S}.T_{B}\right] \qquad (1)$$

where: K is thermal conductivity coefficient (W/m.K).

T_A, T_B, and T_C: are the temperatures of sample (K), respectively.

d_A, d_B, and d_C: are the thicknesses of sample (m), respectively.

d_S: is the thickness of sample (m).

r: is the disk's radius (m).

e: is the quantity of heat flowing through the cross sectional area of the specimen per unit time (W/m^2. K), which is calculated from the following equation [11].

$$H=I.V=\pi r^{2}.e.(T_{A}+T_{B})+2\pi r.e.\left(T_{A}.T_{A}+\frac{d_{s}}{2}(T_{A}+T_{B})+d_{B}.T_{B}+d_{C}.T_{C}\right) \qquad (2)$$

where: I is the current through the heater (A). V is the applied voltage (V).

The thermal conductivity system is shown in Fig.1.

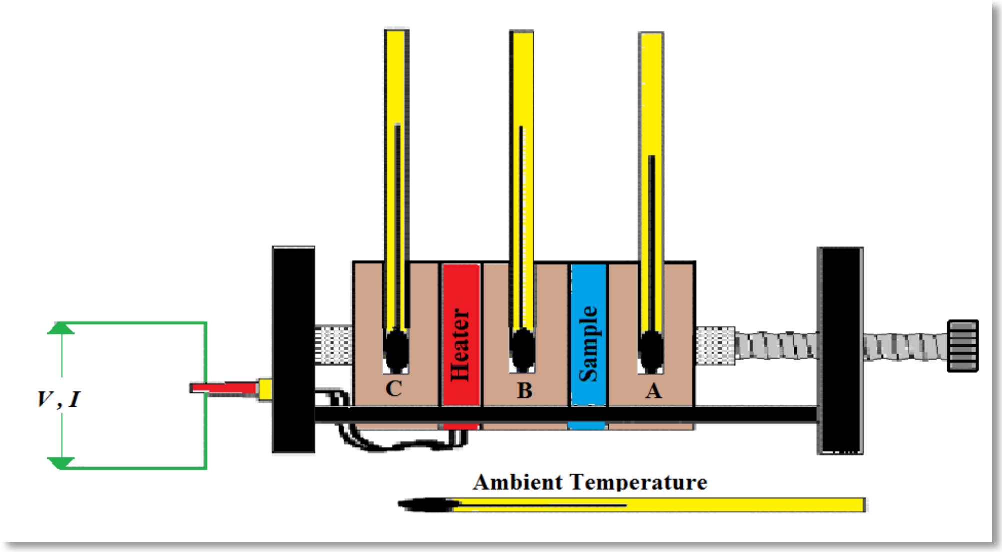

Fig. 1: Scheme of thermal conductivity instrument [11].

Experimental part

Poly methyl methacrylate (PMMA), and Polystyrene (PS) of ICI Company in the form of granules were use as homo polymer. Methylene chloride, (or Die chloromethane) supplied by (GCC) company were used.

Sample preparation

Film casting

The purified polymer were used to cast films of thicknesses within (1.98±0.2) from different concentrations solution. (20 g) of homo polymer was dissolved in methylene chloride and handy shaken until a homogenous solution was obtained, after which solution was transferred to clean glass Petri dish of (7cm) in diameter placed on plate form. The dried film was then removed easily by using tweezers clamp.

The best concentration for film production for casting without bubbling and can be dismounted easily from the petri dish was found to be 20%wt/wt. Fig.2 shows the samples of casted homo polymer. Digital vernier was used to measure the samples thickness to be (1.98 mm), (2 mm), and (1.95) for PMMA and PS, respectively.

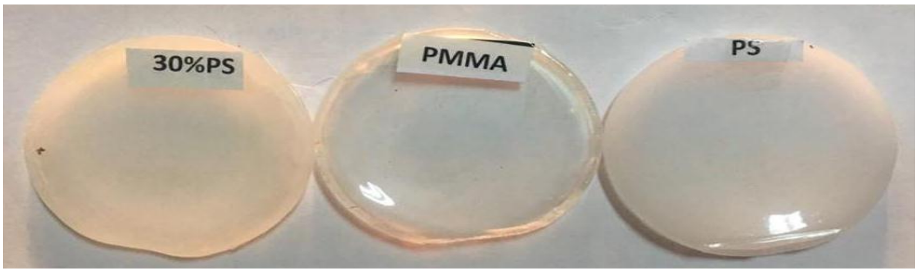

Fig.2: The samples of (PMMA, PS and 30%PS\PMMA).

Table 1: Weight ratios (%) and thickness of polymer blends.

Polymer blend	**Weight ratio (%)**	**Thickness(mm)**
PMMA	100%	1.95
PS	100%	1.98
10%PS	90%PMMA	1.95
30%PS	70%PMMA	1.98
50%PS	50%PMMA	1.96
70%PS	30 %PMMA	1.96
90%PS	10%PMMA	1.94

Accelerated weathering conditions

The prepared film was exposed to the weatherizing conditions such as (ultraviolet radiation (UV), rain, and heat), at different conditions, using (Accelerated weathering tester– QUV/spray- Q-LAB).

Firstly the films were exposed to (UV radiation and rain) by placed them inside an accelerated weathering system, at different exposure times (30, 60, and 90hr) and (5, 10 and 15hr) respectively.

Figs.3-8 present the prepared samples after exposed to (UV radiation and rain) respective

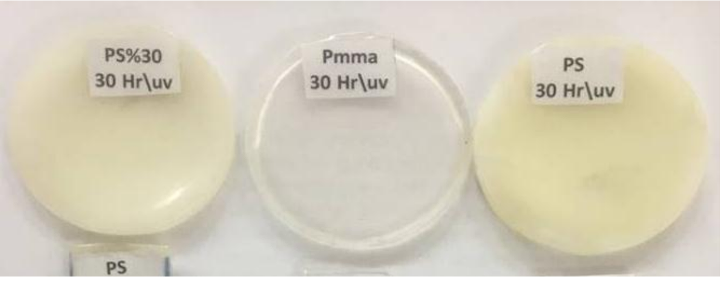

Fig.3: Shows 30hr uv for PMMA, PS, 30%PMMA\PS.

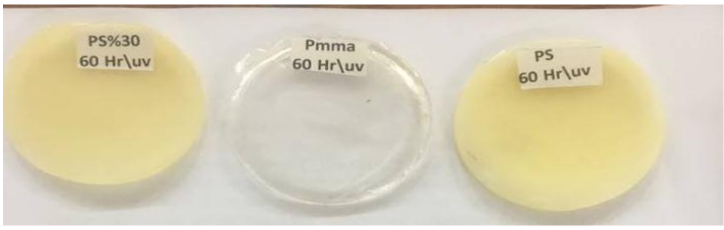

Fig.4: shows 60hr uv for PMMA, PS, 30%PMMA\PS.

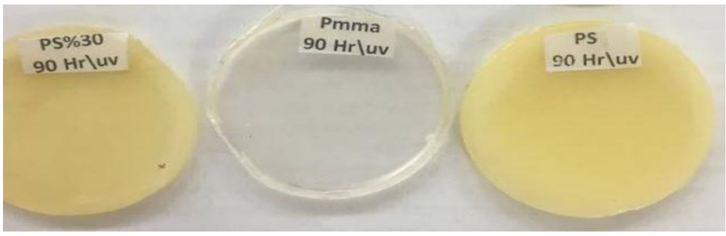

Fig.5: Shows 90hr uv for PMMA, PS, 30%PMMA\PS.

Fig.6: Shows 5hr rain for PMMA, PS, 30%PMMA\PS.

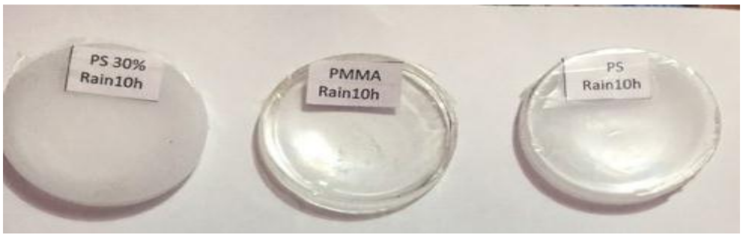

Fig.7: Shows 10hr rain for PMMA, PS, 30%PMMA\PS.

Fig.8: Shows 15hr rain for PMMA, PS, 30%PMMA\PS.

Results and discussion

Thermal conductivity of materials is an important property, which is required to decrease the heat transfer through the material. This property is essential to any potential application on the environmental and thermal stability of the material [11].

Fig.9 shows the effect of PS, PMMA and PS/PMMA at different ratios blends on the thermal conductivity of PMMA. It was seen increase in thermal conductivity of PMMA up to 50% PS/PMMA blend then decreased that was attributed good miscibility of the blend involved.

Fig.10 shows the increase of thermal conductivity of PMMA BY UV=Weathering up to 30 hr. then decrease that was attributed to increase in rigidity of the samples involved then decrease by defect formation .It was systematic decrease in thermal conductivity of PS with time irradiation that was due to systematic (Chain depolymerization involves the successive release of monomer unit from a chain end in a depropagation reaction, which is essentially the reverse of chain polymerization (systematic degradation). photodegration degradation of PS. For 30%PS, the results proved there was unsystematic changes, which was attributed to unsystematic (Random degradation (unsystematic degradation): is an analysis to the stepwise polymerizing. Here chain rupture or scission happens at random points along the chain, leaving fragments, which are unusual large compared to monomer unit. (Unsystematic degradation). Degradation of the samples involved [11-15]. Polymer chain fragments very much depends on the physical state of the polymer. The molecules are almost frozen in their position; that is strongly limited therefore free special found by radiation remains trapped of their mobility is hindered in the medium [11-13].

Fig.11 shows the Rain-weathering effecting thermal conductivity PS, PMMA, and 30%PS, PMMA. It was seen systematic decreased in PS and 30% PS/PMMA thermal conductivity; and systematic decrease in PMMA thermal conductivity. That due to the water diffusion in the samples that created some voids, bubbles, and result in decrease in thermal conductivity. This result was attributed to the decrease in adhesive between the component of polymer systems.

Rain- weathering for the samples involved produces an increase in heat resistance of the component bond arise and decrease in the heat transfer of material [11].

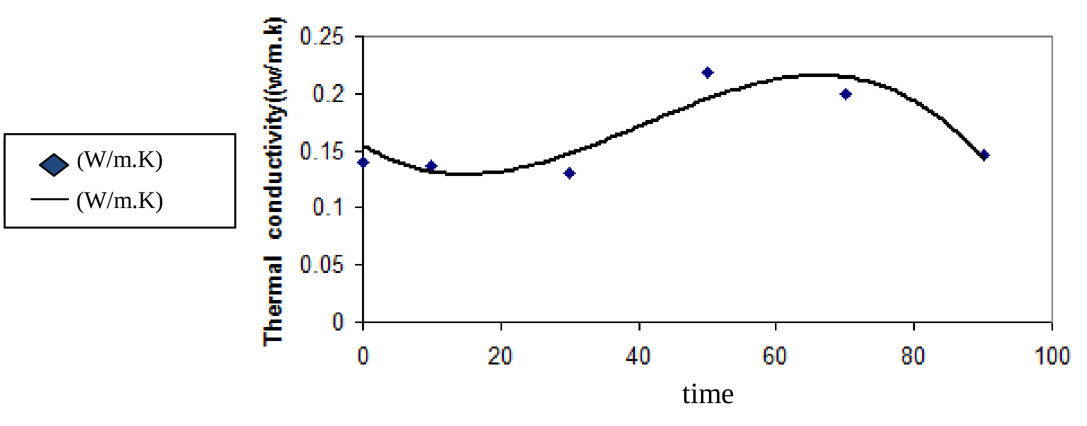

Fig.9: Thermal conductivity for (PMMA and PS) before weathering.

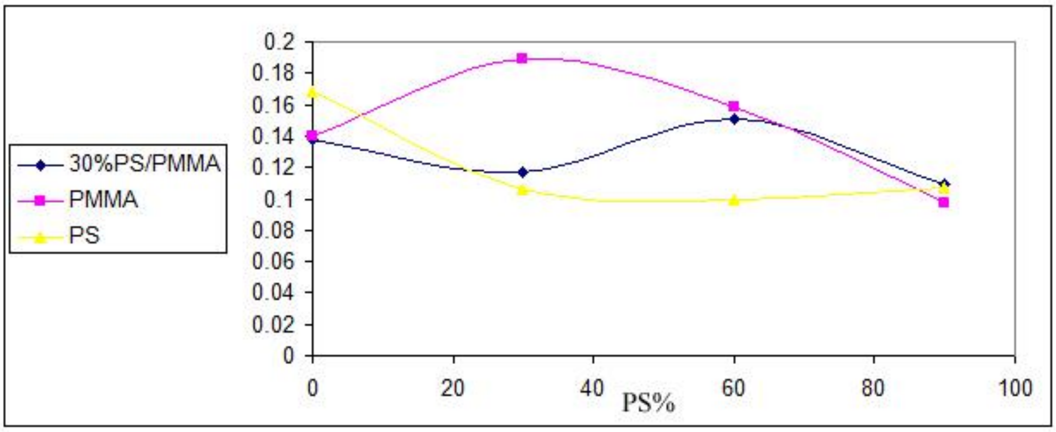

Fig.10: Thermal conductivity for (PMMA, PS and 30%PS), after UV - weathering for (30, 60, and 90 hr).

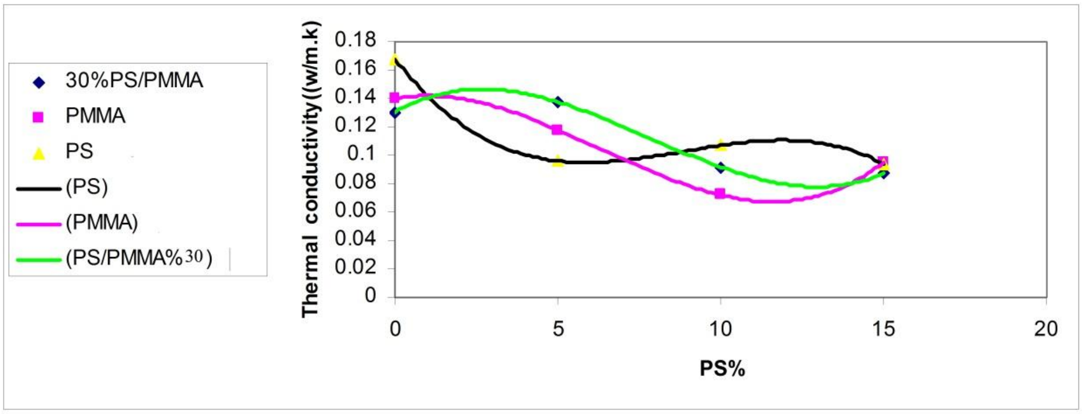

Fig.11: Thermal conductivity for (PMMA, PS and 30%PS), after Rain-weathering for (5, 10 and 15 hr).

Conclusions

It was seen increase in thermal conductivity of PMMA up to 50% PS/PMMA blend then decreased. It was seen that thermal conductivity for PMMA increased with UV-weathering up to (30hr) then decreased, that was attributed to crystallinity and defect formation respectively. For 30%PS/PMMA, there results showed unsystematic decrease in thermal conductivity, which was attributed to unsystematic degradation. By Rain-weathering, it was systematic decrease in thermal conductivity with exposure time for the samples involved. The results suggested that the samples involved could be used for packaging application.

References

[1] D. Patidar and N. S. Saxena, Advances in Nanoparticles, 2 (2013) 11-15.

[2] A. M. Hameed and R.H. Helal, Journal of Al-Nahrain University, 16, 3 (2013) 148-158.

[3] A.Q. Karrar, MSC, thesis "Preparation SnO_2 nanoparticales and study the effect Doping on stracure and Optical properties", University of Technology, (2013).

[4] Y. Mobarak, M. Bassyouni, M. Almutawa, Advances in Materials Science and Engineering, 6, 3 (2013) 6-7.

[5] P. H. Fayiz, C. M. Kutty, M. Jafar, European Journal of Molecular Biology and Biochemistry, 1, 1 (2014) 27-29.

[6] L. N. Shafigullin, A. I. Shveyov, I. F. Gumerov, M. I. Gumerov, A. F. Gumerov, Y. A. Sokolova, World Applied Sciences Journal, 29, 5 (2014) 610-613.

[7] Marianne R. Klaiachuk and Sandra A. Krasovec, "Packaging Design Successful Product Branding from Concept to Shelf", John Wiley & Sons. Inc, USA, (2006).

[8] B. M. Caruta, "Nanomaterials New Research", Nova Science Publishers, Inc, (2005).

[9] K. C. Yung and H. Leim, Journal of Applied Polymer Science, 106, 6 (2007) 3587-3591.

[10] Mariano Xanthos, "Functional Fillers for Plastics", 2nd edition, John Wiley & Sons, (2010).

[11] Rajeev Arova, Anupan Srivastav, Utam Kumar Mandal, International Journal of Modern Engineering Research (IJMER), 2, 4 (2012) 2384-2395.

[12] W.Q. Hadeer, MSC, thesis, "Weathering effect on the physical properties of polymer composite", University of Technology, (2015).

[13] E. S. Al-Hassani, Eng. and Tech. Journal, 28, 10 (2010) 1982-1990.

[14] X. Agan, Aueda, X. Omura, F.Nagai, Polymer, 38, 4 (1997) 801-807.

[15] K. K. Mathur and D. B. vanderheiden, Polymer Additives, J. E. Kresta, Plenun Press, NewYourk and London, 1984, 371-389.