

Investigation of curing kinetics analysis and their effects on properties of epoxy: polystyrene blending

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Abstract

The effect of curing conditions, such as temperature, concentration of toughening material, such as polystyrene, on epoxy resin cure kinetics was studied, along with the effects of curing parameters, such as degree of cure (α) and glass transition temperature (T_g), mechanical properties, thermal properties (TGA), and morphology of epoxy and its blends. T_g , degree of cure, and thermal stability measures were calculated from a DSC chart, mechanical properties (tensile strength, elastic modulus, and elongation at break) were measured using a universal tensile machine, the curing process was the same for all samples with varying temperatures, and the morphology of fracture surface Clearfield was examined using SEM. The samples were prepared by mixing two sets of (resin/hardener)+polystyrene (PS) (0, 2.5 % Wt., 5% Wt., and 7.5% Wt.) by mechanical stirring. The first set was cured at room temperature, while the second set was cured at 80 °C. The chart is drawn with the content of PS, as the degree of value is converging. The value of T_g in the first set decreased in comparison with neat epoxy resin along with increasing polystyrene content, then increased at 5% Wt., 7.5% Wt. PS at room temperature while decreased with 80 °C. The mechanical properties decreased at both room temperature and 80 °C. The thermal stability in the first stage showed good stability with increasing temperature the degradation become faster until reach charring of the sample. SEM was used to examine the broken surface's morphology after PS cure at room temperature reduced.

Keywords: Epoxy Resin, Kinetics analysis, Polystyrene Blending, Thermal properties (TGA), Transition temperature (T_g).

Introduction

Epoxy resins (EP) have been widely used in construction, machinery, aerospace, and other related fields due to their low cost, excellent bonding performance, outstanding mechanical properties, easy processability, dimensional stability, superior thermal and chemical resistance ^{1,2}. Thermoset resins such as epoxy and unsaturated polyester have diversified applications in numerous fields. Epoxy is widely used as a matrix material for making many composites. However, it is brittle in nature and has poor resistance to crack propagation but the single

matrix system has its own disadvantages, like brittleness, evolution of volatiles during cure and less resistance to crack propagation ³. The brittleness and poor elongation after cure are two of the unmodified epoxy resins' principal limitations, limiting their use in a variety of industries. When energy is absorbed by epoxy resins, cracks typically form on their free surfaces and propagate, resulting in fracture ⁴. 'Hardeners, also known as curing or crosslinking agents have the ability to open the C-O-C ring at the ends of epoxy molecules and form bonds with the

molecules to transform the resin into a thermoset network structure'. 'When choosing a specific hardener, consideration should be given to the processing variables (pot life, viscosity, mixing ratio, and temperature) as well as the desired product properties (strength, chemical and thermal resistance, toughness, and flexibility) ⁵. To start a thermal curing reaction, two reactive components are normally mixed together, and the temperature is increased to start an oligomerization and cross-linking reaction. Given that the primary characteristics of the cured materials are significantly connected with the cross-linking network ⁶.

It is common knowledge that the structure of the crosslinking network, the degree of curing, the duration and temperature of the curing reaction, and other factors affect the physical properties of cured epoxy resins. Network formation-related curing kinetics factors may reveal important details about the final composition, qualities, and processability of the epoxy resin network. As a result, to comprehend the relationship between structure, property, and processing in the creation of high-performance composites, it is imperative to analyze the curing kinetics of epoxy resin. To date, there have been few papers on the phenolic amine/epoxy resin system's curing kinetics analysis ⁷. A thermosetting resin must go through several simultaneous reactions known as the curing process. The formula below can be used to calculate the speed of reaction ($d\alpha/dt$), which is proportional to the measured heat flow ⁸:

$$d\alpha / dt = k(T)f(\alpha) \quad 1$$

Where $k(T)$, is the reaction rate constant, depending on the reaction mechanism, reflects the conversion's level. The Arrhenius formula results in $k(T)$ ^{8,9}:

$$k(T) = A \exp(-E_a / RT) \quad 2$$

Where T is the absolute temperature, A is the pre-exponential factor, and R is the universal gas constant [8.314 J (mol K) ⁻¹]. Hence, the following dynamics equation would apply to the curing of blend ²:

$$d\alpha / dt = A \exp(-E_a / RT)f(\alpha) \quad 3$$

Materials and Methods

The epoxy used was Sikadur®-52 LP and polystyrene API 390. Epoxy resin is composed of

It is obvious that "three dynamics factors," E_a , A , and $f(\alpha)$, must be validated to develop the curing reaction kinetics equation. Numerous methods, including the "Kissinger-" "Akahira-Sunose," "Flynn-Wall-Ozawa," and "Ozawa-Kissinger procedures," can be used to compute the three dynamical components of the curing process, in particular E_a . Regardless of the heating rates identified by the Kissinger and Ozawa methods, "the Kissinger and Ozawa non-isoconversional" approaches assume that each DSC exothermic peak will convert at the same rate. The mannequin for the piece is The Ozawa method can be utilized to perform the non-isothermal kinetic analysis as well. The logarithm of the heating rate and the inverse of the exothermic peak temperature, or logarithm of the heating rate ($\ln\beta$) against exothermic peak temperature ($1/T_p$), have this connection. The obtained slope can be used to calculate the activation energy E_a ^{8,9}.

$$D(\ln\beta) / d(1/T_p) = -1.052E_a / R \quad 4$$

To achieve the necessary qualities, epoxy resin is combined with its curing agent and is properly cured. It is possible to enhance and improve coating quality by being aware of epoxy's curing kinetics. Various methods can be used to examine the thermosetting resins' kinetics of cure. One of the most popular and precise techniques for examining these processes is differential scanning calorimetry (DSC) ¹⁰. Once the epoxy is cured, they are characterized by high chemical and corrosion resistance as well as good mechanical and thermal properties. However, the chief drawbacks of epoxy from industrial use are its brittleness and high cost ¹¹. When it comes to modifying the brittle nature of epoxy, an increase in toughness without any reduction in the other important properties is required, such as modulus, thermal properties and environmental corrosion resistance ¹². Toughness also implies energy absorption and it can be achieved through various deformation mechanisms during crack propagation and before a failure occurs ¹³. The current study examined the effects of various parameters on the kinetics of curing epoxy resin and its blends and their effectiveness on the mechanical properties of epoxy and its blends.

polystyrene, bisphenol A (epichlorohydrin), mono (C-12-14 alkyloxy), and 3,6-dioctanethylene

diamine, with 3,5,5, trimethylcyclohexylamine serving as a hardener. In this research, different ratios of polystyrene were blended after dissolving in toluene and then mixed with resin using a mechanical stirrer after mixing the hardener added

to the mixture and poured into the mold cured in two different ways for the curing process done first all the sample cured at room temperature for 24h and using thermal curing by using of an oven to curing process for 4h at temperature 80 °C.

Results and Discussion

Characterization

Thermal tests

Differential Scanning Calorimetry

Using differential scanning calorimetry DSC type ta-60 WS equipment according to ASTM¹⁴, the thermal properties of epoxy resin and epoxy resin/polystyrene blends were assessed (Shimadzu, Japan). The samples, whose weights ranged from 8 to 100.5 mg, were heated at a rate of 10 °C/min from room temperature to 350 °C. The test was done in the laboratory of Babylon University/ Collage of Materials Engineering /Department of polymer and petrochemicals industries.

The TGA test was performed in a nitrogen flow at a 20 °C/min temperature ramp rate. For each of the several blends, there was a different pattern in the early degradation up to 350 °C by instrument type SDT Q600 V20.9 Build 20 with Method: Dual Ramp. In Iran laboratory.

Mechanical tests

The tensile properties were evaluated in accordance with ASTM D638-IV, as shown in Fig. 1. according to Annual Book of ASTM Standard, "ASTM D638: Standard Test Method for Tensile Properties of Plastics," ASTM Stand., no. January, pp. 1–15, 2003, using a standard testing apparatus (WDW 5E, manufacturer, China). The test was done in the laboratory of Babylon University/ Collage of Materials Engineering /Department of polymer and petrochemicals industries. Charpy's definition of impact strength at a rate of 5 mm/min is as follows: A WP 400 impact tester (Gunt, Germany) was used to measure impact strength in line with ASTM D-256¹³ as shown in Fig. 2. The test was done in the laboratory of Babylon University/ Collage of Materials Engineering /Department of polymer and petrochemicals industries. Impact strength can be intended from the following equation:

$$G_c = U_c / A \quad 5$$

Where G_c : The impact strength (KJ/m²), U_c : The needed energy for fracture the sample (J) and A : the cross-section area of the specimen (mm²).

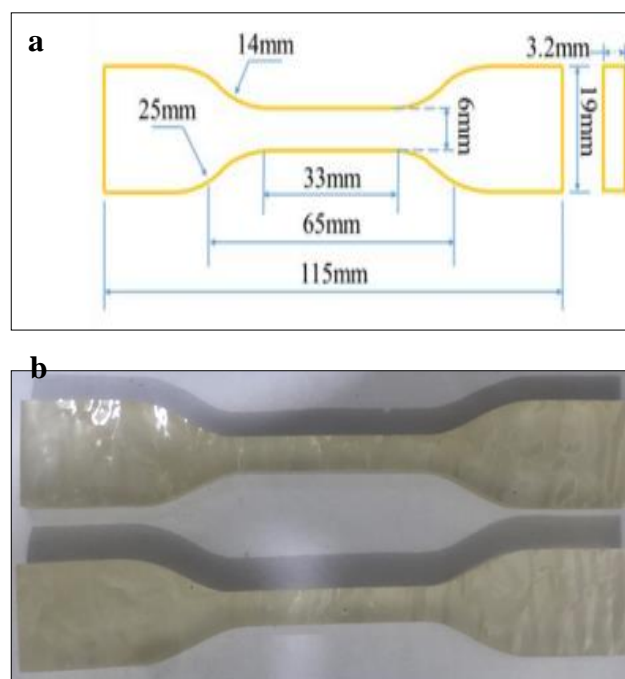


Figure 1. a) Represent the standard dimensions of tensile test specimen¹³ and b) experimental tensile test specimen.

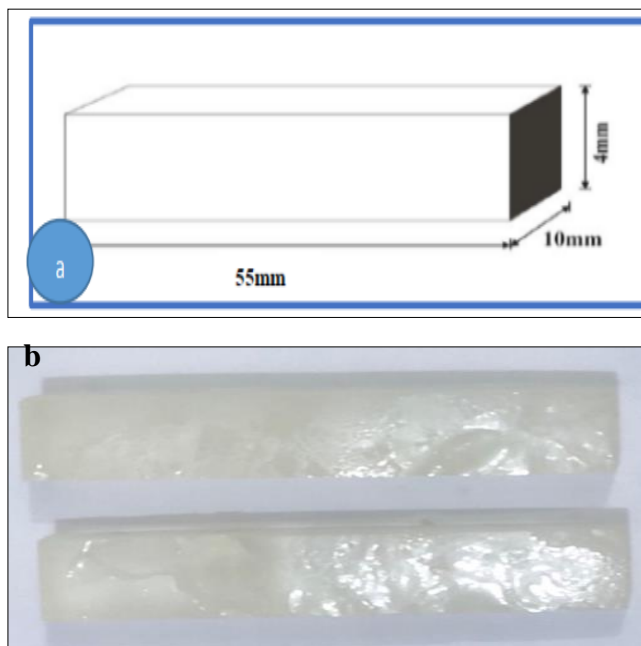


Figure 2. a) Represent the standard dimensions of impact test specimen and b) experimental impact test specimen.

Morphology test

SEM test

A high-resolution scanning electron microscope was used to examine the morphology of the epoxy/polystyrene mixes. utilizing a FESEM-EDS type MIRA III equipment (TESCAN, Czech Republic) at a 15 kV accelerating voltage with a sample cross section of 20 μ m. In Iran laboratory.

DSC Test results

T_g really refers to a range of temperatures where resins have greater molecular mobility. T_g and degree of cure are correlated since the value of the degree of cure is converging the chart will be done between T_g and PS content, as seen in Fig. 3. Since T_g will result in a reduction in heat flow, it can be determined via DSC. When considering the exothermic peak associated with the resin's curing process, T_g can be calculated "as a function of the degree of cure", the kinetic reaction's parameters can be identified, and the premise that the heat flow is proportional to the degree of cure may be accepted. T_g is measured to be 66.30 °C for an epoxy system that hasn't been altered.

The addition of thermoplastic polymer and increasing PS% load content has caused a decrease in temperature. When adjusted with 2.5 weight percent of PS curing at room temperature, this yields

a reduction of about 19% when compared to the unaltered epoxy system. It might be argued that because PS may serve as plasticizers, the reduced crosslinking degree of the PS areas leads to the conclusion that the addition of PS affects the T_g of epoxy resin.

Furthermore, the value of T_g decreased by around 12.669% as content rose, and the reduction reached 25% when 7.5 weight percent of PS was added for all samples that were cured at room temperature for 24 hours. There has been speculation that the amount of reactive group depletion and the overall heat generated by DSC are connected. From room temperature to 350 °C, the sample was dynamically heated at a rate of 10 °C/min. For a variety of 2.5% Wt. PS, 5% Wt. PS and 7.5% Wt. PS, epoxy/polystyrene mix ratios, as shown in Figs. 4,5,6,7 and 8 . The density of crosslinks has decreased because of the existence of flexible PS chains, which have decreased the rigidity of the polymer chains. This phenomenon can be explained, among other things, by the fact that the midway temperature, or T_g, has decreased because the appearance of a second phase inhibits the density of thermoset cross-links from growing.

These effects lead to a decrease in T_g. Furthermore, while certain PS chains were miscible with the epoxy, others were phase separated from the epoxy, which may be a sign of the matrix plasticization process that led to the lower T_g being observed. A cross-linked thermoset, like epoxy resin, will have a higher T_g as the amount of cross-linking increases. It was found that the T_g decreased and changed to a lower value as the polystyrene content increased. This is one of the kinetic parameters that affect the properties of epoxy and its blends that are presented by the T_g, even though only a few glass transition parameters are significantly altered because of the variety of polymer combinations.

Due to their higher adaptability and mobility, chains have a lower T_g than other materials. The mobility of the chain is restricted by cross-links, which act as durable entanglements. As a result, when there are few cross-links present, the temperature at which glass transitions occur increases roughly linearly. A diffuse, ill-defined glass transition is frequently seen in materials with a high cross-link density. The results of (T_{peak}, T_{onset}, and T_{mid}) show "that the curing of epoxy resin" is an exothermic process, in contrast to increased polystyrene content. Because it lowers the activation energy and causes an increase

before it drops or keeps steady, polystyrene appears to encourage the curing reaction when added to epoxy resin. The dynamic cure kinetics of the Epoxy/PS blends were investigated after performing a DSC test with heating rates of 10°C/min. When secondary components are present, the free volume rapidly decreases and the polymer chain mobility affects the T_g ¹⁴.

Because there is no clear pattern in the behavior of reaction heats, which indicates that a non-uniform process is taking place, it is believed that the information from the results is complementary and can help in the understanding of physical processes to be modeled with the cure equations¹⁵. The flexibility of the material's chain, the level of cross-linking, and the potency of the intermolecular hydrogen bonding interaction (amine group) all have a considerable kinetic impact on the T_g of the cured epoxy. By including PS, the T_g of the epoxy resin was not raised but rather lowered.

This could be a result of the PS macromolecular chain coming into touch with the curing agent and preventing the epoxy resin from properly curing. The PS addition also makes the system more viscous, which results in a slower curing reaction. The PS/epoxy composites were more durable than pure epoxy resin because they had a lower T_g . Consider how this relates to the fact that polystyrene has a naturally higher T_g , which may have neutralized its effect on the epoxy resin's level of curing¹.

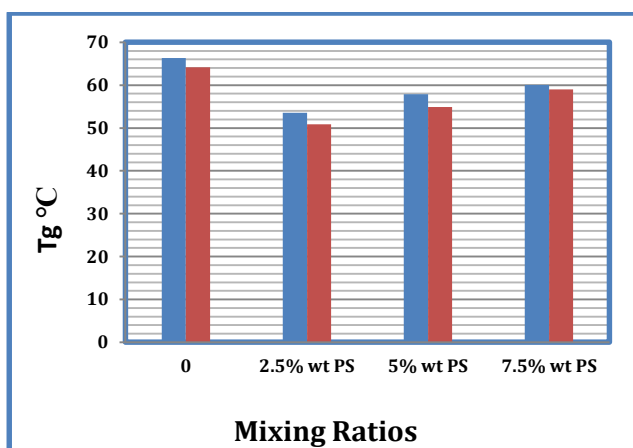


Figure 3. Relation between glass transition temperature (T_g) and mixing ratios of pure epoxy and blends at room temperature and 80 °C.

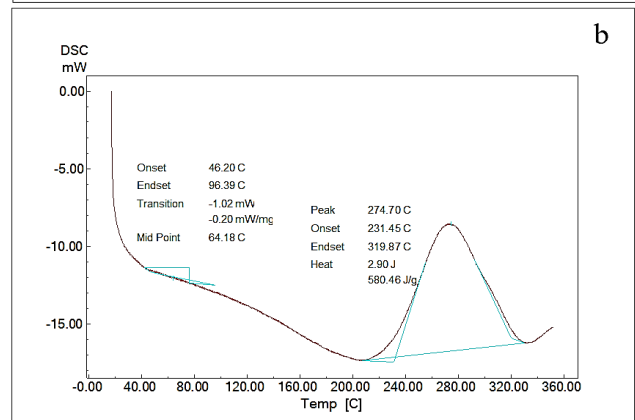
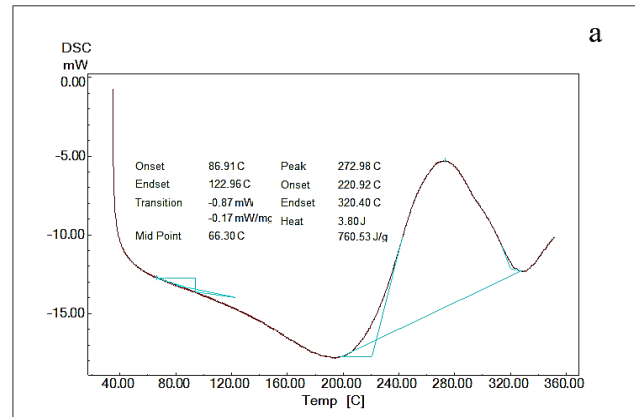


Figure 4. DSC Curves of epoxy pure at: a) room temperature and b) 80 °C.

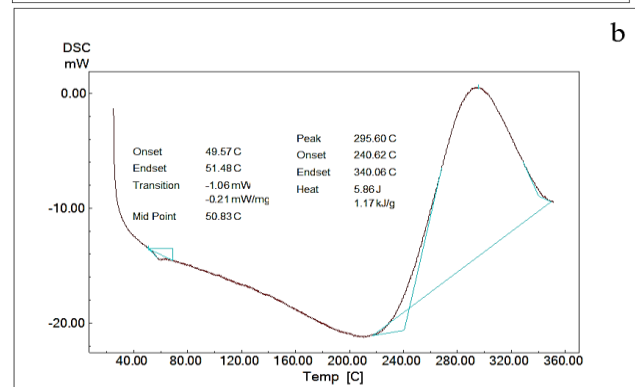
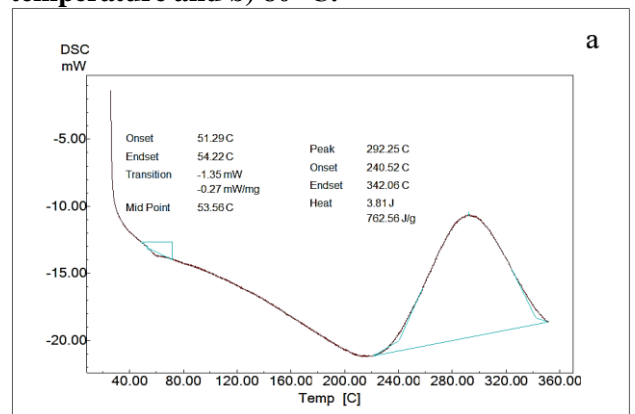


Figure 5. DSC Curves of epoxy blends at: a) room temperature and b) 80 °C.

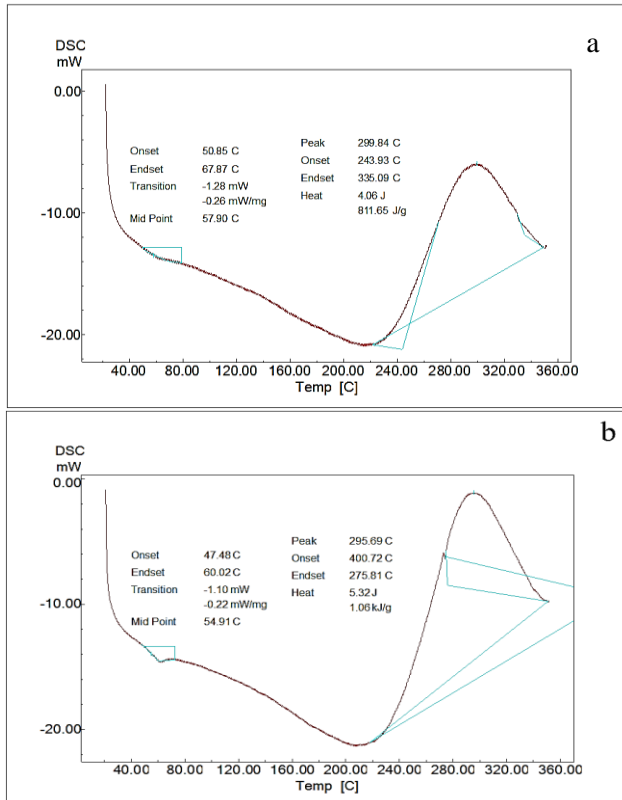


Figure 6. DSC Curves of epoxy blends at: a) room temperature and b) 80 °C.

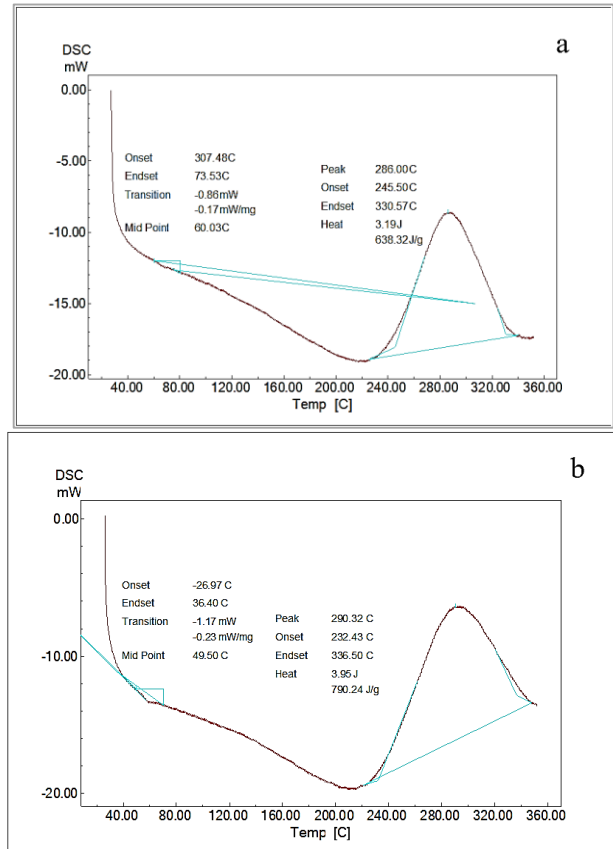


Figure 7. DSC Curves of epoxy blends at: a) room temperature and b) 80 °C.

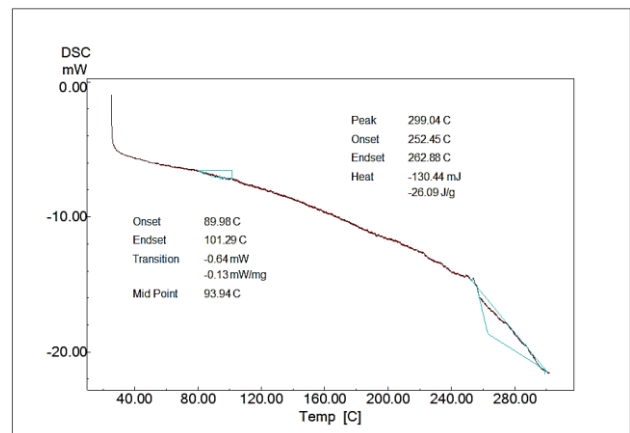


Figure 8. DSC Curves of Polystyrene.

The TGA test results

This test was performed in a nitrogen flow at a 20°C/min temperature ramp rate. Fig. 9 displays the findings. For each of the several blends, there was a different pattern in the early degradation up to 300°C. To examine the thermal stability, TGA was carried out on an epoxy resin that had been cured with polystyrene. The following were the relative mass losses at the indicated stages: 10.49% from 0 to 100 °C, 27.80% at 200 to 250 °C, and 28.59% at 350 to

400 °C. This demonstrates that between 330 °C and 430 °C, the most polymer breakdown takes place. The thermal degradation rate of epoxy and epoxy polystyrene curing at different temperatures is determined by the instrument (up to 350°C by instrument type SDT Q600 V20.9 Build 20 with Method: Dual Ramp. It can be seen from Fig. 9 that epoxy is more stable at the first stage of the test at 3.445%, 3.361%, 3.74 %, 3.2 %, and 3.2 % of mass loss for all samples below with different ratios and curing temperatures which is attributed to that all of the weak linkage between epoxy and polystyrene affected while the mass loses in the middle stage was increased with increasing temperature (16.66 %, 19.08 %, 19.23 %, 14.87 %, and 19.23 %) of mass lose for all the samples consequently, and in the final stage the mass lost was 21.58 %, 19.25 %, 21.31 %, 17.78 %, and 16.08 % of mass lose for all samples consequently in this test the stages of mass lose given the picture of the stability of pure epoxy with its blends and their ability to standing the temperatures in the range of 0-350°C before charring which give the possibility of use of epoxy and its blends in different applications under temperatures required 350°C.

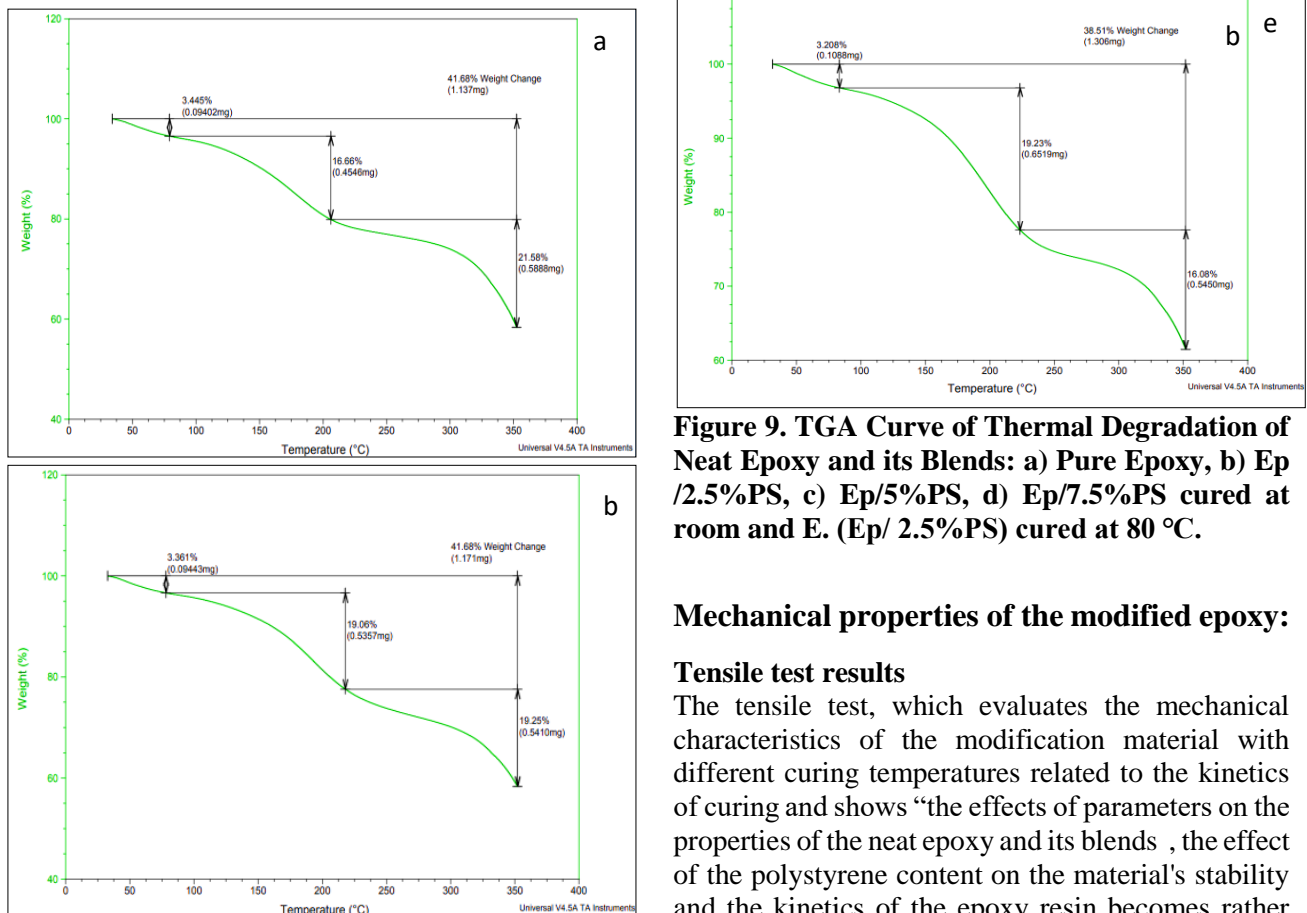


Figure 9. TGA Curve of Thermal Degradation of Neat Epoxy and its Blends: a) Pure Epoxy, b) Ep /2.5%PS, c) Ep/5%PS, d) Ep/7.5%PS cured at room and E. (Ep/ 2.5%PS) cured at 80 °C.

Mechanical properties of the modified epoxy:

Tensile test results

The tensile test, which evaluates the mechanical characteristics of the modification material with different curing temperatures related to the kinetics of curing and shows “the effects of parameters on the properties of the neat epoxy and its blends , the effect of the polystyrene content on the material's stability and the kinetics of the epoxy resin becomes rather

evident as shown in Fig. 10 which represented the relation between stress- strain curves .

The phase morphology created during the blending of the polystyrene and epoxy resin, as well as the interfacial adhesion between the phases, have a substantial impact on the mechanical properties of the blended materials¹⁶ . The polystyrene needs to have strong contacts and good dispersion for the mechanical properties of the blends to be improved. The performance of epoxy mixtures was expected to be enhanced by surface functionalization by enhancing interfacial bonding and dispersion. Fig. 11. compares several epoxy-polystyrene blends' tensile strength varied levels of polystyrene content in the polymer matrix. Pure epoxy is represented by zero polystyrene content. Fig. 11. unequivocally shows a notable improvement in tensile strength with relatively low polystyrene loadings.

Fig. 11. shows that all the blends have improved tensile characteristics at low polystyrene loadings. It was shown that the rate of enhancement was higher at low PS loading than at higher PS loading. Epoxy-PS mixes' tensile strength followed a different pattern from the other blends. Before starting to decrease, it originally grew. When compared to raw EP resin, the better dispersion of EP-PS resulted in a higher tensile strength at lower concentrations. The rise in tensile strength was therefore attributed to specific interactions between the filler and polymer matrix. Because PS is poorly dispersed, its presence may hinder the polymer chains from packing securely and lower the blends' overall tensile strength.

The quantity of polystyrene has an impact on the elastic modulus of epoxy resin mixtures, as seen in Fig. 12. This is the result of faulty epoxy resin curing, which increased elastic modulus, started to stabilize with a rise in PS, and subsequently decreased¹⁷ .

Fig. 13 depicts how different PS content affects elongation at break. The statistic makes it obvious that a rise in PS content was responsible for all blends' decreased EAB. Due to its improved interaction with the epoxy matrix, the epoxy-PS demonstrated a greater reduction in EAB. Results from the EAB and tensile tests show that the right number of PS can improve the mix's mechanical qualities. Unfortunately, the inclusion of PS decreased the modulus and tensile strength. With the increase in PS content, the tensile strength clearly reduced but the tensile modulus remained somewhat

stable. This can be attributed to the poorer load transfer capability caused by the polystyrene particles created by phase separation's insufficient interfacial adherence to the epoxy resin matrix⁷ .

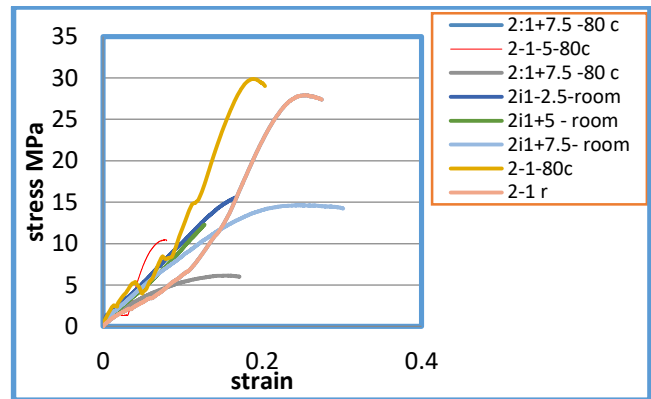


Figure 10. The stress – strain Result of Epoxy/Polystyrene Blend at room temperature and 80 °C.

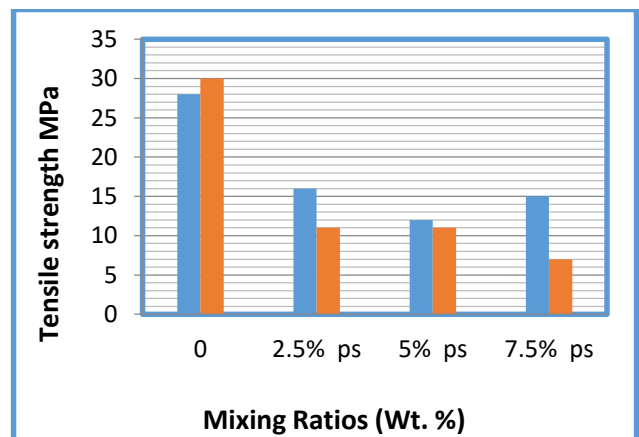


Figure 11. Tensile Strength Result of Epoxy/Polystyrene blend cured at room temperature and 80 °C.

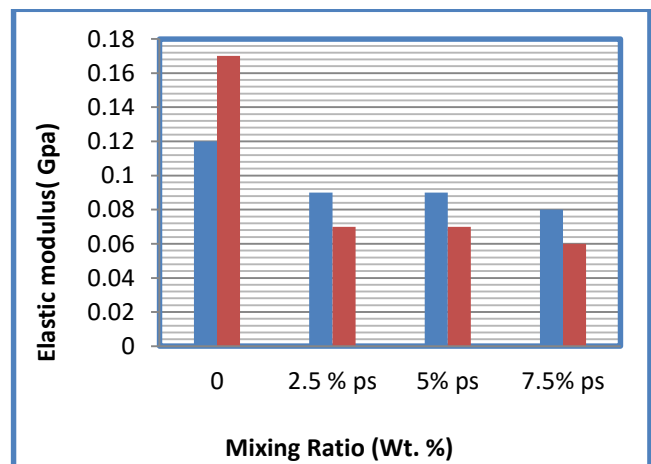


Figure 12. Elastic Modulus result of Epoxy/Polystyrene Blend cured at room temperature and 80 °C.

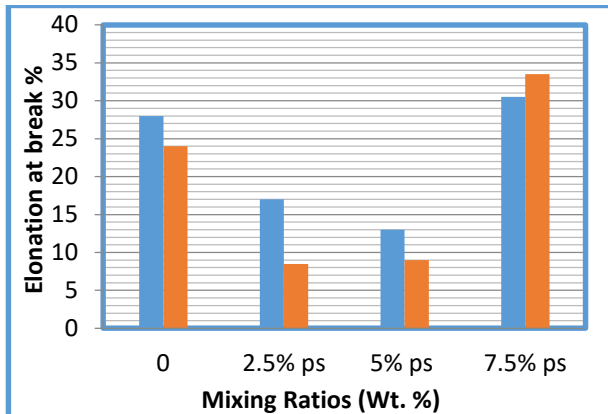


Figure 13. Elongation at break result of Epoxy/Polystyrene blend at room temperature and 80 °C.

Impact Test results

The Impact Test Results The principle of this test is that some of the primary energy which is kept as a potential energy in the hammer was absorbed by the sample during the rupture. As shown in Fig. 14 the impact strength increases in the beginning, then slightly decreases, then surges suddenly, then decreases. This is because there is a strong interpenetrating link and a robust curing response when polystyrene is at 5% Wt. The structure's good impact toughness is a result of the network's enhanced ability to disperse energy and flexible polystyrene connection. According to the findings, there was a noticeable increase in impact strength at PS, followed by a minor increase and no further increase when compared to pure epoxy. This behavior may be attributed to the impact test being conducted quickly, leaving no time for the polystyrene polymer to react. This might be because of the heterogeneous distribution of the micro-sized domain, which may facilitate crack initiation and propagation during sudden impact deformation. The Charpy impact tests give an idea about the macroscopic mechanical behavior of the blends. The slight improvement in mechanical characteristics brought about by the addition of PS may be explained by the compatibility and interfacial adhesion between the matrix and dispersed phase, as well as the softening effect of the flexible PS chains in the rigid epoxy matrix¹⁸. Impact energy is kinetic energy, and when it hits a material that has a second phase with plastic deformation, like PS, it will absorb the impact energy and release it through vibration because its chains are flexible. This makes the material stronger to impact¹⁹.

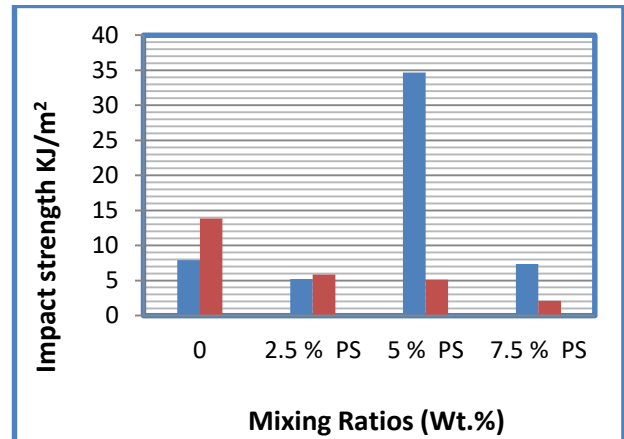


Figure 14. The Impact Strength Result of Epoxy/Polystyrene Blend cured at room temperature and 80 °C.

SEM test results

Fig. 15 shows SEM photos of samples composed of pure epoxy resin and epoxy combined with polystyrene in 20 μm magnification. Fig. 15. (A) shows that the surface of the pure epoxy resin sample is continuous, smooth, and uniform after curing. The sample of epoxy blends with polystyrene, on the other hand, shows a rough and non-uniform surface because of the overlap of the materials, offering the possibility of homogeneity of the materials together despite their difference in polarity. The PS-toughened epoxy's shattered surface, on the other hand, clearly displayed two separate phases: a continuous epoxy matrix and a dispersed Polystyrene phase. The polystyrene particles will serve as the epoxy matrix's energy dissipation center. Due to the triaxial forces present close to the crack tip, polystyrene particles would react by yielding locally²⁰. The polystyrene bridging mechanism in the crack tip zone of the epoxy matrix then occurred, and this was followed by the plastic void expansion that was brought on by cavitation or the debonding of the polystyrene particles from the surface²¹. Deformation lines were shown to spread across the polystyrene particles in the micrographs, providing proof that the ductile fracture actually did occur. Crack energy propagates through the particle and can evaporate in a concentration of microscopic polystyrene particles. An indication of brittle fracture behavior is that the fracture surface of the neat epoxy seems to be smooth. The amount of surface roughness increased as the concentration of the filler increased when added to the polymer²².

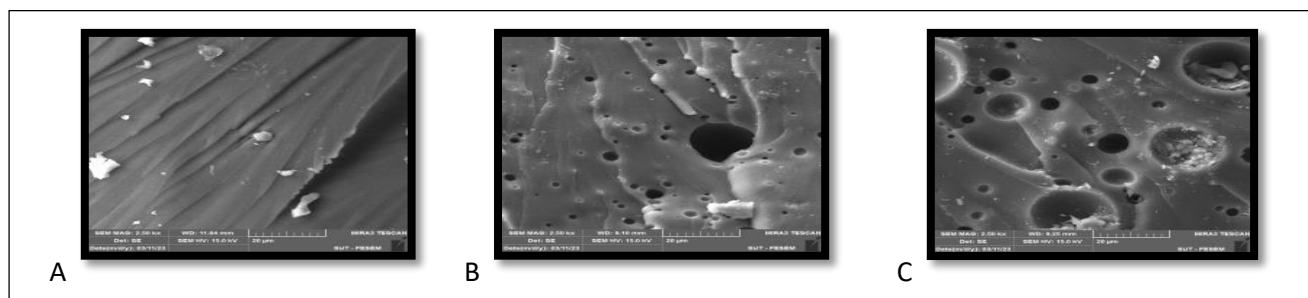


Figure 15. SEM images of a) cured epoxy pure, b) 2:1+2.5% wt. PS, c) 2:1+5% wt. PS at magnifications 20 μm .

Conclusion

In this study, it was found that the addition of polystyrene changed the kinetics of epoxy's curing at room temperature and 80°C showing varying results and responses at different parameters of curing and their effects on kinetics, as shown by the variation in the value of T_g , while increasing the amount of polystyrene also changed the properties of epoxy resin, causing the tensile strength to rise initially before dropping at a PS content of 2.5% , before Sharp increased impact strength at a PS content of

5% , and Sharp decreased impact strength due to what may be a PS content-related with different temperature of curing while thermal degradation showing that the sharing of the sample at 350 °C. This variation may be attributed to that PS may act as a plasticizer which results in a reduction of properties. These results give another contribution to that industry when applications capable of working under temperatures 350°C such as insulator materials.

Acknowledgment

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Authors' Declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee at University of Babylon.
- Ethics statement:
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- No potentially identified images or data are present in the manuscript.

Author's Contribution Statement

This work was carried out in collaboration between all authors. Z.I.M doing the experimental part by preparing the samples and doing all the tests wrote and edited the manuscript with revisions idea and

analysis the data with revision ideas. N..A.S.supervisor on the research. All authors read and approved the final manuscript.

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دراسة تحليل آلية التقسية وتأثيراتها على خواص الايبوكسي وخليط الايبوكسي مع البولي ستايرين

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الخلاصة

تم دراسة تأثير درجة حرارة التقسية وتأثير مادة البولي ستايرين المضاف بتركيز مختلفة على نظام تقسية راتنج الايبوكسي تم قياس درجة التقسية و درجة الانتقال الزجاجية , الخواص الميكانيكية , الخواص الحرارية وهينة السطح لمنطقة الكسر للعينات الايبوكسي النقي و خلأئطه . تم قياس درجة الانتقال الزجاجية ودرجة التقسية من فحص الDSC بينما تم دراسة التحلل الحراري والاستقرار الحراري من خلال فحص TGA , هينة السطح خلال فحص SEM والخواص الميكانيكية (مقاومة الشد, معامل المرونة والاستطالة عند الكسر) تم فحصها باستخدام جهاز فحص الشد العام . حيث ان الية تقسية الايبوكسي بنفس الطريقة لكل العينات التي تكون حسب الاتي PS (0, 2.5 % Wt., 5% Wt., and 7.5% Wt.) هذه تمثل نسب اضافة البولي ستايرين باختلاف درجة حرارة التقسية حيث تم استخدام مجموعتين الاولى تمت تقسيتهما بحرارة الغرفة والمجموعة الثانية لنفس التراكيز تمت تقسيتهما بحرارة 80 درجة مئوية. تم رسم العلاقة بين مستوى نسبة البولي ستايرين مع درجة الانتقال الزجاجية , لوحظ بان درجة الانتقال الزجاجية تقل بزيادة محتوى البولي ستايرين داخل ارضية الايبوكسي عند تراكيز (5 % Wt. + 7.5 % Wt.) عند تقسية العينات بحرارة 80 درجة مئوية مقارنة مع العينات التي تم تقسيتهما بحرارة الغرفة. بالنسبة للخواص الميكانيكية بصورة عامة تكون متذبذبة بين الزيادة و النقصان بصورة عامة تقل في كلا الحالتين. في حالة التحلل الحراري عند المراحل الاولى من التسخين هناك استقراره للعينات ومع زيادة درجة الحرارة يبدأ التحلل بصورة سريعة لحد الوصول للتفحم. عند فحص الصدم يبدأ بزيادة طفيفة وفضل نسبة تكون عند تركيز 5% من البولي ستايرين وتم فحص منطقة الكسر بSEM.

الكلمات المفتاحية: بولي ستايرين و الخليط و تحليل الية التقسية ودرجة الانتقال الزجاجي و الايبوكسي و الخواص الحرارية.