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Dynamic Mechanical Analysis of Epoxy-Allyl Guar Gum Based Composites

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Abstract

Epoxy–guar gum-based composites are advanced materials that combine the excellent mechanical strength and chemical resistance of epoxy resin with the renewable and biodegradable characteristics of guar gum. These composites hold significant potential to meet the growing demand for high performance and environmental sustainability in the aerospace, automotive, and construction industries. In the present study, the dynamic mechanical properties of epoxy– allyl guar gum composites were evaluated using Dynamic Mechanical Analysis (DMA). The primary objective was to analyze the effect of incorporating allyl guar gum (AGG) with Different Degree of substitution DS-0.0389, DS-0.06 at various concentrations into the epoxy resin matrix. DMA tests were conducted to determine values for storage modulus, loss modulus, and tan δ across a range of temperatures and frequencies. The results revealed that the incorporation of Allyl Guar Gum significantly influences the viscoelastic behavior of the composites. Lower Concentration 0.5Phr) of AGG led to improved mechanical performance,
The thermal stability of the composites was also investigated using Thermogravimetric Analysis (TGA), providing insights into changes in decomposition temperature and char residue.

Keywords: Epoxy guar gum composites, Dynamic mechanical analysis (DMA), Viscoelastic properties, Thermal stability, Sustainable materials

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Introduction

A naturally occurring polymer called guar gum (GG) is taken from the endosperm of the plant Cyamopsis tetragonalobus. GG and its compounds are hydrophilic and soluble in water [1]. Guar gum's main structural component is a linear chain of 1-4 linked β D mannopyranose backbone, with 1-6 linked α D-galactopyranose units occurring as a side chain [2]. The biomedical, pharmaceutical, textile, cosmetic, and food industries can all benefit from its outstanding stiffening properties and non-toxicity [3]. Nevertheless, the commercialization of biopolymers is restricted by their comparatively low mechanical qualities when compared to materials derived from petroleum. Utilizing biopolymer as a filler in conjunction with a petroleum-based matrix to create advanced material is one strategy for enhancing the mechanical qualities of the material [4]. ERs, or epoxy resins, are a significant class of thermosetting polymers. They can be utilized to create composite materials that are incredibly strong, have excellent adhesion to other materials, and are more resistant to heat and chemicals [5]. Epoxy–guar gum-based composites are innovative materials that integrate the excellent mechanical, adhesive, and chemical resistance properties of epoxy resins with the natural, renewable, and eco-friendly characteristics of guar gum. This combination yields advanced composites offering enhanced performance and potential for diverse industrial applications. Various researchers have reported the successful development of guar gum-based composites and functional materials for film fabrication [6, 7]. Guar gum, derived from guar seeds, is highly valued for its biodegradability, stability, and ability to control viscosity and flow behavior, whereas epoxy resins are widely utilized for their high mechanical strength, excellent adhesion, and chemical stability. These complementary attributes allow for the development of tailored solutions across various industries, including packaging, biomedical, and aerospace, where both environmental sustainability and durability are essential. This study explores the introduction of allyl groups improves compatibility with hydrophobic epoxy resin, which enhances interfacial interaction with the epoxy matrix. The mechanical performance of the composites has been correlated with Dynamic Mechanical Analysis (DMA) parameters such as, Storage modulus, Loss modulus, Tan δ (damping factor) to the best of our knowledge, DMA-based correlation for AGG-epoxy composites has not been previously reported in the literature. Earlier reports mainly focused on tensile or impact properties without analysing the viscoelastic behaviour [8]. The present study

attempts to establish a relationship between filler modification, dispersion behaviour, and mechanical reinforcement in epoxy resin. Thermogravimetric analysis has been included to evaluate the thermal stability of the materials. The degradation behaviour indicates the structural modification of guar gum after grafting. The development of sustainable and bio–based composite materials has gained considerable attention due to increasing environmental concerns associated with petroleum–based polymers. Natural polysaccharides such as guar gum are promising renewable materials because of their biodegradability, low cost, and abundant availability. However, the highly hydrophilic nature of guar gum limits its compatibility with hydrophobic polymer matrices such as epoxy resins. Therefore, chemical modification of guar gum is required to enhance its compatibility and interfacial interaction with polymer matrices.

The chemical modifications can significantly influence filler–matrix interactions and consequently the mechanical and thermal properties of the resulting composites.

Several studies have reported guar gum–based composites with epoxy or polyester matrices. However, most of these investigations mainly focused on mechanical properties such as tensile strength or impact strength. A detailed correlation between the mechanical behaviour and viscoelastic properties obtained from Dynamic Mechanical Analysis (DMA) has rarely been reported for AGG–epoxy composite systems.

In the present work, epoxy composites were prepared using allyl guar gum (AGG) The objective of this study is to investigate the influence of filler modification and filler concentration on the mechanical performance of epoxy composites and to correlate the mechanical properties with viscoelastic behaviour obtained from DMA analysis. The structure–property relationships were further analysed using thermo gravimetric analysis (TGA), and scanning electron microscopy (SEM).

The key findings show that incorporating guar gum filler affects the composites' damping, loss, and storage moduli, which in turn reflect alterations in their energy dissipation, stiffness, and viscoelastic properties. This study provides a comprehensive understanding of the changes in the dynamic mechanical properties of epoxy composites resulting from the incorporation of Allyl guar gum. The findings indicate that this material holds significant potential for applications in sectors such as automotive, construction, and aerospace, where both high mechanical performance and environmental sustainability are essential. Future research could focus on optimizing the structure and composition of the composites, developing novel functional properties, and expanding their utility across various engineering applications, thereby further promoting the practical use of these advanced and eco-friendly materials.

Materials and Method

The guar gum used in this study was obtained from Hindustan Gum and utilized after undergoing the necessary purification process. Allyl chloride and all other chemicals were of analytical grade and were used directly without further purification. A Diglycidyl Ether of Bisphenol-A (DGEBA)-based epoxy resin served as the polymer matrix, while polyetheramine (D230) was used as the curing agent.

Synthesis of Allyl Guar Gum (AGG)

Allyl-guar gum was synthesized by the etherification of guar gum in the presence of allyl chloride under alkaline conditions. During this chemical modification, allyl functional groups replace the hydrogen atoms of the hydroxyl groups in the guar gum [9]. Consequently, the hydrophobic nature of the modified guar gum increases, and its compatibility with the epoxy matrix improves. The degree of substitution was determined using titration methods [10].

Preparation of Epoxy Composites

Epoxy composites were prepared by the casting technique. The modified guar gum fillers (AGG were dispersed into epoxy resin using mechanical stirring to obtain a homogeneous mixture. The filler loading was varied from 0.5 to 4.5 phr. The unit Phr (parts per hundred resin) refers to the amount of filler present per 100 parts by weight of epoxy resin. For example, 0.5 phr corresponds to 0.5 g filler in 100 g epoxy resin after the filler was uniformly distributed, a specified amount of curing agent (polyetheramine D230) was added to the mixture and blended thoroughly. Subsequently, a degassing process was employed to remove air bubbles from the mixture. Finally, the prepared mixture was poured into a preheated metal mould [11].

Curing Conditions

A two-stage curing process was employed for the fabrication of the epoxy composite. Initial curing was carried out at 60°C for 4 hours, followed by post-curing at 120°C for 1 hour. The thickness of the resulting composite sheet was approximately 3 mm. To ensure the accuracy of the test results, test specimens were prepared by cutting the sheet to

the required dimensions, and their edges were carefully polished to minimize potential errors. Epoxy resin (DGEBA) was purchased from Dow Chemicals.

Dynamic Mechanical Analysis

DMA analysis provides information about storage modulus, loss modulus, and damping factor (tan δ), which reflect the stiffness and energy dissipation characteristics of polymer composites [12]. Dynamic Mechanical analysis (DMA) is a method that measures the stiffness and mechanical damping of a cyclically deformed material as a function of temperature. The Dynamic Mechanical Analysis (DMA was done using a PerkinElmer DMA 8000, at 1 Hz heating from 20°C to100 °C with ramp of 3 °C min^{-1}.The samples were analysed with a Dual cantilever mode.

Results and Discussion

Storage Modulus

Epoxy allyl Guar Gum Composites with varying Content of allyl Guar gum (AGG1 and AGG 2) are shown in **Figure 1** and **Figure 2** therefore, the T_g of sample could indicate the Crosslink density of polymeric material. The Storage Modulus of Composites was observed in case of AGG1 is $4.923E^{+10}$, while in case of AGG2 it is Observed as $3.85E^{+10}$, this decrease at higher concentration could be due to the presence of double bond, At lower concentration the rise in properties due to the reinforcing action of filler. A lower value of storage modulus of AGG2 composites at same concentration of filler as compared to AGG1 indicated that higher Degree of substitution hindered the polymer filler interaction The decrease in storage modulus at was observed at filler concentration above 0.5Phr due to phase separation and poor Interaction [13], the storage modulus of neat epoxy was found to be approximately $4.098E^{+10}$ at 30°C. Upon incorporating 0.5 Phr of filler into AGG1-based composites, E′ increased to approximately $4.926E^{+10}$, reflecting effective stress transfer and improved filler-matrix interaction. However, increasing the filler content to 1.5 Phr and 3 Phr caused E′ to drop to 3.505 E^{+10} and $2.875E^{+10}$ respectively. This reduction may be attributed to a decline in matrix stiffness and filler agglomeration.

In contrast, a continuous decline in storage modulus was observed for AGG2-based composites. E′ values of approximately were recorded at filler concentrations of 0.5 Phr, 1.5 Phr, and 3.0 Phr, respectively. The higher degree of substitution in AGG2 weakened the interfacial attraction between the filler and the epoxy matrix, resulting in reduced effective load transfer and compromised mechanical performance.

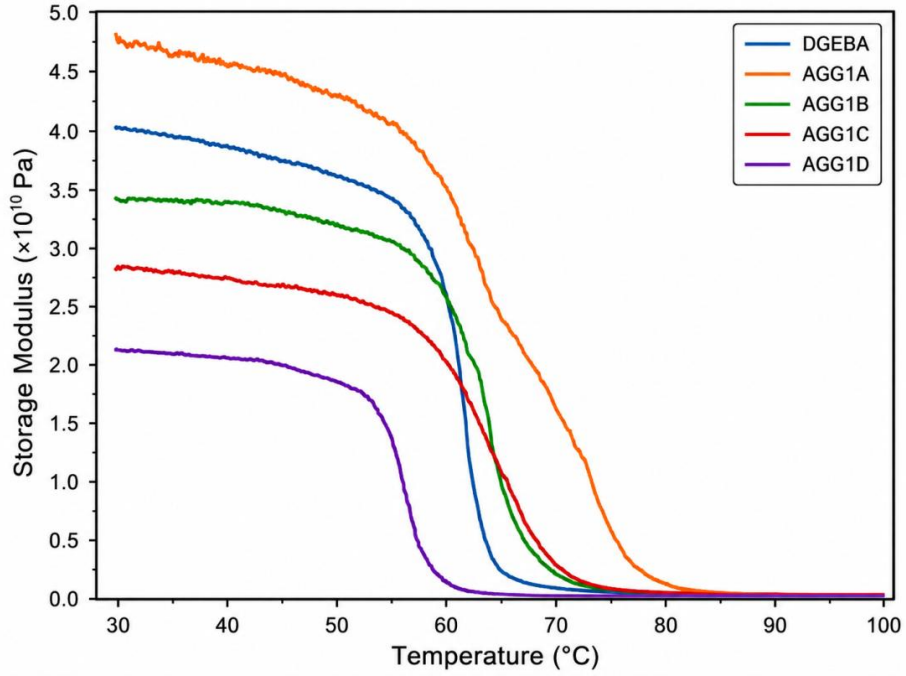

Figure 1 Variation of storage modulus (E`) of Epoxy –Allyl guar gum (DS 0.0389) samples (AGG1

Loss factor

The Loss factor (Tan δ), is a sensitive indicator of crosslinking and the glass transition temperature (T_g) value is assumed as the temperature corresponding the max of (tan δ), versus temp curve. In this study, the dynamic mechanical behavior

of epoxy composites reinforced with Allyl Guar Gum (AGG) at various concentrations was evaluated using Polyetheramine (D230) as the curing agent. Changes in the loss factor (tan δ) with temperature at a frequency of 1 Hz were analyzed, as illustrated in **Figure 3**.

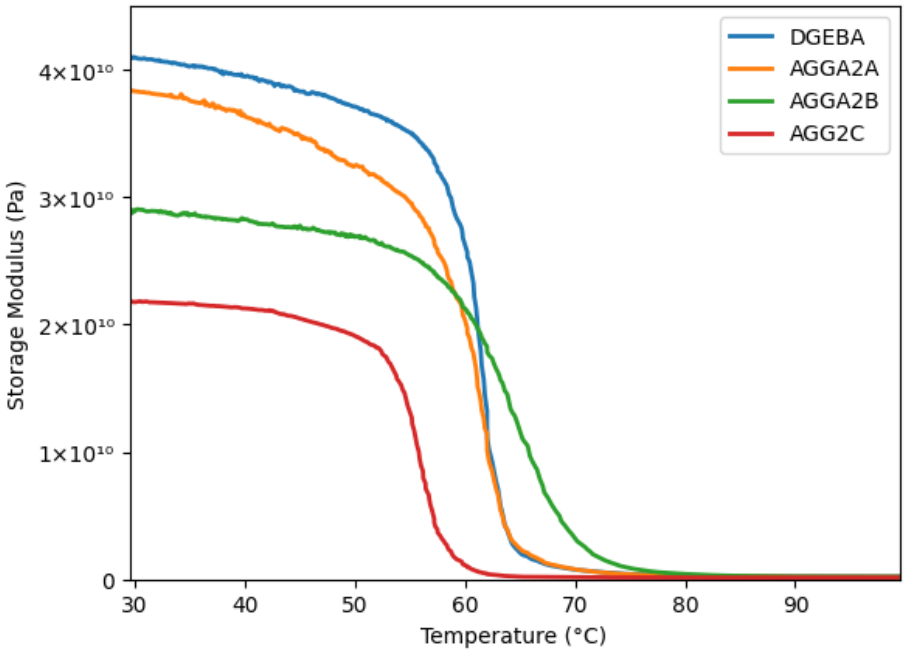

Figure 2 Variation of storage modulus (E`) of Epoxy –Allyl guar gum (DS 0.06) samples (AGG2).

For composites containing AGG1 (DS = 0.0389), the tan δ value shows maximum 0.9590, 71.2^{O}C at 0.5 phr. Beyond this point, a decrease in tan δ, 0.9037, 0.8455, 0.7244 is observed, although the values of neat epoxy is 0.9175. Conversely, for composites containing AGG2, the maximum tan δ value 0.8500, 69.9 ^{O}C is attained at 0.5 phr, followed by a decline in values. The incorporation of Allyl Guar Gum shifts the tan δ peaks of the composites toward the lower temperature region compared to neat epoxy. This behaviour likely arises from the incorporation of flexible allyl-guar gum segments into the epoxy network, which enhances chain mobility. The height of the tan δ peak represents the material's energy absorption capacity and damping behavior. Higher tan δ values indicate greater molecular mobility and superior vibration-energy dissipation capability [14].

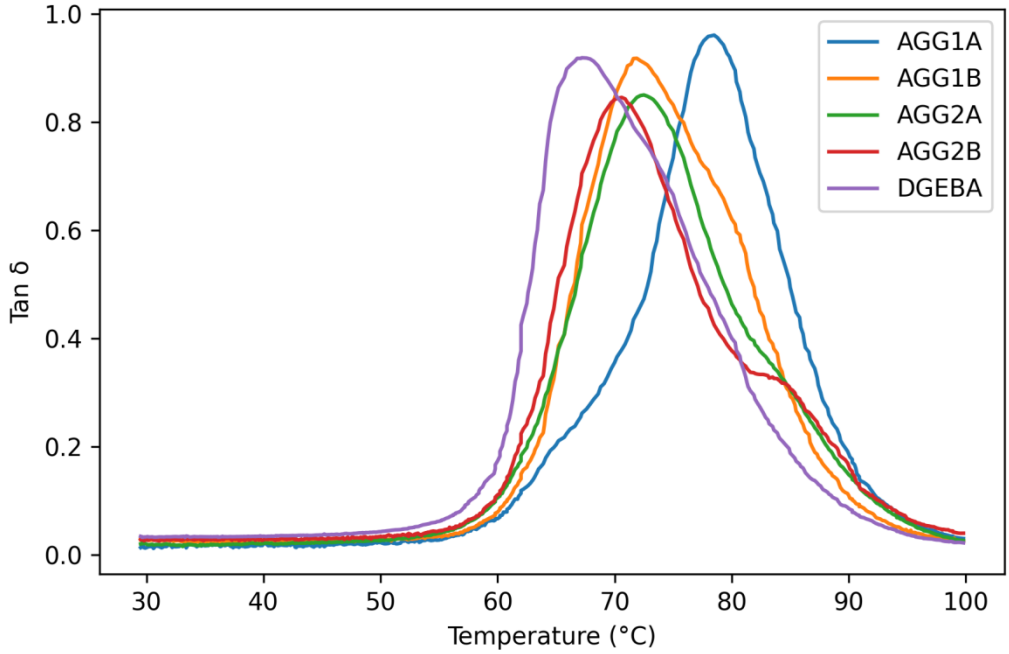

Figure 3 Variation of Tan (δ) of Epoxy –Allyl guar gum Composites

Thermogravimetric analysis

Thermogravimetric analysis (TGA) was conducted in a nitrogen atmosphere to evaluate the thermal stability of the epoxy–allyl guar gum composites shown in **Figure 4**. TGA is an instrument used to analyse the Thermal degradation and thermal stability of Polymeric samples [15]. The TGA curves revealed that AGG2 exhibited a higher initial decomposition temperature compared to AGG1, indicating superior thermal stability. Additionally, a reduction in residual weight (% residue) at 600°C was observed due to decrease in interfacial interaction. The amount of char residue obtained at 600°C for the allyl-modified epoxy system AGG2 was found to be lower than that of the AGG1 modified epoxy system, suggesting that the allyl modification with DS-0.06 influenced the char formation behavior at high temperatures.

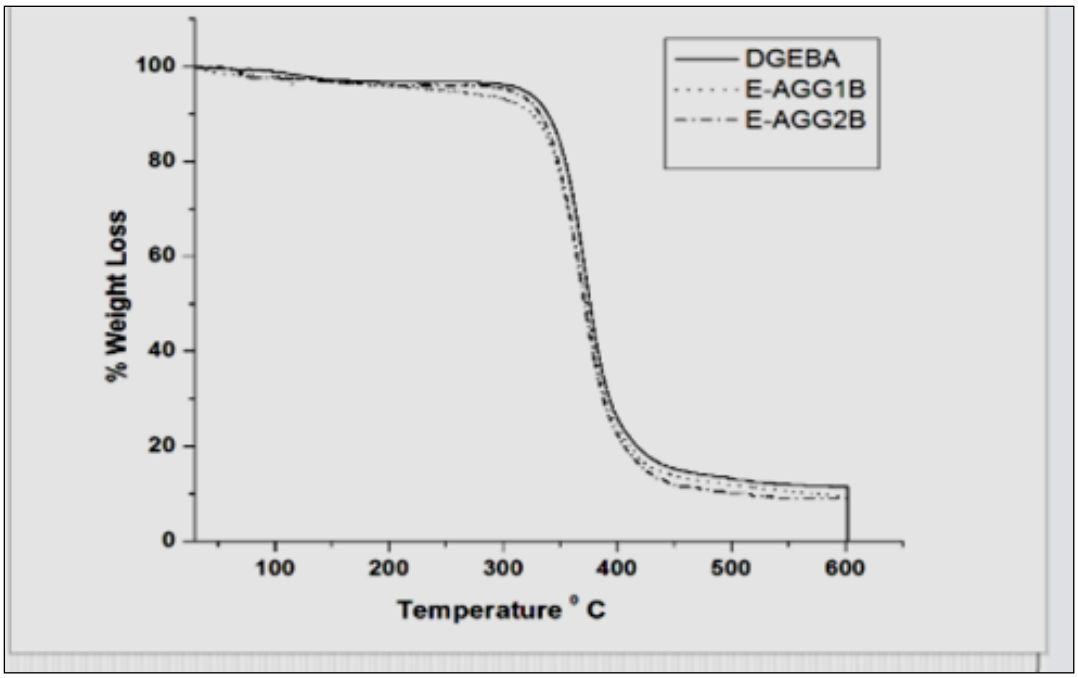

Figure 4 TGA Curves of Epoxy allyl Guar gum Composites

Conclusion

In the Present Study AGG with different degree of substitution are used to prepare a polymer composite with epoxy resins. The Polymer filler interaction varied with degree of substitution and composition. The dynamic mechanical analysis of composites was studied with DMA 8000. The Storage Modulus of composites was found to be enhanced at 0.5% Concentration as compared to neat epoxy resin, The Tan δ values of composites showed max at 0.5PHr after that the value of Tan δ decreases. In AGG2 at higher degree of substitution the Properties decreases with concentration it is due to higher degree of substitution hindered the Polymer filler interaction and hence properties decrease. Thermogravimetric study shows that the thermal stability of E AGG1 is higher than EAGG2.

References

[1] A new transient network model for associative polymer networks. / Wientjes, R.H.W.; Jongschaap, R.J.J.; Duits, Michael H.G. et al.In: Journal of rheology, Vol. 43, No. 2, 1999, p. 375-391.
[2] Polysaccharides Development Properties and Application A.Tiwari Nova Science Publishers, Inc,2009
[3] Shenoy, M., and D'Melo, D. (2008). Evaluation of Mechanical Properties of Epoxy-Guar Gum Composites. Polymer Engineering and Science, 48, 124-132.
[4] M.A. Shenoy, and D.J. D'Melo, "Evaluation of mechanical propertiesof unsaturated polyester-guar gum/ hydroxypropyl guar gumcomposites", Express Polym. Lett., vol. 1, no. 9, pp. 622-628, 2007. [http://dx.doi.org/ 10.3144/expresspolymlett.2007.85]
[5] Brydson, J.A. (1999) Plastic Materials. 7th Edition, Butterworth-Heinemann, Oxford.
[6] Ahmed Madni, Ayesha Khalid, Fazli Wahid, Humaira Ayub, Romana Khan, Rozina Kousar, Preparation and Applications of Guar Gum Composites in Biomedical, Pharmaceutical, Food, and Cosmetics Industries, Current

Nanoscience; Volume 17, Issue 3, Year 2021, DOI: 10.2174/1573413716999201110142551
[7] Simran Kaur, Soumava Santra, Recent Progress in Chemical Modification of the Natural PolysaccharideGuar Gum, Current Organic Synthesis; Volume 19, Issue 2, Year 2022, e091121197820. DOI: 10.2174/1570179418666211109105416
[8] Arora, Gopal and A.P Gupta. "Mechanical and Structural Properties of Epoxy Resin-Allyl Guar Gum Composites." *The Open Chemical Engineering Journal* (2023).
[9] A.P Gupta , Gopal Arora, Preperation and Characterization of Allyl Modified Guar Gum , International Journal of Scientific Research , Volume III, Issue III, 2014
[10] M. Li, Z. Zhu, and E. Jin, "Graft copolymerization of granular allyl starch with carboxyl-containing vinyl monomers for enhancing grafting efficiency", Fibers Polym., vol. 11, no. 5, pp. 683-688, 2010. [http://dx.doi.org/10.1007/s12221-010-0683-7]
[11] Gopal Arora , Jay Prakash , Swati Varshney , Designing of allyl Guar gum g-Polyacrylic acid –based epoxy composites J Res Chem 2024 :5(1):204-210.DOI:1022271/reschem.2024.v5.i1c.137
[12] Menard, K.P. (2008). Dynamic Mechanical Analysis: A Practical Introduction, Second Edition (2nd ed.). CRC Press. https://doi.org/10.1201/9781420053135
[13] Haris, N. I. N., Hassan, M. Z., Ilyas, R. A., Suhot, M. A., Sapuan, S. M., Dolah, R., Mohammad, R., Asyraf,M.R.M.(2022) Dynamic mechanical properties of natural fiber reinforced hybrid polymer composites: a review,Journal of Materials Research and Technology,19,167-182.
[14] Saba, N., Jawaid, M., Alothman, O. Y., &Paridah, M. T. (2016). A review on dynamic mechanical properties of natural fibre reinforced polymer composites. Construction and Building Materials, 106, 149–159.
[15] Hore, R., Dhore, N., Agarwal, K. (2026). Thermal Analysis of Polymers. In: Chattopadhyay, S., Kumar, N. (eds) Polymer Characterization. Springer, Singapore. https://doi.org/10.1007/978-981-95-2609-3_6.

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