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Advances In UV Curing Of Elastomers: A Comprehensive Literature Review

Abey K Jose

T M Jacob Memorial Government College Manimalakkunnu, Ernakulam, Kerala, India.

Ultraviolet (UV) curing of elastomers has emerged as a transformative technology in material science, offering significant advantages over conventional thermal curing methods. Compared to thermal curing, UV vulcanisation provides rapid processing, efficient energy usage, and minimal thermal shrinkage, making it an environmentally friendly and technically superior alternative. This literature review explores the advances in UV vulcanization, focusing on its mechanisms, material properties, and industrial applications. The review presents a general discussion on the fundamentals of elastomers, their classification, and the evolution of vulcanization techniques—highlighting the transition from sulfur-based methods to UV-initiated crosslinking. The mechanisms of UV curing, including free-radical and thiol-ene reactions, are analyzed in detail alongside the role of photoinitiators in optimizing cure efficiency and material properties. Comparisons between UV-cured and thermally cured elastomers reveal superior mechanical properties, transparency, and functional versatility in the UV based processing. However, challenges such as limited UV penetration in thicker materials and oxygen inhibition persist. Finally, the paper discusses emerging trends such as hybrid curing systems, bio-based polymers, and self-healing materials, bringing out the growing relevance of UV-curable elastomers in advanced technologies like 3D printing, soft robotics, and wearable electronics. This review underscores the potential of UV vulcanization to revolutionize elastomer processing while addressing its limitations and suggesting future directions.

1. Introduction

The advent of elastomers has transformed various industrial applications due to their unique properties and versatility. Defined as polymers that exhibit elastic behavior, elastomers can stretch and return to their original shape, making them indispensable in numerous sectors, including automotive, aerospace, and consumer goods. The classification of elastomers encompasses a wide array of materials, each tailored for specific applications, underscoring their importance in modern manufacturing processes. Central to the functionality of elastomers is the process of vulcanisation, which enhances their mechanical properties by inducing crosslinking among polymer chains. Historically, vulcanisation has evolved from its initial discovery in the 19th century to become a critical step in elastomer processing, ensuring durability and performance. In recent years, UV vulcanisation has emerged as a revolutionary alternative to traditional thermal curing methods. This technique offers a range of advantages, including faster processing times and reduced energy consumption, making it an attractive option for manufacturers. The significance of UV vulcanisation is further highlighted by its diverse applications across various industries, from automotive components to consumer products. The historical development of UV vulcanisation reflects a trajectory of innovation, with key milestones marking advancements in photoinitiation and crosslinking mechanisms that enhance the efficiency of the curing process. This literature review aims to explore the intricacies of UV curing of elastomers, focusing on the materials utilized, the mechanical and physical properties of UV-cured elastomers, and their comparative performance against thermally cured counterparts. Moreover, this review will address the advantages and limitations of UV curing technologies, alongside emerging trends and future research directions that promise to further refine this pivotal process in elastomer manufacturing. Through this comprehensive examination, the review seeks to contribute to a deeper understanding of UV vulcanisation and its implications for the future of elastomer technology.

2. Elastomers

An elastomer is a material that can exhibit a rapid and large reversible strain in response to a stress. An elastomer is differentiated from other materials that demonstrate an elastic response, which is a property observed in numerous substances. An elastic response is characterized by the relationship wherein the strain is directly proportional to the stress, as articulated by Hooke's Law; however, the strain may be minimal, for instance, approximately 0.001 for silicate glass. An elastomer possesses the ability to demonstrate a considerable strain, for example, within the range of 5–10, and to achieve this capability, an elastomer must inherently be a polymer. Elastomers can be categorized into several types, including natural rubber, synthetic rubber, and thermoplastic elastomers, each possessing distinct characteristics that cater to specific industrial needs. The versatility of these materials is further enhanced by their ability to be modified through blending and the incorporation of fillers, which can improve their mechanical properties and performance in various applications. Additionally, the choice of additives and processing techniques can influence the final properties of elastomers, leading to tailored solutions for specific performance requirements. This adaptability is particularly beneficial in applications where enhanced durability and flexibility are essential, such as in automotive seals and gaskets.[1][2]

2.1 Definition of Elastomers

Elastomers are a special class of amorphous and elastic polymers composed of long, chain-like cross-linked molecules with high elastic memory, tensile strength, and low elastic modulus. Their unique viscoelastic properties allow them to undergo deformation while returning to their original shape, making them suitable for a wide range of applications.[3] The molecular structure of elastomers typically includes a network of cross-linked polymer chains that provide the necessary elasticity and resilience. This structure is pivotal in applications requiring materials that can withstand repeated stress and strain without permanent deformation. The processing of elastomers often involves various techniques, including extrusion, molding, and casting, which are essential for achieving the desired shape and properties of the final product. Additionally, the incorporation of advanced fillers and additives can enhance specific characteristics, such as thermal stability and chemical resistance, further expanding their applicability in demanding environments.[4] The development of elastomers has been driven by the need for materials that can perform under extreme conditions while maintaining their elasticity and strength. Recent innovations in filler technology, such as the use of nanofillers, have shown promising results in enhancing the properties of elastomers, leading to improved performance in applications ranging from automotive to medical devices.[5]

2.2 Types of Elastomers

Elastomers are categorized into natural and synthetic types, each engineered for specific applications due to their unique molecular structures and physical properties. Natural rubber, extracted from the latex of the Hevea brasiliensis tree, is renowned for its exceptional elasticity and tensile strength, making it important in tire manufacturing and industrial belts.[6] Synthetic elastomers, designed to surpass the limitations of natural rubber, include several key variants. Styrene-butadiene rubber (SBR) is prized for its abrasion resistance and affordability, widely used in automotive tires and conveyor systems[7]. Nitrile rubber (NBR) stands out for its superior resistance to oils and chemicals, making it ideal for seals, gaskets, and hoses in harsh industrial environments. EPDM is favored for its excellent weather resistance, and often used in roofing and automotive weatherstripping. Other synthetic elastomers, such as silicone and polyurethane, offer tailored properties like thermal stability and wear resistance, finding applications in medical devices and flexible coatings .[5]The selection of elastomer type is crucial for optimizing performance in various applications, as each type offers distinct advantages based on its chemical composition and structure.[3] .

2.3 Elastomers in Industry

Elastomers play a crucial role in enhancing product performance and reliability across numerous applications. Their unique properties, such as flexibility, durability, and resistance to various environmental factors, make them indispensable in sectors like automotive, aerospace, and healthcare, where safety and efficiency are paramount. Additionally, ongoing advancements in elastomer technology continue to drive innovation, enabling the development of new materials that meet the evolving demands of modern manufacturing. Furthermore, the integration of advanced elastomer formulations with sustainability practices is becoming increasingly significant, as industries strive to reduce their ecological footprint. This trend includes the use of bio-based elastomers and recycling initiatives aimed at minimizing waste and enhancing the lifecycle of elastomer products.[8]

These efforts not only contribute to environmental sustainability but also align with global market demands for greener alternatives, fostering a shift towards more responsible manufacturing practices. As industries continue to evolve, the role of elastomers in developing innovative solutions will remain vital for achieving both performance and sustainability goals.

3. Vulcanisation

Vulcanisation is a chemical process that involves the crosslinking of polymer chains in elastomers, typically through the addition of sulfur or other agents, resulting in improved elasticity, strength, and durability. This transformation is essential for enhancing the performance characteristics of elastomers, enabling them to withstand varying environmental conditions and mechanical stresses while maintaining their functional integrity. The vulcanisation process not only increases the mechanical properties of elastomers but also enhances their thermal stability and resistance to aging. By creating a network of cross-linked structures, vulcanisation ensures that the elastomers retain their shape and functionality even under extreme conditions, making them suitable for a wide range of demanding applications.

Charles Goodyear's discovery of vulcanization in 1839 was a pivotal moment in the history of rubber. By treating rubber with sulfur, Goodyear was able to stabilize the material, preventing it from becoming sticky in heat and brittle in cold[9]. Over the years, the vulcanization process has been refined with the introduction of various chemical additives. These additives enhance the rubber's resistance to deformation, abrasion, and compression, making it suitable for a wide range of industrial applications[10].Different vulcanization methods, such as autoclave and press vulcanization, have been developed to optimize the crosslink density and mechanical properties of rubber. Autoclave vulcanization, for instance, has been shown to produce rubber with superior mechanical properties compared to other methods.The development of synthetic rubbers, derived from petroleum, has expanded the applications of vulcanized rubber. Synthetic rubbers are now used extensively in the production of tires and other industrial products, highlighting the industrial importance of vulcanization[11].The disposal of rubber products, particularly tires, poses environmental challenges. Recycling and reuse strategies are being explored to mitigate these issues. Traditional vulcanization accelerators, such as tetra methyl thiuram disulphide (TMTD), have been found to produce carcinogenic by-products. Safer alternatives, like tetrabenzyl thiuramdisulphide (TBzTD), have been developed to reduce health risks while maintaining the desired properties of vulcanized rubber.[12]

In addition to sulfur, various alternative agents and methods are being explored to enhance the vulcanisation process, including the use of dynamic covalent bonds and supramolecular interactions. These innovative approaches aim to create more sustainable and reprocessable elastomers, addressing the challenges posed by traditional vulcanisation techniques in waste management and circular economy efforts.[13] and expanding the potential applications of elastomers in various industries. The integration of such advanced methods not only improves mechanical properties but also allows for the development of elastomers that can be reshaped and recycled, thereby contributing to sustainability initiatives in material science.[13]

While vulcanization has revolutionized the rubber industry, it is not without its challenges. The environmental impact of rubber disposal and the health risks associated with certain vulcanization chemicals are ongoing concerns. Efforts to develop safer and more sustainable vulcanization processes continue to be a focus of research and innovation in the field.

4. UV Vulcanisation

4.1 Early Research and Development

The history of UV curing technology began in the 1960s, with significant industrial impact noted since then. The first commercial application in the U.S. occurred in 1970, focusing on particle board filler, which remains a major application today. By 1972, UV curing was being explored for metal decorating by can manufacturers, and patents emerged for acrylated urethanes to replace traditional moisture cure urethanes in floor tiles. Early applications also included overprint varnishes for paper, which saw intense development during this period.
In Europe, UV-curable unsaturated polyester-styrene wood sealers and topcoats were introduced in the 1960s, although they faced challenges such as brittleness and oxygen sensitivity**.** The first UV ink production began in June 1970, with lithographic inks introduced

in Europe shortly after. The evolution of UV vulcanisation technology has been marked by continuous advancements in photoinitiators and curing systems, enhancing the efficiency and versatility of elastomer applications.[14]

The growth of UV curing has been driven by environmental and energy advantages, alongside rapid advancements in raw materials and equipment, which have improved performance over other technologies. Key developments included addressing issues like oxygen inhibition and adhesion, which have allowed for expansion into new application areas. The evolution of acrylate oligomers, particularly acrylated epoxies, has also played a significant role, with these materials being faster curing and more effective than previous options.

4.2 Mechanisms of UV Vulcanisation

UV curing of elastomers involves the use of ultraviolet light to initiate chemical reactions that crosslink polymer chains, resulting in the formation of a three-dimensional network. This process is faster and more energy-efficient compared to traditional thermal or chemical curing methods. The curing mechanism typically involves the following steps:

1. **Photoinitiation**: A photoinitiator absorbs UV light and generates free radicals. These radicals initiate the polymerization or crosslinking process by abstracting labile hydrogen atoms from the polymer chains, creating reactive sites.[15][16].

   Effect of photoinitiators:

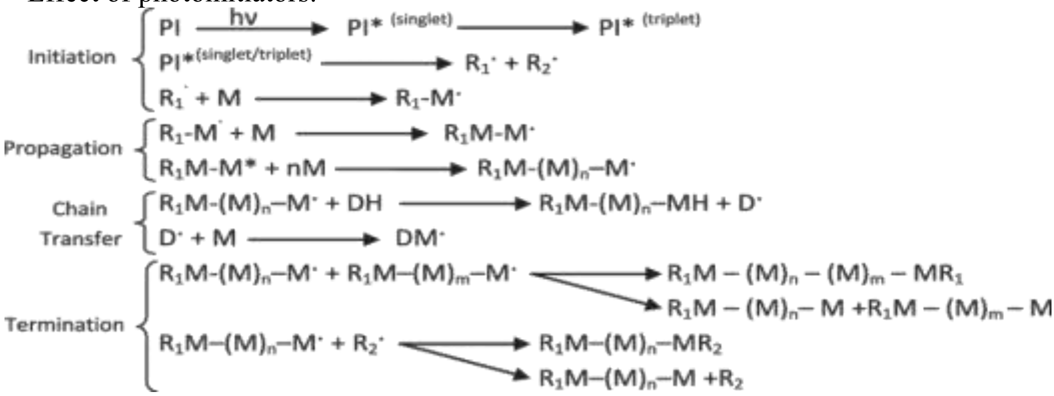

Figure 1General ultraviolet (UV) photocuring steps. PI: photoinitiator, M: monomer, D: donor; and R: radical.

The choice of photoinitiator is crucial, as it influences the efficiency of the curing process and the final properties of the elastomer. Various types of photoinitiators are available, each suited for specific applications and wavelengths of UV light, ensuring optimal crosslinking and performance of the elastomers during and after curing.[15] The effectiveness of the photoinitiation process can be further enhanced by adjusting the concentration of the photoinitiator and the exposure time to UV radiation, which can influence the mechanical properties of the cured elastomers. Additionally, the interaction between the photoinitiator and the elastomer matrix plays a vital role in determining the ultimate performance characteristics of the final product

2. **Crosslinking**: The free radicals react with unsaturated bonds in the polymer, leading to the formation of covalent bonds between polymer chains. This crosslinking enhances the

mechanical properties of the elastomer, such as tensile strength and elongation at break and also contributes to their thermal stability and resistance to environmental factors, making them suitable for a wide range of applications.[15] [16]

3. **Thiol-Ene Reactions**: In some systems, thiol-ene chemistry is used as an alternative to free-radical crosslinking. This mechanism involves the reaction of thiols with alkenes under UV light, forming new bonds without the need for an inert atmosphere. This approach is particularly useful for soft elastomers and can enable reversible crosslinking.[17] [16]

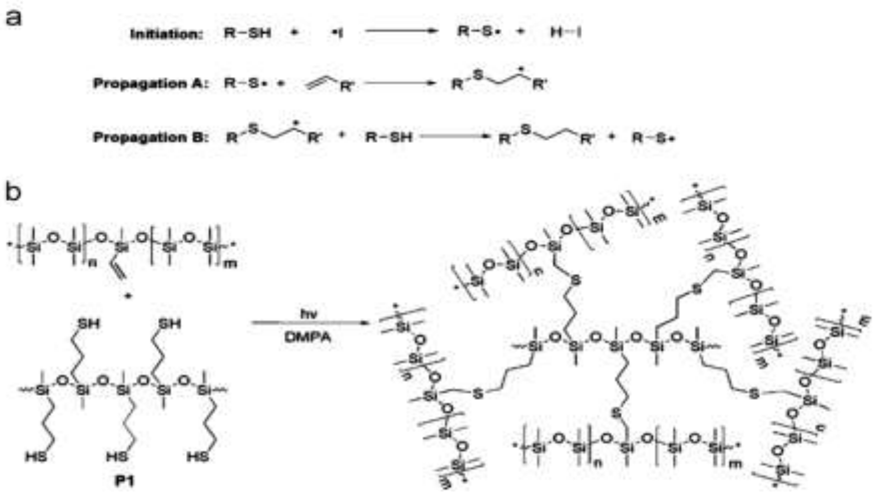

Figure 2 Mechanism of thiol-ene reaction (a) and the network formation by reaction of gum and crosslinker Poly(mercaptopropylmethlysiloxane) (b)[18]

The choice of mechanism depends on the specific application and the desired properties of the cured elastomer. For example, free-radical crosslinking is commonly used for acrylate-based systems, while thiol-ene reactions are preferred for soft and flexible elastomers[17]

4.3. Comparison with Thermally Cured Elastomers

The comparison between UV-cured elastomers and thermally cured elastomers reveals differences in their curing processes, mechanical properties, and applications. UV curing offers advantages such as faster processing times and reduced thermal shrinkage, while thermal curing is traditionally used for its established reliability and mechanical performance. This analysis will delve into the specific characteristics and benefits of each curing method, supported by findings from the provided research papers.

Curing Process and Efficiency

1. **UV Curing**: UV curing is a rapid process that involves the use of ultraviolet light to initiate a photochemical reaction, leading to the cross-linking of elastomers. This method is energy-efficient as it operates at ambient temperatures and does not require prolonged heating[15]. UV curing is particularly advantageous for applications

requiring high precision, as it minimizes thermal shrinkage, achieving less than 0.02% compared to 2.91% in thermally cured elastomers.[19]

2. **Thermal Curing**: This traditional method involves heating the elastomer to initiate cross-linking, which can lead to thermal shrinkage and deformation. Despite these drawbacks, thermal curing is well-established and widely used in various industrial applications due to its reliability and the mechanical robustness of the resulting materials.[19]

Mechanical Properties

1. **UV-Cured Elastomers**: These elastomers often exhibit superior mechanical properties, such as increased tensile strength and elongation at break, due to the efficient cross-linking achieved through UV exposure. For instance, UV-cured silicone elastomers have shown mechanical strength approximately three times greater than their thermally cured counterparts.[19],[15] Additionally, UV curing allows for the manipulation of mechanical properties by adjusting the photoinitiator concentration and exposure time.[15][20]
2. **Thermally Cured Elastomers**: While they may not match the mechanical strength of UV-cured elastomers, thermally cured elastomers are known for their durability and stability under various conditions. They are often used in applications where long-term performance is critical.[21]

Applications and Versatility

1. **UV-Cured Elastomers**: These materials are increasingly used in advanced applications such as microfluidic systems, soft robotics, and dielectric elastomer actuators due to their high precision and rapid processing capabilities[21] [22]. The ability to cure under ambient conditions also makes them suitable for applications where thermal sensitivity is a concern.
2. **Thermally Cured Elastomers**: These elastomers are traditionally used in applications requiring robust mechanical performance and thermal stability, such as automotive and industrial components. Their established use in these sectors is due to their proven reliability and performance over time.[19]

Environmental and Economic Considerations

1. **UV Curing**: This method is considered more environmentally friendly as it typically involves little to no solvent use and operates at lower energy levels. The absence of high temperatures also reduces the risk of volatile emissions.[16]
2. **Thermal Curing**: While effective, this method can be energy-intensive and may involve the use of solvents or catalysts that have environmental impacts. The longer processing times also contribute to higher operational costs[16]

5. Properties of UV-Cured Elastomers

Table 1.

Property	Description	Citation
Elongation at Break	Up to 1100%	[23]

Transmittance	Over 90% at 550 nm	[23]
Curing Time	As fast as 3 seconds	[24]
Self-Healing	Recovery of up to 90% shear strength after healing	(Yu et al., 2023)
Tensile Strength	Up to 3.40 MPa	[25]
Applications	Stretchable electronics, 3D printing, optical devices, soft robotics	[23])

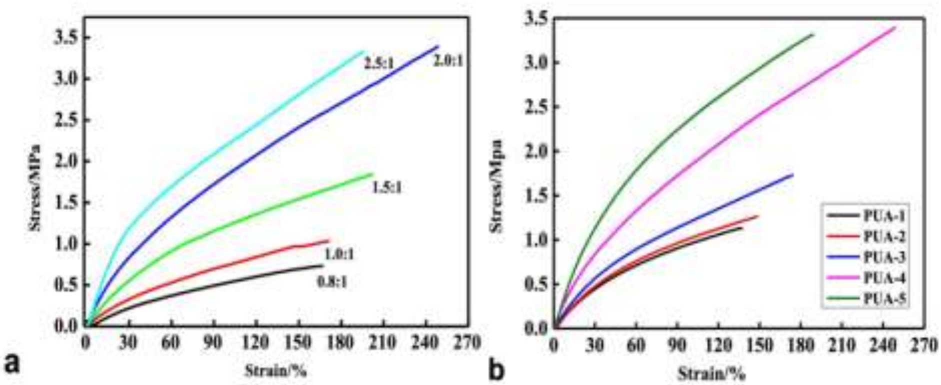

Figure 3 Stress–strain curves of UV-cured materials(polysiloxane polyurethane acrylate).[25]

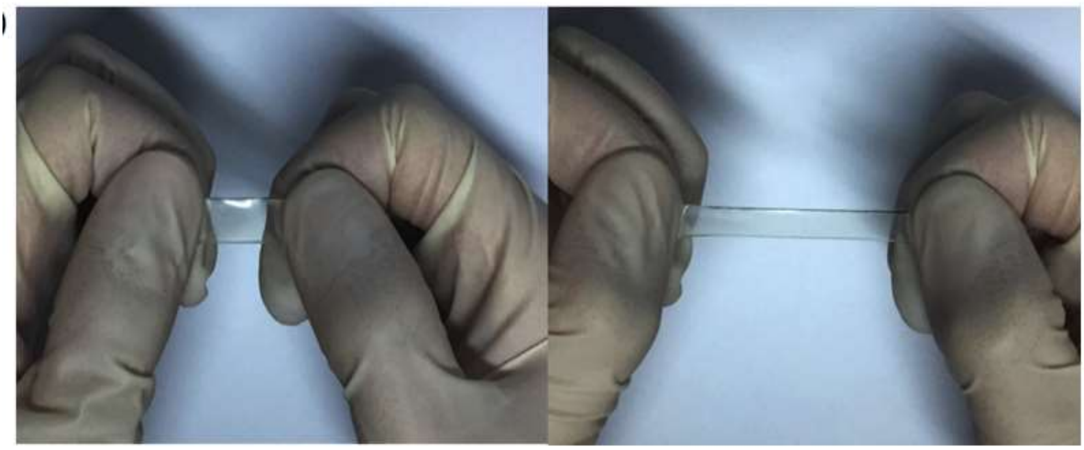

Figure 4 snapshot of stretching of poly(urethane-acrylate) elastomer (MA:BA mass percentage ratio of 100:0 [23]

6. Applications of UV Cured Elastomers

Ultraviolet (UV) cured elastomers are versatile materials with a wide range of applications across various industries due to their unique properties such as high stretchability, transparency, and self-healing capabilities. These elastomers are synthesized through UV-curing processes that enable rapid polymerization and cross-linking, resulting in materials with enhanced mechanical and chemical properties. The applications of UV cured elastomers span from consumer goods to advanced technological fields, offering innovative solutions and improvements over traditional materials.

1. **Stretchable Electronics and Sensors**: The high stretchability and transparency of UV-cured elastomers make them ideal for use in stretchable sensors and wearable electronics. For example, they have been used to fabricate stretchable ionic conductors and motion sensors[23].
2. **3D Printing and Additive Manufacturing**: UV-cured elastomers are widely used in 3D printing technologies, such as DLP and vat photopolymerization, to create complex structures with high precision. These materials are particularly useful for producing soft robotics, biomedical devices, and flexible actuators[23] [26].
3. **Optical and Electronic Devices**: The high transparency and UV resistance of UV-cured elastomers make them suitable for use in optical and electronic devices, such as flexible displays and optical coatings.[25]
4. **Dielectric Elastomers**: UV-cured elastomers are used as dielectric materials in actuators and sensors. They can achieve high actuation strains under relatively low voltages, making them suitable for applications in soft robotics and smart devices. [22]
5. **Barrier Coatings**: Some UV-cured elastomers, such as polyurethane acrylates are used as barrier coatings to protect against chemical warfare agents and other hazardous substances. These materials exhibit high crosslinking densities and excellent barrier properties
6. **Soft Robotics and Wearable Devices**: The combination of high stretchability, transparency, and self-healing properties makes UV-cured elastomers ideal for use in soft robotics and wearable devices. They can be used to fabricate soft actuators, grippers, and flexible switches.[27]
7. **Flexible Coatings and Films**: UV-cured elastomers are used to produce flexible coatings and films with excellent adhesion, chemical resistance, and tactile properties. These materials are applied in various industries, including automotive and aerospace.[24]
8. **Smart Coatings and Self-Healing Materials:** UV cured elastomers are used in smart coatings that can self-heal, which is advantageous for extending the lifespan of materials and reducing maintenance costs. These coatings are applicable in fields such as automotive and consumer electronics.[28] The self-healing properties are achieved through mechanisms like thermally reversible hydrogen bonding and UV-induced disulfide metathesis, allowing the material to recover its mechanical properties after damage[28].
9. **Consumer Goods and Medical Technology:** In the consumer goods sector, UV cured elastomers are used for creating durable and flexible components that can withstand environmental stressors. Their application extends to medical technology, where their biocompatibility and stability are crucial for developing medical devices and implants.[4] The ability of these elastomers to maintain mechanical properties

over a wide temperature range makes them suitable for use in diverse environmental conditions, further broadening their application scope[4].

7. Key Advancements and Applications in UV Curing Technology

Table: 2

Technology/Material	Key Features	Citation
LED UV Curing	High energy efficiency, long lifetime, reduced environmental impact	[29]
Bio-Based Polymers	Sustainable, biodegradable, derived from renewable resources	[30]
Nanocomposite Coatings	Enhanced mechanical and thermal properties, improved dispersion techniques	[31]
Dual-Curing Polymer Systems	Balances fast curing speeds with excellent mechanical properties	[32]

8. Advantages and Limitations of UV Curing

8.1 Advantages of UV Vulcanisation over Traditional Methods

Ultraviolet (UV) vulcanization offers several advantages over traditional vulcanization methods, primarily due to its efficiency, environmental benefits, and enhanced material properties.

UV-cured elastomers offer several advantages over traditionally cured elastomers like:

1. **High Mechanical Properties**: UV-cured elastomers exhibit superior mechanical properties, including high tensile strength, elongation at break, and resilience. For example, some UV-cured polyurethane acrylates can achieve elongation at break values exceeding 1100%.[23] [26]

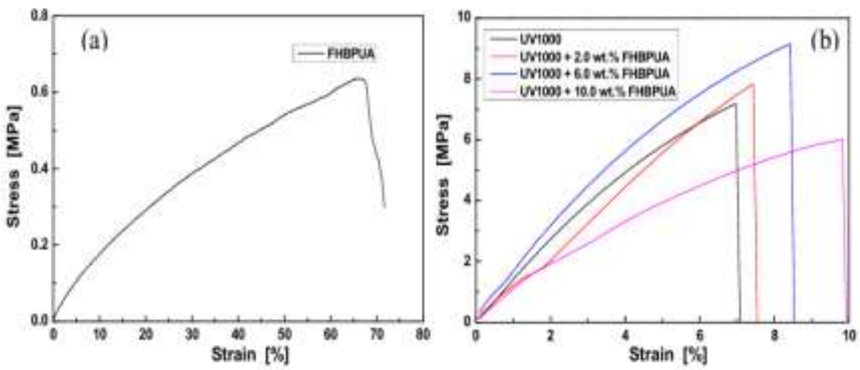

Figure 5 Tensile stress-strain curves of UV-cured film (a) Flexible Hyperbranched Polyurethane Acrylate (FHBPUA) and (b) UV1000 resin. [22]

2. **Transparency and Optical Clarity**: Many UV-cured elastomers are highly transparent, making them suitable for applications in optical and electronic devices. For instance, UV-cured polyurethane acrylates have been reported to achieve transmittance levels of over 90% in the visible light region [33].

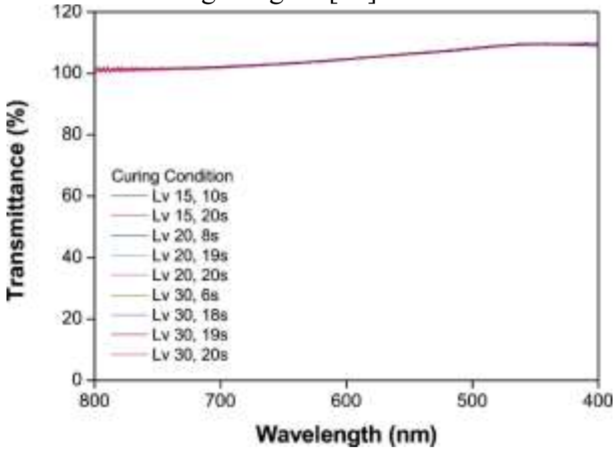

Figure 6 Visible-light transmittance of acrylic PSA samples cured at UV exposure intensities of Level 15, 20, and 30. [33]

3. **Fast Curing**: UV curing is a rapid process that can be completed in a matter of seconds or minutes, depending on the intensity of the UV light and the formulation of the elastomer. This rapid curing enables high-throughput manufacturing and reduces production costs.[16] [34]
4. **Environmental Benefits**: UV curing is an environmentally friendly process as it does not require solvents and can be performed at ambient temperatures, reducing energy consumption and emissions[16].
5. **3D Printability**: UV-cured elastomers are compatible with 3D printing technologies, such as digital light processing (DLP) and vat photopolymerization. This allows for the creation of complex structures with high precision.[26] [23]
6. **Self-Healing Properties**: Some UV-cured elastomers incorporate reversible crosslinking mechanisms, such as disulfide metathesis, which enable self-healing properties. These materials can recover from damage when exposed to heat or additional UV light.[27] .

Additionally, it minimizes the risk of thermal degradation of sensitive materials, allowing for the preservation of the unique properties of elastomers while achieving rapid curing. Moreover, the ability to control the curing process with precision using UV light enables manufacturers to achieve consistent quality and performance in their products. This adaptability has led to a growing interest in UV vulcanisation across various industries, particularly in applications where rapid production cycles are essential.

8.2 Limitations and Challenges of UV Curing

While UV vulcanization presents numerous advantages, it is important to consider the limitations and challenges associated with this method. For instance, the penetration depth of

UV light can be limited, which may affect the curing of thicker or opaque materials. Additionally, the initial setup costs for UV curing equipment can be higher compared to traditional methods.
Some other limitations of UV-cured elastomers are listed below

1. **Atmospheric Requirements**: Some UV-curing systems require an inert atmosphere to prevent side reactions, such as oxygen inhibition. This can complicate the curing process and limit its scalability [16].
2. **Photodegradation**: Prolonged exposure to UV light can lead to photodegradation of the cured elastomer, resulting in a loss of mechanical properties over time.[15]
3. **Material Viscosity**: High-viscosity UV-curable resins can be challenging to process, particularly in 3D printing applications. This can limit the complexity and resolution of the printed structures.[35]
4. **Anisotropy in 3D Printing**: In some cases, UV-cured elastomers exhibit anisotropic mechanical properties when printed in specific directions, which can affect their performance in applications requiring isotropic behaviour.
5. **Limited Solvent Resistance**: While UV-cured elastomers are generally resistant to many solvents, some formulations may exhibit reduced barrier properties against certain chemicals, depending on their composition However, the long-term benefits in terms of efficiency, material properties, and environmental impact often outweigh these initial challenges, making UV vulcanization a promising alternative to conventional vulcanization techniques.

9. Future Perspectives

Future Trends in UV Curing Technology

1. Hybrid Curing Systems
The development of hybrid curing systems that combine UV curing with other curing mechanisms, such as thermal curing, is expected to be a key area of research. These systems offer the potential to overcome current limitations and expand the range of applications for UV curing technology.
2. Sustainable Materials
The continued development of bio-based and biodegradable materials is expected to drive the growth of UV curing technology. Researchers are exploring new bio-based monomers and polymers, such as those derived from castor oil and lignin, to create sustainable UV-curable materials[30] .
3. Smart Coatings
The development of smart coatings with UV-curable materials is an emerging trend. These coatings can respond to environmental changes, offering potential applications in self-healing materials and sensors.[36]
4. Digital Manufacturing
The integration of UV curing technology with digital manufacturing techniques, such as 3D printing, is expected to revolutionize the production of complex structures. The use of bio-based resins in 3D printing has already demonstrated the potential for sustainable and flexible manufacturing processes.[37]

10. Conclusion

This literature review has comprehensively explored the UV curing of elastomers, highlighting its transformative impact on elastomeric product manufacture. UV vulcanisation offers advantages over traditional thermal curing, including faster processing times, reduced energy consumption, and minimal thermal shrinkage, making it an efficient and environmentally friendly alternative. The review detailed the diverse types of elastomers, their molecular structures, and their critical role across industries such as automotive, aerospace, and healthcare. UV-cured elastomers exhibit superior mechanical properties, such as enhanced tensile strength and elongation at break, alongside unique characteristics like high stretchability, transparency, and self-healing capabilities. These properties enable their use in advanced applications, including soft robotics, microfluidic systems, and dielectric elastomer actuators. However, challenges such as oxygen inhibition, adhesion issues, and the need for advanced photo initiators remain, necessitating ongoing research to optimize UV curing processes. The historical evolution of UV curing technology, from its inception in the 1960s to modern advancements in acrylate oligomers and curing systems, underscores its growing versatility and industrial relevance.

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