Research progress of polyurea elastomers

Jin Shuhan [1], Liang Wei [2]

(1. Daqing Chemical Research Center, Daqing 163000, Heilongjiang, China;
2. Research Institute of PetroChina Daqing Refining and Chemical Company, Daqing 163411, Heilongjiang, China)

Abstract: Polyurea elastomer is a kind of high-performance new polymer material with excellent properties such as high strength, high toughness, wear resistance, and corrosion resistance, as well as adhesive properties and energy absorption. It has become one of the important materials for achieving efficient and lightweight protection. This article first reviews the synthesis and modification of polyurea elastomer, focuses on introducing its research progress in various application fields, and looks forward to its development prospects.

Key words: polyurea elastomer; synthesis; modification; application field

Classification number: TQ323.8 **Article number:** 1009-797X(2026)01-0001-09

Document code: B **DOI:**10.13520/j.cnki.rpte.2026.01.001

Polyurea elastomers are polymers containing repeating urea groups (−NH−CO−NH−) in their main chains, featuring multiple functionalities such as explosion resistance, impact resistance, wear resistance, waterproofing, and energy absorption. With high solid content and low VOC content, they are widely used in daily life, transportation, industry, and national defense, making them indispensable materials for the national economy and defense industry. Research on polyurea synthesis began in the 1960s. In 1995, Huang Weibo's team introduced polyurea technology to China, and it was commercially used in the country in 1999. With the innovation of production technology and optimization of quality for polyurea elastomers, they have been widely used in various industries such as machinery, electricity, chemical engineering, and construction. This article focuses on the development of polyurea elastomers in recent years.

1 Research on polyurea elastomer materials

1.1 Development of polyurea elastomers

Polyurea elastomers have evolved into three generations, including the first generation of aromatic polyurea, the second generation of aliphatic polyurea, and the third generation of polyaspartic ester polyurea (aspartic polyurea). The domestic market for aspartic polyurea is experiencing rapid development. From a production volume of less than 1 ton in 2009, it surpassed 4,000 tons in 2021, and is expected to exceed 5,000 tons in 2023.

Aromatic polyurea is composed of aromatic isocyanate (Component A) and polyol and amino chain extender (Component R). Due to the fact that the reactivity of primary amines with isocyanate in the reaction system is much higher than that of hydroxyl groups with isocyanate in the polyurethane system, the reaction between isocyanate and moisture in the air is reduced, making the polyurea coating less prone to issues such as bubbles and pinholes. However, the high reactivity also leads to problems such as excessively fast reaction speed, short gel time (3~5 s), poor adhesion, and short service life. The presence of rigid aromatic rings in the hard segments of the molecular chain brings

---

Biography: Jin Shuhan (1990-), female, master's degree and senior engineer. Her main research interests include refining additives and new materials.

about good mechanical properties, but also makes the polyurea coating prone to yellowing and aging under light exposure, and prone to self-oxidation to form quinone imine under ultraviolet light. Therefore, antioxidants and UV-resistant components are usually added to prolong its service life.

The A component of aliphatic polyurea is prepared by prepolymerizing aliphatic diisocyanate with amino-terminated polyether, while the R component consists of polyether and aliphatic amine chain extenders, without the need for catalysts. The second-generation polyurea exhibits excellent light resistance and low temperature resistance, and is dense, seamless, waterproof, and corrosion-resistant, making it suitable for outdoor settings where high color accuracy is required. The second-generation polyurea reduces the reaction rate to some extent, but it is mechanically soft and has poor high temperature resistance.

The third-generation aspartic polyurea achieves slow reaction and tunable properties by introducing different substituents into aliphatic secondary amine compounds with steric hindrance structures - polyaspartic ester molecules, while retaining excellent performance, thus solving the problem of difficult-to-control reaction speed. In addition, weather-resistant aspartic polyurea has high solid content and can achieve zero VOC emissions, making it a high-performance, environmentally friendly, and green elastomeric material. It is currently a research hotspot, but there are few varieties and high prices.

1.2 Synthesis of polyurea elastomers

The synthesis of polyurea elastomers involves two steps: prepolymerization and chain extension. In the synthesis reaction of the prepolymer, component A is generally a polymer, derivative, prepolymer, or semi-prepolymer of isocyanate.

In the chain-extending synthesis reaction, the R component is generally composed of polyethers, amine chain extenders, and additives. The essence of the synthesis lies in the reaction between the prepolymer and the terminal amino polyether and amine chain extenders. By adjusting the ratio of soft and hard segments in components A and R, polyurea materials with different elasticity, tensile strength, and hardness can be prepared.

1.3 Microphase separation structure of polyurea elastomers

The molecular chain segment of polyurea elastomers is composed of alternating soft and hard segments, forming an (AB)n-type block copolymer. The schematic diagram of its molecular chain structure is shown in Figure 1. The microphase structure has a significant impact on its thermal properties, mechanical properties, and processing, especially on the mechanical properties. The soft segment with a lower glass transition temperature (Tg) is the basic phase, which has good flexibility. The hard segment with a higher Tg forms a hard phase under the action of hydrogen bonding, which is rigid and can serve as a physical cross-linking and reinforcing filler, significantly improving the physicochemical properties of polyurea. The differences in thermodynamic properties between the soft and hard segments, as well as the complex interaction forces between the molecular chains, result in a complex multiphase system within them. Within a certain range, the greater the degree of microphase separation, the significantly enhanced tensile strength, hardness, and modulus of polyurea. Currently, the views on the factors affecting the microphase separation structure of polyurea mainly focus on: 1. the composition of soft and hard segments; 2. the effect of hydrogen bonding.

1.3.1 Influence of soft and hard segments

The structural types, chemical ratios, segment structures, and chain lengths of raw materials all affect the microphase separation structure of polyurea. When the content of hard segments remains constant, the higher the molecular weight of soft segments, the greater the degree of microphase separation, resulting in increased tensile strength and impact strength, and significantly reduced hysteresis and creep. Currently, diisocyanates or their trimers

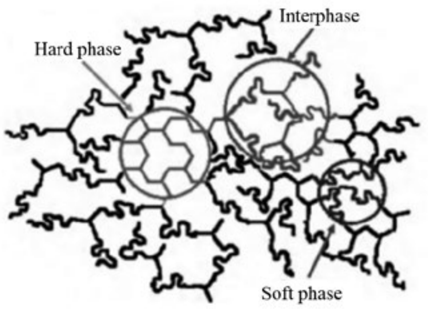

Figure 1 Microphase separation structure of polyurea elastomer

are commonly used in the preparation of polyurea elastomers, as studies have found that the better the symmetry of isocyanates, the higher the degree of microphase separation in the resulting polyurea products, and the better the mechanical properties. Symmetric isocyanate monomers are more conducive to the ordered accumulation and crystallization of hard segments in polyurea elastomers, forming firmly bonded hard segment microdomains internally, leading to a stronger reinforcement effect from fillers.

The isocyanate index is a crucial indicator that affects the physicochemical properties of polyurea elastomers. By designing the chemical ratio of isocyanate to amino-terminated polyether and amino-terminated polyether to chain extender, and adjusting the ratio of soft to hard segments in polyurea, the mechanical properties of polyurea can be altered. The ratio of isocyanate component to amino component is typically 1.05 ~ 1.10.

1.3.2 The influence of hydrogen bonding

Hydrogen bonding is the primary intermolecular force influencing the internal microphase separation in polyurea, promoting the ordered accumulation and crystallization of hard segments, thereby endowing polyurea elastomers with excellent wear resistance, strength, and an elevated melting point. The two active hydrogens in the urea bond of the polyurea molecular chain can form a planar bifurcated structure. The double-coordinated hydrogen bonds formed between urea bonds exhibit stronger cohesion in the hard segment microdomains, leading to a greater degree of microphase separation and superior mechanical properties, as illustrated in Figure 2.

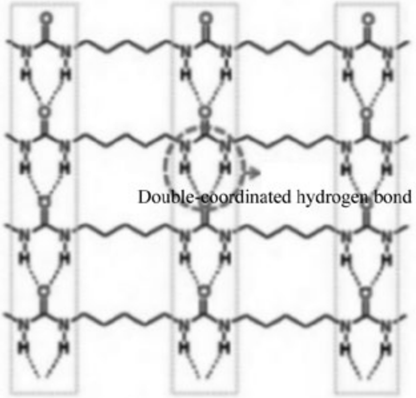

Figure 2 Microscopic schematic diagram of hydrogen bonding in polyurea elastomers

1.4 Modification of polyurea elastomers

To enhance the low-temperature flexibility, high-temperature resistance, flame retardancy, and other properties of polyurea elastomers, they are often modified. Currently, the main modification methods for polyurea elastomers include nanomaterial modification, resin modification, and other modifications.

1.4.1 Modification of nanomaterials

By introducing nanomaterials into polyurea elastomers, the surface active centers of nanoparticles can be bound to urea bonds. By adjusting the structure, content, and crosslinking degree of soft and hard segments to form an aggregated structure, the wear resistance, stain resistance, weather resistance, adhesion, and mechanical properties of polyurea elastomers can be effectively improved.

Feng Yonghui utilized core-shell structured nano-Ag@SiO_2 materials to modify the prepared silicone-based polyurea. Compared to traditional silicone-based anti-fouling materials, the prepared PDMS-PUa/Ag@SiO_2 not only exhibits superior mechanical properties, adhesion, and self-healing capabilities, but also demonstrates optimal anti-protein adsorption and bactericidal effects when the nano-silver addition is 0.5% (mass fraction).

Wang Weifeng modified waterborne polyurea using nano-SiO_2. When the addition of nano-SiO_2

was 2%, the thermal decomposition temperature of the coating film increased by 10℃, and the water absorption rate decreased from 30.56% to 11.12%. The tensile strength first increased and then decreased, reaching a maximum of 29.7 MPa, while the elongation at break continuously decreased.

1.4.2 Resin modification

Resin modification is a method of incorporating resin molecules into polyurea molecules through means such as block copolymerization and grafting. Commonly used resins for modification include phenolic resin, epoxy resin, and silicone resin. This approach is used to improve the temperature resistance, reaction rate, and mechanical properties of polyurea elastomers. The method is simple and effective. Furthermore, after modification, the internal steric hindrance of the material increases, hindering the reaction with−NCO. This can extend the bonding time of the coating to a certain extent and improve the adhesion.

Phenolic resin modification is commonly used to enhance the mechanical, thermal, and electrical properties of materials. Wang Liuyang et al. prepared phenolic resin-modified polyurethane/polyurea coatings and found that when the phenolic resin content in the R component of the material was around 50%, the tensile strength of the coating film increased from 8.9 MPa to 13.2 MPa, and the resistance to strong acids and damping properties were improved, with Tg increasing from 12 ℃ to 106 ℃. Epoxy resin has excellent physical, mechanical, and electrical insulation properties, and the epoxy molecular chains can be well dispersed and interpenetrated into the polyurea molecular chains to form a cross-linked network.

Liu Fangfang et al. modified polyurea using self-made epoxy resin and found that various properties were improved to some extent after modification. When the self-made epoxy resin completely replaced 1000D and D2000 in the R component, the tensile strength of the resulting coating increased from 4.55 MPa to 16.63 MPa, the initial decomposition temperature rose from 288.1 ℃ to 334.1 ℃, and the glass transition temperature (Tg) increased from 12.6 ℃ to 90.0 ℃.

To enhance the damping performance of polyurea materials, Li Cangang et al. used silane coupling agent A-187 as a modifier to modify 100-mesh mica powder by solution immersion method. The modified mica powder was then added to the polyurea damping resin. The results showed that the addition of silane coupling agent A-187 modified mica powder to the polyurea resin could improve the damping performance of the material. When the addition level of silane coupling agent A-187 was 4%, the modified mica powder exhibited the highest activation index and the largest water contact angle, indicating the best modification effect. As the pigment-to-base ratio increased, the tensile strength and elongation at break of the polyurea damping material increased, the peak value of the damping factor rose, and the glass transition temperature (T_g) shifted towards lower temperatures.

Silicone is a kind of material with excellent properties such as low surface energy and low elastic modulus, and it also has good thermal stability and oxidation resistance.

Liu Junren and his team modified aspartic polyurea using double-ended epoxy-based polysiloxane (PDMS). Through a ring-opening reaction between D200 and the terminal epoxy group, PDMS was grafted onto the main chain, followed by a Michael addition reaction with diethyl maleate, resulting in the synthesis of silicone-modified polyaspartic ester (PAE-S). PAE-S was then polymerized with HMDI prepolymer at room temperature to produce silicone-modified polyaspartic ester polyurea. Evaluation revealed that the high-temperature resistance of the silicone-modified polyurea was improved to varying degrees. Furthermore, the polyurea exhibited the highest elongation at break when the hard segment content was 12.8%, while also demonstrating good flexibility.

Hu Chunyan et al. synthesized a siloxane-modified polyurea elastomer (SPUR) with both rigid and flexible synergistic mechanical properties and repairability, using amino-terminated polydimethylsiloxane, amino-terminated polyether (polyetheramine, PEA), isophorone diisocyanate (IPDI), and n-butylaminomethyltriethoxysilane (S151) as raw materials. Through the "prepolymer capping method" and "soft and hard segment regulation method", and in combination with PEA20 and PEA9 monomers, they achieved a synergistic effect. The tensile test and repair performance test of SPUR were conducted: SPUR4 exhibited a tensile strength of 5.26 MPa, an elongation at break of 530%, and a repair rate of 30%, combining optimal comprehensive strength and elasticity.

1.4.3 Other modifications

Polyurea modification also includes methods such as fluorine modification, epoxy soybean oil (ESO) modification, and castor oil modification. The strong electronegativity of fluorine atoms enables the high bond energy carbon-fluorine bond to protect the main chain macromolecules, imparting the material with excellent surface and electrical properties. Moreover, organic fluorine can also exhibit excellent hydrophobic effects.

Feng Mingwei and others synthesized fluorine-modified polyurea materials by using fluorine-modified alicyclic slow-reacting secondary amine resin as the A component of a novel polyurea system, and the B component as a prepolymer made from the reaction of polyester polyol and aliphatic polyisocyanate. Due to the introduction of fluorine, which possesses various characteristics such as high electronegativity, high F-C bond energy, and low surface energy, combined with special formulation design, the material exhibits excellent aging resistance, waterproofing, low-temperature flexibility, impact and abrasion resistance, strong adhesion, and other advantages. It can be cured at low temperatures and is less affected by external temperature and humidity, making it highly suitable for various surface protective treatments of hydraulic structures.

Zhang Yuying developed a kind of ultra-high solid content modified aliphatic aspartic polyurea topcoat for wind turbine blade protection, using fluorosilicon-modified aliphatic aspartic polyurea resin as the main resin and aliphatic isocyanate as the curing agent. The hydrophobicity, abrasion resistance, rain erosion resistance, and weather resistance of the topcoat were investigated. The results showed that the solid content of the modified aliphatic aspartic polyurea topcoat reached 95%, with a film gloss of ≤30; the mechanical properties, rain erosion resistance, and UV aging resistance of the paint film were excellent, and the hydrophobicity was good.

Epoxy soybean oil (ESO) is abundant, renewable, environmentally friendly, and inexpensive, with good thermal stability and solvent resistance. After ring-opening with primary amines, ESO can be used to synthesize mild network cross-linking, improving the mechanical properties of polyurea.

He Jinwen et al. obtained Michael addition products by reacting IPDA with diethyl maleate and then added ESO to catalyze the synthesis of modified polyaspartic ester (PAE). The research results showed that ESO-modified PAE formed a cross-linked network structure. The reaction temperature was controlled at 95~105 ℃, with ZnCl2 as the catalyst, and the molar ratio of epoxy groups to amino groups was 1:1.25. The optimal addition amount of ESO was controlled at 6%~13%. The addition of ESO improved the thermal stability of PAE.

Wang Xiaotao et al. added a certain amount of modified castor oil to the polyurea component and obtained castor oil modified spray polyurea elastomer through spraying. They studied the influence of castor oil content on the contact angle, mechanical properties, water absorption rate, and tensile strength retention of the spray polyurea elastomer. The results showed that castor oil could improve the water resistance of the spray polyurea elastomer. When the mass fraction of castor oil was 30%, the water absorption rate of the spray polyurea elastomer after 7 days was 0.8%, the contact angle was 105°, and the tensile strength retention after 30 days was greater than 90%. The mechanical properties of the spray polyurea elastomer decreased with the increase of castor oil content. When the mass fraction of castor oil was 50%, the tensile strength of the material decreased to 15 MPa, and the tear strength decreased to 100 N/mm.

2 Application of polyurea in various fields

Currently, the polyurea market is primarily concentrated in countries such as the United States and Japan, with a growing demand in China in recent years. Domestic polyurea materials are primarily used in marine corrosion protection, railway construction, and the construction of important facilities. In 2022, the global polyurea coatings market reached a value of 6.294 billion yuan, with China accounting for 1.823 billion yuan.

2.1 Application of polyurea in the construction field

Polyurea is most widely used in the construction field, such as waterproofing walls, sealing and preventing infiltration and leakage of underground water conveyance systems, etc. Its wet slip resistance also makes it suitable for large sports venues with high anti-slip requirements, such as swimming pools and marine animal performance halls. Spray polyurea was first promoted and applied in anti-corrosion projects in the power industry and marine facilities in 2004. After its application in Olympic venues in 2008, spray polyurea has been widely used in the field of sports architecture.

As a competition venue for the 2022 Hangzhou Asian Games, the main stadium of the Zhejiang Huanglong Sports Center has seen its surface layer of the stands age over time. It underwent renovation using a weather-resistant PAE polyurea topcoat. The A component of the material is an IPDI prepolymer, while the R component consists of PAE mixed with an appropriate amount of powder and additives. The paint film contains no discoloring groups and exhibits high strength, good elasticity, excellent wear resistance, and resistance to yellowing. In practical applications, it maintains high color retention and offers significant waterproofing effects.

The 2022 Beijing Winter Olympics spurred the development of artificial simulation ice. Simulated ice rinks are typically constructed by splicing together simulation ice boards made of ultra-high molecular weight polyethylene, which offers low cost, fast construction speed, and simple maintenance. However, the joints can affect the overall flatness of the ice surface, and it is impossible to pre-bury markings and lines. Especially after skates glide across the ice, numerous burrs or plastic fibers emerge, hindering athletes from performing difficult and skillful maneuvers. Additionally, polyethylene boards are prone to deformation or even ignition when heated, posing safety hazards and fire risks. Polyurea liquid simulation ice, being both "crisp" and wear-resistant, with a simple manufacturing process and excellent performance, has strong wear resistance and weather resistance, making it the focus of artificial ice research.

Patent CN106634496B has synthesized an artificial simulated ice using aspartic polyurea, nano-scale rigid solid fillers HDI and HMDI, and diluent. Compared with existing artificial ice rinks, the polyurea simulated ice surface exhibits excellent load-bearing rigidity, optimal sliding resistance coefficient, simple and convenient construction, extremely rich sports colors, and meets international top environmental standards. Furthermore, when the ice rink is relocated or its specifications are changed, it is only necessary to re-segment or splice the polyurea simulated ice body, and then pour new liquid material into the joints. In addition, aspartic polyurea has characteristics such as low volatile organic compounds and heavy metal content, and no solvents, which does not pollute the environment or harm the health of construction workers.

Polyurea elastomers are recognized as key materials for protecting the strength and safety of projects such as highways, rail transit, and cross-sea bridges due to their excellent waterproofing, rust-proofing, and corrosion resistance. Their superior resistance to salt spray and oxidation also makes them ideal anti-corrosion materials in the field of marine and offshore engineering.

The high-speed railway adopts the CRTS II type ballastless track slab bridge deck design, which requires the waterproof layer to not only be impermeable and crack-resistant, but also to withstand the high-speed and heavy loads, alternating impacts, etc. brought by high-speed trains. Sprayed polyurea coating is an amorphous liquid waterproof material at room temperature, with no joints and strong bonding strength, which can achieve "skin-type" waterproofing. At the same time, it also possesses excellent performance, fully meeting the special requirements of high-speed railways.

The 2006 Beijing-Tianjin high-speed railway marked the first large-scale successful application of spray polyurea elastomer (SPUA) technology on a high-speed railway. In this project, over 2,000 tons of SPUA materials were used, covering a protective area of 950,000 square meters. Subsequently, high-speed railways such as the Beijing-Shanghai, Beijing-Shijiazhuang, Shijiazhuang-Wuhan, and Shanghai-Hangzhou railways also adopted SPUA waterproof layers. Notably, the Beijing-Shanghai high-speed railway, constructed in 2009, spans 1,318 kilometers and utilizes a total of 20,284 tons of SPUA, making it the world's largest infrastructure SPUA protection project since the technology was introduced in the United States in 1986.

2.2 Application of polyurea in the military field

Conventional materials such as epoxy resin and polyurethane, due to their general performance in impact resistance and wear resistance, as well as their lack of environmental friendliness, can no longer meet the important requirements of corrosion prevention and protection in the military field. Polyurea materials combine strength with ductility, and possess strong energy absorption capability while also exhibiting ultra-high adhesion performance. This has made research on their composite with other materials a hot topic, opening up a new horizon for China's military field.

Currently, existing protective equipment is primarily designed to withstand ballistic penetration injuries caused by explosions, lacking targeted design and multi-functional coupling research on other injury factors such as blast-induced injuries and thermal radiation injuries. Xue Shengpeng designed a new type of micro-nano inclusion composite polyurea material, PU-SiO2 and PU-HP modified helmets, to resist blast-induced injuries. The research results show that the protective effect of the two modified polyurea materials on blast waves increases with the increase of particle content. Compared to PU material, at the highest inclusion ratio and a thickness of 12 mm, the peak pressure of PU-SiO2 and PU-HP decreases by 8.71% and 16.77%, respectively. The results of cranial brain protection experiments indicate that, compared to the unprotected state of a bare head, both helmets provide good protection at frontal and parietal measurement points, but the protective effect at the occiput is not significant. The attenuation of frontal pressure is reduced by 44.51% and 51.74%, respectively, and the peak acceleration attenuation is 55.80% and 57.80%, respectively. At the parietal pressure measurement point, after helmet protection, the peak pressure is significantly reduced overall, and the peak acceleration is reduced to within 40.0 g.

Qin Yinxing utilized the high elasticity and strong adhesion of polyurea materials, combining them with lightweight and high-strength glass fiber reinforced composites that are relatively weak in impact resistance. He then conducted an analysis on the impact resistance performance of the resulting polyurea-coated glass fiber composite panels. The results showed that at an impact velocity of 18 m/s, the coating structure on the back-facing surface exhibited the strongest impact resistance against a flat-headed impact rod. The composite panels with polyurea as the interlayer exhibited superior impact resistance mechanical properties compared to those with polyurea as the coating layer.

In modern naval warfare, ships and submarines are subject to explosion and impact damage. Yu Xia compounded fibers with negative Poisson's ratio and polyurea to obtain a polyester-carbon fiber/polyurea composite material with combined properties. The research results show that:

(1) As the winding angle decreases and the diameter ratio increases, the fracture energy of the material increases. The winding angle of 5°, diameter ratio of 9:1, and epoxy coating constitute the optimal combination parameters for mechanical properties and deformation, with the fracture energy increased by 1.6 times, 1.4 times, and 1.1 times, respectively.

(2) The composite material with the optimal combination parameters, featuring double-layer weaving, exhibits the maximum displacement of 24.93 mm when stretched to cracking, with a maximum strain tolerance of 2.513. Additionally, its energy dissipation during tensile fracture is 2.65 times that of pure polyurea. This is expected to provide a reference for the selection of protective material systems for naval vessels and the structural design of functional protective coatings for naval vessels' explosion and impact resistance.

2.3 Application of polyurea in the automotive industry

With the intensification of national efforts to combat environmental pollution, VOC emissions have become a stumbling block to the development of the automotive industry. Furthermore, the core component of new energy vehicles, the automotive power battery pack, demands extremely high collision protection, which simultaneously requires the automotive chassis to achieve energy saving and consumption reduction, as well as improved protective effects. It is necessary to consider the impact strength and rigidity in humid environments, while also resisting collisions and scratches from sharp objects to prevent the battery from violently igniting due to external forces. These requirements can be met by adjusting the supporting polyurea coating, which possesses complex mechanical properties such as waterproofing, impact resistance, super-viscoelasticity, and hysteresis characteristics. Moreover, polyurea coatings are suitable for continuous production, saving a significant amount of energy and space.

Yao Xuemin et al. studied the protective effect of a polyurea topcoat combined with an epoxy zinc-rich primer on automobile chassis. When the coating thickness was 40μm, the salt spray resistance and aging resistance reached 1,000 hours.

Wang Nan and colleagues prepared a protective coating for new energy vehicle chassis using silica, titanium dioxide, single-layer graphene, and polyaspartic ester polyurea. The mechanical properties, weather resistance, salt spray resistance, and stone chip resistance of the protective coating were investigated. The results showed that the polyaspartic ester polyurea coating exhibited excellent adhesion, mechanical properties, corrosion resistance, and stone chip resistance. After adding silica and titanium dioxide, the corrosion resistance and adhesion of the coating improved further after artificial accelerated aging and neutral salt spray resistance tests, but the tensile strength and tear strength decreased. However, the addition of single-layer graphene improved all properties of the coating, especially its stone chip resistance.

Ding Minghui and others adopted nano-modified aliphatic polyurea paint as the top coat for bus roofs. The gel time of the paint is more than 25 minutes, and the film thickness achieved after one-time spraying is 80 μm without sagging. The surface drying time at room temperature is 10~15 minutes, which meets the requirements of DI type products in Q/ZZ 21039 (Various Colors of Automotive Top Coat). Moreover, it is convenient for large-scale assembly line production and has good compatibility and adhesion with existing automotive paint systems. The modified polyurea paint has been tested on bus roofs for one year, showing no discoloration or powdering. It not only completely solves the problems of corrosion prevention and waterproofing but also has heat insulation, damping, and noise reduction functions. Due to its excellent physical and chemical properties and almost zero VOC emissions, nano-modified aliphatic polyurea paint will inevitably gain increasing attention in the automotive industry.

2.4 Application of polyurea in high-end fields

With the innovation of production technology and optimization of quality, polyurea has broad application prospects in high-end fields such as electronics, medical care, and aerospace.

Linear dielectric polyurea polymers, characterized by their high dipole moment and dipole density, can maintain a high dielectric constant with low dielectric loss, achieving high energy storage density. Due to their advantages such as low manufacturing cost, low dielectric loss, high breakdown strength, and high reliability, they have become highly promising materials for electric energy storage.

The presence of dynamically hindered urea bonds in polyurea endows it with controllable hydrolysis properties, making polyurea dry gel (Polyu) a versatile carrier often used to provide high drug loading and controlled release, potentially becoming an effective alternative to classic polyacrylate, polyester, or polyamino acid drug delivery nanosystems.

Aircraft are subjected to various extreme mechanical stresses and harsh environmental conditions. Due to its excellent properties, polyurea elastomer is suitable for structural components, parts, and surface protection of aircraft and spacecraft. At the same time, its good adhesion property allows it to firmly adhere to the surfaces of metals, composite materials, and other materials, forming a strong protective film. Currently, due to the late start of research on polyurea elastomer materials in China, there are still issues with low strength, impact resistance, conductivity, thermal conductivity, and other properties, which cannot fully meet the strict requirements of the aerospace industry for materials. Therefore, polyurea elastomer has not been widely used in the field of aircraft in China.

3 Conclusion

This paper summarizes the synthesis, modification, and research progress of polyurea elastomers in various application fields both domestically and internationally, with a focus on the discussion of modification and development in each field. The polyurea material system is diverse, and research and testing methods vary. Existing research has gained some basic understanding of polyurea elastomers, but domestic research on polyurea elastomers is not deep enough, and it mostly leans towards engineering applications, with less exploration in high-end fields. In view of this, the following directions for future research on polyurea elastomers are proposed:

(1) Clarify the relationship between the structure and properties of polyurea elastomers, conduct qualitative and quantitative research on polyurea microphase separation, and establish a unified and systematic characterization method.

(2) The research and development of polyurea systems should continue to focus on molecular structure design or material modification tailored to different application environments, service lifetimes, adhesion, and other performance requirements, in order to optimize the polyurea molding process.

(3) Polyurea elastomers are easy to process, cost-effective, and have a wide range of applications. However, research in high-end fields such as electronics and aerospace is still in its infancy and has not yet been industrialized.