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Mini review polyurethane hybrids: preparation, characterization and applications

[1]El-Sayed Negim, [2]Marwan Shalash, [3]Mukatayeva Zh.S., [4]Baidullayeva A.K., [1]Alferov T.K., [1]Nurtazina A.A., [1]Karabayeva A.E., [5]Moshera Samy

[1]*Kazakh-British Technical University, Almaty, Kazakhstan*
[2]*College of Science, Northern Border University, Arar 9280, Saudi Arabia*
[3]*Institute of Natural Science and Geography of KazNPU named after Abai, Almaty, Kazakhstan*
[4]*S.D. Asfendiyarov Kazakh National Medical University, Almaty, Kazakhstan*
[5]*National Research Centre, 33 El Buhouth St., Dokki, Giza 12622, Egypt*

**Corresponding author: elashmawi5@yahoo.com*

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ABSTRACT
Polyurethane hybrids (PUHs) are a type of versatile materials with a broad variety of possible applications. Considering the connections between their structure and characteristics, this is especially true. Because of its special mechanical stability, toughness, stickiness, sustainability of the finished product, biological properties, and chemical properties, PUHs are the subject of extensive research and development for use in a wide range of applications. Polyurethane /acrylic hybrids are important type of binders in coating industries due to their exceptional properties. This mini review aims to provide an overview of different types of polyurethane/acrylic hybrids, including waterborne, blending, and UV curable hybrids. The synthesis of these hybrids through addition and emulsion polymerization techniques is discussed, emphasizing the importance of achieving intimately homogenous latex. The hybrids (PUHs) enhanced the physical, chemical, and mechanical properties of the final products including coatings, paints, adhesives, and performance of other products. In addition, the anticorrosion coatings based on PUHs exhibits the properties of polyurethane and acrylic to reduce or prevent the corrosion.

Keywords: Polyurethane hybrids, Acrylic, Water borne, UV curable, Blending, Emulsion

Information about authors:

El-Sayed Negim	*School of Materials Science and Green Technologies, Kazakh-British Technical University, St. Tole bi, 59, Almaty 050000, Kazakhstan. Email: elashmawi5@yahoo.com*
Marwan Shalash	*Chemistry Department, College of Science, Northern Border University, Arar 9280, Saudi Arabia. Email: marwan.shalash@nbu.edu.sa*
Mukatayeva Zh.S.	*Institute of Natural Science and Geography of KazNPU named after Abai, Almaty, Kazakhstan Email: jazira-1974@mail.ru*
Baidullayeva A.K.	*Department of Engineering disciplines and good practices, School of Pharmacy, S.D. Asfendiyarov Kazakh National Medical University, Almaty, Kazakhstan. Email: ainasha.kz@list.ru*
Alferov T.K.	*School of Materials Science and Green Technologies, Kazakh-British Technical University, St. Tole bi, 59, Almaty 050000, Kazakhstan. Email: t_alferov@kbtu.kz*
Nurtazina A.A.	*School of Materials Science and Green Technologies, Kazakh-British Technical University, St. Tole bi, 59, Almaty 050000, Kazakhstan. Email: a_nurtazina@kbtu.kz*
Karabayeva A.E.	*School of Materials Science and Green Technologies, Kazakh-British Technical University, St. Tole bi, 59, Almaty 050000, Kazakhstan. Email: a_karabayeva@kbtu.kz*
Moshera Samy	*Polymers and Pigments Department, National Research Centre, 33 El Buhouth St., Dokki, Giza 12622, Egypt. Moshera_samy1984@yahoo.com*

Introduction

Acrylic-polyurethane hybrids are binders based on combining polyurethane and acrylic and become important type of binders in coating industries because of their high-performance properties, good dispersion to the pigments and lower cost, as well as the highest performance of polyurethane such as excellent chemical resistance, adhesion, sustainability of the final products, toughness, and mechanical stability [[1], [2], [3], [4], [5], [6], [7], [8], [9], [10]]. The properties of hybrids depend on the types, concentrations, ratios, and molecular weight of raw materials of polyurethane and acrylic. To achieve the highest properties of polyurethane and acrylic polymer is to synthesise polyurethane/acrylic hybrids using addition and emulsion polymerization, resulting in intimately homogenous latex [[10], [11], [12], [13], [14]].

There are different kinds of polyurethane/acrylic hybrids: 1) emulsion waterborne polyurethane/acrylic hybrids which produce water-base hybrids based on different kinds of surfactants including anionic, cationic and nonionic surfactants as well as acrylic monomers with hydroxyl groups. 2) blending polyurethane prepolymer with polyacrylic through cross-linking between functional groups of both polymers to produce a blending copolymer with the highest physical and chemical properties. 3) UV-curable waterborne polyurethane/acrylic to produce eco-friendly polymer using UV-radiation for polymerization of polyurethane-acrylic with a network structure to improve mechanical properties as well as chemical and corrosion resistance. Therefore, waterborne UV-curable coating exhibited excellent hardness, scratch-resistance, impact-resistance as well as chemical and corrosion resistance. 4) polyurethane/acrylic solution type: polymerization of hybrids was prepared by solution technique in presence of solvents including toluene, acetone and characterized different standard methods [[15], [16], [17], [18]].

Emulsion waterborne polyurethane/ acrylic hybrids

Stable emulsions of waterborne poly(urethane-urea) and hybrid materials including n-butyl acrylate (BA), glycidyl methacrylate (GMA), and perfluoro decyl acrylate with varying acrylate contents were effectively synthesized by Lee *et al.*2013 [19]. The emulsify of the waterborne emulsion was restricted at 40 wt. % acrylic monomer content. With the highest acrylate content prompted expanded molecule size, hardness, thermostability, and water/methylene iodide-contact points, while diminishing consistency, lengthening at break, water enlarging and surface energy.

While Sukhawipat *et al.* 2020 [20] combined a mixture of waterborne polyurethane by emulsion technique process utilizing a mix of hydroxyl telechelic and hydroxylated oil as the polyol. The waterborne polyurethane showed good dependability with 16% complete solids content and shaped excellent coatings. Further improved mechanical properties were accomplished by emulsified butyl acrylate (BA) and methyl methacrylate (MMA) co-monomers onto the waterborne. The extent of BA/MMA was found to impact the morphology, mechanical properties, surface wetting, and cement strength of the films. Waterborne hydroxyl-practical polyurethane/acrylic emulsions for two-part coatings were created by Ma *et al.* 2015 [21] through the copolymerization of hydroxyethyl acrylate (HEA)/BA with methyl methacrylate and acrylic-ended polyurethane scattering. The results showed that expanding the HEA/BA weight proportion diminished molecule sizes, limited size circulation, and expanded emulsion consistency. Films showed upgraded warm obstruction, substrate bond, rigidity, and hardness, however, decreased water opposition and expanded wettability with higher HEA/BA proportions. Application in two-part coatings further developed water obstruction, decreased wettability, and further expanded glass change temperature, warm steadiness, attachment, rigidity, and hardness. The review recommends that hydroxyl bunches in polyurethane add to hydrogen holding and covalently crosslinked networks with polyisocyanate in the coatings. Liu *et al.* 2020 [22] incorporated semi-gleam waterborne polyurethane-polyacrylate half and half scatterings with shifting styrene/butyl acrylate monomer proportions utilizing arrangement polymerization and stage reversal. The PUA films displayed superb bond qualities and great hardness.

Qu *et al.* 2014 [23] synthesized semi-batch acrylic-polyurethane emulsions by emulsion copolymerization, using a combination of acrylic monomers and an isocyanate-ended polyurethane. The authors examined the effect of polyurethane content on the emulsion morphology and film properties. Expanding polyurethane content stimulated harsher film surfaces. Ultra violet conveyance spectra diminished with higher polyurethane content, lining up with changes in film surface unpleasantness. Electrophoresis on an aluminum composite surface and ensuing drying at 120°C brought about films with phenomenal mechanical execution because of a restoring response among polyurethane and the air conditioner copolymer. The film gleam dropped to 4.0 after electrophoresis testing, showing possible use in elimination electrophoresis applications.

Alvarez *et al.* 2018 [24] studied the combination of waterborne polyurethane/acrylate scatterings by joining with bisphenol-A-glycidyl dimethacrylate. Using a prepolymer self-emulsifying approach, waterborne polyurethane/acrylate were organized with styrene and n-butyl acrylate in the polyacrylate segment and isochrone diisocyanate, poly (tetramethylene ether) lycol, dimethylolpropionic corrosive, and ethylenediamine in the polyurethane section. As the polymerization initiator, a redox pair configuration of hydrogen peroxide and ascorbic corrosive was added. Expanding the bisphenol-A-glycidyl dimethacrylate/1,4 butanediol proportion expanded molecule size, yielding stable scatterings with adversely charged particles and low thickness regardless of high solids content (27 wt. %). The expansion of 35 wt.% bisphenol-A-glycidyl dimethacrylate fundamentally expanded cross-cut attachment of polyurethane/acrylate coatings to treated steel.

Pardini *et al.* 2018 [25] synthesized PU/DEA hybrid films with pH-responsive characteristics by preparing films with different concentrations of 2-(diethylamino)ethyl methacrylate (DEA) and a polyurethane based on isophorone diisocyanate (PU). In instance, in the DEA-rich hybrid system (50 wt. %), batch investigations analyzing Cu^{2+} and Zn^{2+} sorption on the polymer films show best removal at pH 4.0 with an initial concentration of 250 mg/L for each ion. Zn^{2+} is more favored by the polymer systems than Cu^{2+} is, and the equilibrium sorption data closely match the Langmuir sorption isotherm model.

Deng *et al.* 2018 [26] conducted a study, where hybrid emulsions of waterborne polyurethanes-acrylate were synthesized using isophorone diisocyanate, polytetramethylene glycol, and an acrylate monomer. The study concentrated on how different characteristics of the hybrid emulsions and films were impacted by the NCO/OH ratio and the polyurethane/polyacrylic ratio. The findings demonstrated that the hybrids latex particles exhibited regular spherical shapes and excellent stability. Particularly at a polyurethane/polyacrylic ratio of 30/70, the hybrids films displayed a significant loss factor (tanδ) of ≥0.3 across a temperature range of 75℃, making them suitable for damping applications.

Degrandi-Contraires *et al.* 2013 [27] demonstrated the production of urethane/acrylic hybrid latexes for pressure-sensitive adhesive applications by miniemulsion polymerization. The technique provided addition polymerization of an isocyanate-terminated polyurethane with hydroxyl groups of one acrylic component (HEMA) and simultaneous free-radical polymerization of acrylic monomers. The concentration of HEMA significantly influenced the polymer microstructure, impacting the gel content, crosslinking density, and the formation of smaller loops in the network. Computer simulations using a Monte Carlo method provided insights into the polymer microstructure, revealing the potential for developing a new generation of urethane/acrylic with enhanced shear resistance. While Lopez *et al.* 2011 [28] conducted one-step miniemulsion polymerization to prepare waterborne polyurethane-acrylic hybrid nanoparticles for use in pressure-sensitive adhesives. The addition of polyurethane significantly increased cohesive strength, resulting in a much higher shear holding time, making it desirable for pressure-sensitive adhesives. Nevertheless, phase separation was caused by the addition of a tiny amount of methyl methacrylate to the acrylic copolymer, leading to a hemispherical morphology and reduced tack energy. The study underscores the sensitivity of viscoelastic and adhesive properties to polymer network architecture, emphasizing the importance of precise composition and synthesis conditions. In order to investigate the effects of colloidal structure, grafting between the two polymers, and the makeup of the polymer phases on the mechanical properties of cast films, Mehravar *et al.* 2019 [29] created a number of polyurethane/acrylic dispersions using a solvent-free approach. The dispersions exhibited a polyurethane shell/acrylic core structure, translating into a morphology that acted as a filler material, allowing the use of high T_g copolymers, and resulting in films with exceptional mechanical strength. Grafting between polyurethane and acrylic phases enhanced compatibility but had a minimal impact on mechanical characteristics. The study provides design principles for synthesizing polyurethane/acrylic hybrids with controlled mechanical properties. Poly(siloxane–ether–urethane)-acrylic (PU-AC) hybrid emulsions were created by adding different amounts of hydroxyethoxypropyl-terminated polydimethylsiloxane (PDMS) to the acrylic-terminated poly(ether–urethane) backbone in a study by Yi *et al.* 2017 [30]. Larger particle sizes and reduced viscosity in the hybrid emulsions were observed upon the introduction of PDMS, according to in situ copolymerization with methyl methacrylate and butyl acrylate via an emulsion technique. The resulting films exhibited improved flexibility, water resistance, and surface hydrophobicity with increasing PDMS content, making them potentially valuable for applications such as fouling-release coatings, biomaterials, and surface finishing.

Waterborne polyurethane/acrylic hybrid emulsions were prepared by Ma *et al.* 2015 [31] using a hybrid synthesis technology. The content of 2-ethylhexyl acrylate and N-acryloylmorpholine affected the hybrid emulsions and films that resulted from the polymerization of methyl methacrylate, butyl acrylate, 2-ethylhexyl acrylate, and N-acryloylmorpholine in the presence of acrylic-terminated polyurethane dispersion, as the study examined. This study demonstrated that the addition of ethylhexyl acrylate enhanced film elasticity, while N-acryloylmorpholine contributed to high gloss, substrate adhesion, toughness, and hardness. The combination of both monomers produced hybrid materials with moderate properties, and an increase in the N-acryloylmorpholine/ethylhexyl acrylate weight ratio resulted in changes in emulsion properties and film characteristics, including a synergistic effect on film gloss and increased hydrogen bond interaction with higher N-acryloylmorpholine content.

A study on the production of hydroxyl-functional polyurethane-acrylate (PUA) emulsions for two-component coatings was carried out by Ma *et al.* 2015 [21]. The effects of changing the hydroxyethyl acrylate/BA ratio on PUA emulsions, films, and two-component coatings were observed through copolymerization of varying weight ratios of hydroxyethyl acrylate (HEA) and BA with a constant amount of methyl methacrylate (MMA) and acrylate-terminatedpolyurethane (PU). Increasing the HEA/BA weight ratio led to smaller particle sizes, a narrower particle size distribution, increased special surface area, and higher viscosity in the emulsions. The resultant PUA films showed improved hardness, tensile strength, adhesion on surfaces, and thermal resistance, but also increased wettability and decreased water resistance. Furthermore, in two-component coatings, the reaction between polyisocyanate (PIH) and the hydroxyl group of PUA resulted in covalent crosslinking, leading to increased glass transition temperature, improved water resistance, and enhanced adhesion, tensile strength, and hardness in the cured films.

The fabrication of stable emulsions of crosslinkable waterborne polyurethanes (CWPU) and waterborne polyurethane-acrylic (CWPU/AC) hybrids using variable amounts of trimethylolpropane (TMP) and acrylic monomers was studied by HyeLin *et al.* 2016 [32]. The investigation focused on the effects of these components on emulsion stability, particle size, viscosity, as well as the mechanical, thermal, and surface properties of resulting film materials. The study found that specific content limits of TMP and acrylic monomer were critical for emulsion stability. The film samples, enriched with silicone and fluorine according to XPS analysis, exhibited improved tensile strength, modulus, and hardness with increasing crosslinkable TMP/acrylic monomer content, demonstrating potential for high-performance antifouling coating materials at an optimum composition of approximately 0.04 mol/50 wt%. Zhang *et al*. 2014 [33] successfully prepared a waterborne polyurethane–polyacrylic ester hybrid emulsion (PUPA) by physically blending polyacrylic ester emulsion (PA) and waterborne polyurethane emulsion (PU). The hybrid nanoparticles were characterized for structure and chemical components, revealing promising properties. While PUPA-C, a humidity-sensitive coating, showed noteworthy humidity sensitivity and retention qualities, films made from PUPA revealed good hardness, gloss, water resistance, and water absorption. In their comprehensive investigation of PU/acrylic hybrid dispersions, Mehravar *et al.* 2019 [34] highlight the importance of seeded emulsion polymerization in the large-scale synthesis of surfactant-free waterborne PU/acrylic hybrids. PU's dominance in film formation allows the incorporation of acrylic compositions with higher T_g values without major effects on the film formation process. The study underscores the need for ongoing research, particularly considering environmental concerns and evolving regulations impacting PU/acrylic hybrid synthesis. Yi *et al.* 2017 [35] created robust waterborne polyurethane-acrylic (PU-AC) hybrid emulsions with different AC/PU weight ratios (45/55 to 70/30) by using allyl polyoxyethylene ether (APEE) as a coupling agent. The resulting emulsions exhibited a core-shell structure without cross-linking of copolymers. Increasing the AC/PU weight ratio led to larger particle sizes and broader size distributions, accompanied by reduced emulsion viscosity. The films that were produced using these emulsions showed enhanced mechanical characteristics, including higher water resistance, water contact angle, glass transition temperature, shore A hardness, tensile stress, and storage modulus. The choice of acrylate type (MMA, BA, or their mixture) influenced emulsion properties for specific applications. The study underscores APEE's role in establishing chemical bonds between PU and AC, promoting self-emulsification during polymerization, and facilitating the synthesis of high AC/PU ratio PU-AC hybrid emulsions. Water-borne polyurethanes (WPU) ended with vinyl groups and various concentrations of dimethylolpropionic acid (DMPA) were produced by Wu *et al.* 2019 [36].These WPU emulsions were utilized as surfactants in the soap-free emulsion copolymerization to produce core-shell polyurethane/polyacrylate (PUA) composite emulsions. The incorporation of WPU in copolymerization resulted in low surface tension (38.8 mN m^-1), and the reactive seed with WPU achieved a high final conversion of acrylic monomer (98%). The core-shell structure of PUA was confirmed by FTIR-ATR, and the compatibility between WPU and PUA improved with increased grafting efficiency, as observed in TEM results. PUA composite particle morphology changed from scattered to multi-core, core-shell, and core-shell architectures with different DMPA contents. Tensile testing revealed reinforcing and toughening effects in PUA films with increased DMPA content. In order to overcome the inadequate water resistance of conventional waterborne polyurethane (WPU), Xu *et al.* 2021 [37] created CO_2-triggered hydrophobic/hydrophilic switchable waterborne polyurethane–acrylate (WPUA) containing methyl methacrylate (MMA) units. The resultant WPUA, especially with 10 weight percent MMA, showed excellent mechanical qualities, such as high tensile strength (16.7 MPa) and modulus (85.9 MPa), as well as outstanding water resistance (low water uptake of 2.15 weight percent and linear swelling ratio of 0.17 L%). The study highlighted the stable dispersion of CO_2-triggered WPUA latex particles in water and their excellent properties post-film formation. Ma *et al.* 2017 [38] created a composite emulsion, waterborne polyurethane-acrylate (WPUA), by polymerizing waterborne polyurethane (WPU) as a seed emulsion dispersion, followed by methyl methacrylate (MMA) and BA. To examine their impact on performance qualities, the researchers altered the mass ratio of MMA to BA and the concentration of polyacrylate (PA) in WPU, using poly(propylene carbonate) (PPC) diol as a soft segment. The resulting WPUA films showed improved adhesion, pencil hardness, water resistance, and hydrophilicity, indicating good compatibility and a synergistic effect between PPC-based WPU and PA, leading to enhanced thermal properties and coating characteristics. Maurya *et al.* 2018 [39] present a comprehensive review on polyurethane-acrylate (PUA) oligomers, a novel class of polyurethanes produced by capping polyols with diisocyanate and acrylate. The review covers topics such as structure, modification, reactive diluents, curing, and the mechanical, optical, and thermal behavior of PUA, providing insights into the chemistry and mechanisms underlying these oligomers. The authors highlight the growing demand for modifying PUA to enhance its properties and note that the understanding of PUA chemistry has advanced to a level where tailor-made formulations for specific applications can be developed. Waterborne polyurethane modified by acrylate/nano-ZnO (PUA/ZnO) was manufactured and employed by Jiang *et al*. 2018 [40] to improve the wet rubbing fastness of cotton fabric dyed reactively. The treated fabrics showed a notable improvement of about 0.5-1 rate in wet rubbing fastness, achieving a rating of 3-4. Moreover, the treated fabrics exhibited enhanced ultraviolet protection with a UPF level of 50+, and SEM analysis revealed a smooth and reticular coating on the fabric surface, contributing to improved rubbing fastness by reducing mechanical friction forces. Using a solvent-free technique, Shi *et al.* 2013 [41] created a TDI-polyurethane/polyacrylate (TDI-PU/PA) composite emulsion by substituting methyl methacrylate (MMA) and butyl acrylate (BA) for acetone as a diluent. TDI, polypropylene glycol (PPG), 1,6-hexanediol (HDO), and dimethylol propionic acid (DMPA) were used in the emulsion synthesis, with the resulting latex film exhibiting increased tensile strength and pendulum hardness. The addition of MMA improved water resistance, and compared to IPDI-PU/PA, TDI-PU/PA offered cost efficiency and increased pigment loading, enhancing film hardness, and covering power.

Blending polyurethane/acrylic hybrids

Mehravar *et al.* 2019 [42] zeroed in on study of blending synthetically united polyurethane/(meth)acrylic half and half scatterings for wood floor coatings. Utilitarian monomers with hydroxyl gatherings and different vinyl functionalities (acrylic, allylic, methacrylic) were utilized for joining polyurethane and acrylic polymer stages. The polymerization method of (meth)acrylic monomers (bunch and semibatch) and the reactivity of monomers during acrylic polymerization were examined. The utilization of less responsive monomers brought about restricted gel portion arrangement, while additional receptive twofold bonds prompted higher gel content and molar mass. TEM examination showed that united mixtures displayed more homogeneous molecule and film morphologies. Comparing the connected and non-united polymer films, the former showed a greater Young's modulus and strain solidifying, with a more articulated impact for crossovers with higher gel content. Wood floor coatings arranged with these scatterings showed last properties practically identical to an industrially accessible reference covering. Kozakiewicz *et al. 2016* [43] in the second part of the survey centers around the blend and portrayal of watery polyurethane-acrylic scatterings (APUAD) with cross breed molecule structures. These scatterings yield coatings that show better properties analyzed than those created from mixes of watery polyurethane scatterings (APUD) and acrylic polymer scatterings. The paper talks about the potential outcomes of crosslinking coatings from APUD and APUAD, as well as the development of filled composites, including nanocomposites, from these scatterings. Also, the survey momentarily sums up current uses of APUD and APUAD. The paper features huge turns of events and distinguishes regions where further examination is required, zeroing in on the blend, portrayal of APUAD, and investigating crosslinked and filled frameworks including APUD or APUAD. Peruzzo *et al.* 2011 [44] blended polyurethane/acrylate cross breed composites with changing acrylic content (10-90 wt.%) through emulsion polymerization of acrylic monomers within the sight of preformed polyurethane chains. Mixes with identical acrylic content were likewise ready by blending polyurethane and acrylic scatterings. FTIR, UV, SEC, TEM, AFM, DLS, SAXS/WAXS, and gel division examination were among the methods used to portrayal. Mechanical characteristics, surface roughness, pencil and Buccholz hardness, and partially settled water contact point. The half breeds displayed crosslinked structures with changing molecule and film morphologies in view of acrylic content, showing non-straight conduct in film properties. Actual mixes exhibited a steady change from polyurethane to acrylic. FTIR showed preferred similarity in mixture frameworks over in actual mixes. By SAXS, crossover composites containing up to 70% acrylic were homogenous, while AFM uncovered ease isolation in mixes at all piece levels. Mehravar *et al.* 2017 [45] investigate the glue properties of strain delicate cements (public service announcements) got by mixing latexes with various qualities. Generally, public service announcement execution is surveyed in view of the sub-atomic load of the solvent polymer division and gel content. In any case, the examination recommends that depending entirely on gel portion and sol atomic weight distorts the portrayal. All things considered, the review stresses the requirement for an extensive comprehension of the whole sub-atomic weight dissemination, decided utilizing Lopsided Stream Field-Stream Fractionation (AsFlFFF), for a more significant connection between polymer microstructure and glue properties. Saeed *et al.* 2013 [46], conducted a study where emulsion-synthesized polyurethanes/polyurethane blend resins offer an environmentally conscious solution by minimizing solvent usage during leather resin application, thereby addressing pollution concerns. The resulting films exhibit desired properties such as high flexibility, gloss, fast-dry, and non-flammability, coupled with high thermal stability and cost-effectiveness. PU/PA-1, PU/PA-2, and PU/PA-3 blend resins exhibit notably varied drying times (4.0 to 7.0 min), with the faster curing reaction in PU/PA-1 attributed to a higher hexamethylene diisocyanate (HDI) content, leading to enhanced crosslinking. By adding polyacrylate resin emulsions, the films become impermeable in organic solvents and water, extending the polyurethanes' application endurance.

Mohamed *et al.* 2020 [47], conducted research focused on developing an eco-friendly water-based protective coating for steel pipelines, aiming to replace coatings containing hazardous materials to eco-friendly ones. The coating, formed by blending acrylic emulsion (AC) with varying proportions of polyurethane (PU) polymer, underwent comprehensive characterization to assess chemical structure and morphology. Additionally, the innovative mixed metal pigment that was generated from bauxite ore was added to the modified acrylic emulsion (AC-PU). The formulated coatings, particularly those with AC mixed with 15% polyurethane and the prepared pigment, demonstrated superior corrosion protection in 3.5% NaCl and 10% HCl solutions compared to other formulations and individual polymers. Negim et al. 2023 [48] prepared polyurethane hybrids based on different kinds of polyurethane and 2-hydroxyethyl methacrylate to modifiy unsaturated polyester resins. The results showed that the polyurethane hybrids improved physical and mechanical properties of polyester due to the crosslinking between hybrids and polyester.

UV curable waterborne polyurethane/acrylic

The raw ingredient for UV-curing coatings is waterborne polyurethane that is UV-curable. Environmentally friendly and safer than solvent-based paints are waterborne UV curing coatings. Since UV-curing technology is environmentally friendly and has superior qualities including high hardness, gloss, scratch resistance, and chemical resistance because of the high crosslink density from the acrylate group, it has therefore been proposed as a solvent-borne coating replacement. When creating products with unique waterborne qualities like low skin irritation and no flash point, UV polyurethane might be a useful tool. UV-curable waterborne polyurethane dispersions made by addition of copolymers of polycarbonate diols with various end-capping groups. According to the molecular weight (800, 1000, or 2000 g/mol) of polycarbonate diols, the physical properties were analyzed, and the authors [49] investigated the impacts of the polyol molecular weight on the UV-curing behavior. Similar research was conducted to determine how the end-capping group's functionality affected the physical characteristics and behavior of UV curing. To give the end-capping group functionality, 2-hydroxyethylmethacrylate, 2-hydroxyethylacrylate, and pentaerythritol tri-acrylate were utilized, in that order. The findings demonstrated that when the molecular weight of the polycarbonate diols decreased, so did the pendulum hardness, curing rate, and conversion. Compared to the other dispersions with mono-methacrylate or mono-acrylate functionality, the dispersion with tri-acrylate functionality on end-capping groups exhibited significantly higher pendulum hardness, curing rate, and conversion. UV-curable polyurethane dispersions were created by Kim *et. al.* (2006) [50] using varying prepolymer chain lengths and capping agents, such as 2,3-epoxy-1-propanol (glycidol) and 2-hydroxyethyl acrylate. Because the terminal isocyanate groups were capped with glycidol, the resulting films based on polyurethane dispersion had exceptional hardness, maximum elongation at break above 200%, and were tack-free before curing.

Conclusion

Polyurethane hybrids (PUHs) are versatile materials with a wide range of potential applications. The combination of polyurethane and acrylic in hybrid binders has gained significant attention in the coating industry due to their exceptional properties. Polyurethanes hybrids, particularly those incorporating acrylic components offer a wide range of properties and applications. The synthesis and characterization of polyurethane/acrylic hybrids through various techniques, including emulsion and addition polymerization, have been discussed. The resulting polyurethanes hybrids exhibit improved mechanical stability, adhesion, toughness, and chemical resistance. These materials have shown great potential in coating industries, two-part coatings, damping applications, and pressure-sensitive adhesives. Further research and development in this field can lead to the exploration of new hybrid combinations and the enhancement of their properties for various applications.

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[1] El-Sayed Negim, [2]Marwan Shalash, [3] Мукатаева Ж.С., [4] Байдуллаева А.К., [1] Алферов Т.К., [1] Нуртазина А.А., [1] Карабаева А.Е., [5]Moshera Samy

[1]Қазақстан-Британ техникалық университеті, Алматы, Қазақстан
[2]Ғылым колледжі, Солтүстік шекара университеті, Арар 9280, Сауд Арабиясы
[3]Абай атындағы университетінің жаратылыстану және география институты, Алматы, Қазақстан
[4] С.Ж. Асфендияров атындағы ҚазҰМУ, Алматы, Қазақстан
[5] Ұлттық Зерттеу Орталығы, Египет, Эль Бухут көш., 33, Докки, Гиза 12622

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ТҮЙІНДЕМЕ
Полиуретанды будандар (гибридтер) (ПУГ) алуан түрлі қолданылу аясы бар, әмбебап материал. Олардың құрылысы мен сипаттамаларының арасындағы байланысты есепке алғанда бұл ең өзекті мәселе. Арнайы механикалық тұрақтылығына, беріктігіне, жабысқақтығына, дайын өнімнің тұрақтылығына, биологиялық және химиялық қасиеттеріне байланысты полиуретанды будандар ПУГ қолданбалардың кең ауқымында пайдалану үшін ауқымды зерттеулер мен әзірлемелердің нысаны болып табылады. Өзінің өзіндік қасиеттеріне орай полиуретанды гибридтер мен акрил бояу өнеркәсібіндегі байланыстырғыштардың маңызды түрі болып саналады. Бұл қысқаша шолудың мақсаты полиуретанды/акрилді гибридтердің әртүрлі түрлеріне шолу жасау, соның ішінде су негізіндегі, қоспа және ультракүлгін сәулесімен қатырылатын гибридтерді таныстыру. Барынша біртекті латекске қол жеткізудің маңыздылығын көрсете отырып, қоспалы және эмульсиялы полимерлеу әдістерінің көмегімен осы будандардың синтезі талқыланады.

Түйін сөздер: полиуретанды будан (гибрид), акрил, су негізінде, ультракүлгін сәулелерімен қатыру, қоспа, эмульсия.

Авторлар туралы ақпарат:

El-Sayed Negim	*Материалтану және жасыл технологиялар мектебі, Қазақстан-Британ техникалық университеті, 050000, Төле би көшесі, 59, Алматы, Қазақстан. Email: elashmawi5@yahoo.com*
Marwan Shalash	*Химия бөлімі, Ғылым колледжі, Солтүстік шекара университеті, Арар 9280, Сауд Арабиясы. Email: marwan.shalash@nbu.edu.sa*
Мукатаева Ж.С.	*Абай атындағы университетінің жаратылыстану және география институты, Алматы, Қазақстан. Email: jazira-1974@mail.ru*
Байдуллаева А.К.	*Инженерлік пәндер және тиісті практикалар кафедрасы, С.Ж. Асфендияров атындағы ҚазҰМУ, Алматы, Қазақстан. Email: ainasha.kz@list.ru*
Алферов Т.К.	*Материалтану және жасыл технологиялар мектебі, Қазақстан-Британ техникалық университеті, 050000, Төле би көшесі, 59, Алматы, Қазақстан. Email: t_alferov@kbtu.kz*
Нуртазина А.А.	*Материалтану және жасыл технологиялар мектебі, Қазақстан-Британ техникалық университеті, 050000, Төле би көшесі, 59, Алматы, Қазақстан. Email: a_nurtazina@kbtu.kz*
Карабаева А.Е.	*Материалтану және жасыл технологиялар мектебі, Қазақстан-Британ техникалық университеті, 050000, Төле би көшесі, 59, Алматы, Қазақстан. Email: a_karabayeva@kbtu.kz*
Moshera Samy	*Полимерлер және Пигменттер, Ұлттық Зерттеу Орталығы, Египет, Эль Бухут көш., 33, Докки, Гиза 12622. Email: moshera_samy1984@yahoo.com*

Мини-обзор полиуретановых гибридов: получение, характеристика и применение

[1] El-Sayed Negim, [2]Marwan Shalash, [3] Мукатаева Ж.С., [4] Байдуллаева А.К., [1] Алферов Т.К., [1] Нуртазина А.А., [1] Карабаева А.Е., [5]Moshera Samy

[1] Казахстанско-Британский технический университет, Алматы, Казахстан
[2] Научный колледж, Университет Северной границы, Арар 9280, Саудовская Аравия
[3]Институт естествознания и географии КазНПУ имени Абая, Алматы, Казахстан
[4] Казахский национальный медицинский университет им. С.Д. Асфендиярова, Алматы, Казахстан
[5] Национальный исследовательский центр, ул. Эль Бухут, 33, Докки, Гиза 12622, Египет

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АННОТАЦИЯ
Полиуретановые гибриды (ПУГ) представляют собой тип универсальных материалов с широким спектром возможных применений. Учитывая связь между их строением и характеристиками, это особенно актуально. Благодаря своей особой механической стабильности, прочности, липкости, устойчивости готового продукта, биологическим и химическим свойствам ПУГ являются предметом обширных исследований и разработок для использования в широком спектре применений. Гибриды полиуретана и акрила являются важным типом связующих в лакокрасочной промышленности благодаря своим исключительным свойствам. Целью этого мини-обзора является предоставление обзора различных типов гибридов полиуретана и акрила, включая гибриды на водной основе, смеси и гибриды, отверждаемые УФ-излучением. Обсуждается синтез этих гибридов с помощью методов аддитивной и эмульсионной полимеризации, подчеркивая важность достижения максимально гомогенного латекса.

Ключевые слова: полиуретановые гибриды, акрил, на водной основе, отверждаемые УФ-излучением, смешивание, эмульсия.

	Информация об авторах:
El-Sayed Negim	*Факультет материаловедения и зеленых технологий, Казахстанско-Британский технический университет, ул. Толе би, 59, Алматы 050000, Казахстан. Email: elashmawi5@yahoo.com*
Marwan Shalash	*Химический факультет, научный колледж, Университет Северной границы, Арар 9280, Саудовская Аравия. Email: marwan.shalash@nbu.edu.sa*
Мукатаева Ж.С.	*Институт естествознания и географии КазНПУ имени Абая, Алматы, Казахстан. Email: jazira-1974@mail.ru*
Байдуллаева А.К.	*Кафедра инженерных дисциплин и передовой практики фармацевтического факультета Казахского национального медицинского университета им. С.Д. Асфендиярова, Алматы, Казахстан. Email: ainasha.kz@list.ru*
Алферов Т.К.	*Факультет материаловедения и зеленых технологий, Казахстанско-Британский технический университет, ул. Толе би, 59, Алматы 050000, Казахстан. Email: t_alferov@kbtu.kz*
Нуртазина А.А.	*Факультет материаловедения и зеленых технологий, Казахстанско-Британский технический университет, ул. Толе би, 59, Алматы 050000, Казахстан. Email: a_nurtazina@kbtu.kz*
Карабаева А.Е.	*Факультет материаловедения и зеленых технологий, Казахстанско-Британский технический университет, ул. Толе би, 59, Алматы 050000, Казахстан. Email: a_karabayeva@kbtu.kz*
Moshera Samy	*Факультет Полимеров и Пигментов, Национальный Исследовательский Центр, Египет, ул. Эль Бухут, 33, Докки, Гиза 12622. Email: moshera_samy1984@yahoo.com*

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