

Article

Oligocarbonate Diols as Modifiers of Polyurethane Coatings

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Abstract

Carbon dioxide-derived oligocarbonate diols (OCDs) represent a promising class of sustainable raw materials that can enhance the environmental profile of polyurethane (PUR) coatings without compromising their performance. In this work, six oligocarbonate diols, differing in chemical structure (aromatic, aliphatic, and cycloaliphatic), were employed as modifiers in solvent-based PUR coatings designed for wood substrates. The study evaluates the influence of OCD's chemical nature on the mechanical and optical properties of the resulting coatings. The results demonstrate that the structure of the oligocarbonate diol plays a decisive role in determining coating performance. PUR systems containing aliphatic soft segments exhibited the most favorable mechanical response, particularly in terms of wear resistance, outperforming coatings modified with cycloaliphatic and aromatic OCDs—wear reduction ranged between 43% and 71%. In contrast, the highest hardness values (0.46 and 0.41) were observed for the coatings incorporating aromatic moieties, indicating increased rigidity associated with aromatic structures. Importantly, adhesion at the wood–coating interface remained excellent and unaffected by the type of OCD used (cross-cut class I or II), confirming the compatibility of all investigated formulations with wooden substrates. Overall, the findings clearly show that newly developed CO₂-based oligocarbonate diols are effective and versatile modifiers for polyurethane wood coatings, enabling the tuning of functional properties while supporting more sustainable coating technologies.

Keywords: polyurethane; oligocarbonate diol; coating; hardness; abrasion



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1. Introduction

Polyurethane (PUR) coatings play a pivotal role in modern materials engineering owing to their versatility, durability, and the ability to tailor their mechanical and chemical properties. Their performance is strongly governed by the molecular architecture of the polyol component, which influences crosslink density, flexibility, hydrophobicity, and resistance to environmental stress factors. With the growing demand for high-performance and environmentally compliant coatings, increasing attention has been directed toward polyols that provide precise structural control and tunable functionality [1,2].

Oligocarbonediols have emerged as a promising class of polyols capable of addressing these evolving requirements. Featuring carbonate linkages within their polymer backbone, these oligomers offer distinct advantages over conventional polyether and polyester polyols.

The presence of carbonate groups confers enhanced hydrolytic stability, improved oxidative resistance, and superior mechanical strength [3–5]. Additionally, their well-defined oligomeric structure facilitates precise control over molecular weight and functional end-groups, which is critical for designing high-performance PUR networks [6,7].

In polyurethane coatings, the incorporation of oligocarbonate diols enables the design of materials with an improved balance between rigidity and elasticity. Their backbone architecture facilitates the formulation of PURs that retain flexibility while demonstrating enhanced scratch resistance, solvent resistance, and thermal stability [5,8]. These attributes are critical for coatings subjected to harsh environments, such as those used in automotive clearcoats, industrial equipment, and architectural exterior wooden structure protection.

An additional advantage of oligocarbonediols lies in their compatibility with sustainability objectives. Oligocarbonate polyols can be produced via more environmentally benign routes, including phosgene-free processes, CO₂-based chemistry, and the use of bio-derived carbonate precursors [9–11]. Coatings derived from such polyols may offer reduced volatile organic compound content, improved lifecycle metrics, and compliance with emerging environmental regulations [12].

The utilization of CO₂ as a feedstock in the synthesis of oligocarbonate diols provides several notable environmental benefits. Through catalytic copolymerization—most commonly with epoxides—captured CO₂ is incorporated directly into the polymer backbone, thereby partially substituting fossil-derived carbon sources and mitigating overall greenhouse gas emissions. In contrast to conventional carbonate production routes based on toxic phosgene or energy-intensive esterification processes, CO₂-based methodologies offer higher atom economy, proceed under milder reaction conditions, and substantially reduce the use of hazardous chemicals. Life-cycle assessment studies consistently indicate that CO₂-derived polycarbonate polyols possess a lower global warming potential and superior environmental performance, particularly with respect to reduced human toxicity and primary energy demand [13–15].

These sustainability advantages position CO₂-derived oligocarbonate diols as attractive building blocks for polyurethane coatings aimed at improving environmental performance without sacrificing material properties. Partial replacement of fossil-derived carbon with captured CO₂ leads to a quantifiable reduction in life-cycle emissions, while advances in heterogeneous and organometallic catalysis—such as zinc glutarate and chromium-salen complexes—have enabled efficient, phosgene-free synthesis routes. Consequently, CO₂-based production pathways support broader circular-carbon strategies by converting industrial CO₂ streams into long-lived, high-value materials. Recent studies underscore the significant potential of CO₂-derived oligocarbonate diols in advancing sustainable polymer chemistry, particularly when incorporated into high-performance polyurethane coating systems [15–18].

In view of these functional and environmental advantages, oligocarbonediols are increasingly recognized as next-generation building blocks for polyurethane coating technologies. Nevertheless, their successful implementation in commercial formulations requires a more comprehensive understanding of structure–property relationships, reaction kinetics with different isocyanates, and long-term performance under real-world service conditions [19].

In contrast to a typical approach [20], we used oligocarbonate diols as modifiers of 2-component PUR coatings instead of using them as reagents in the synthesis of PURs. In this work, six oligocarbonate diols were synthesized by transesterification of commercially available (UBE Corp.) oligo(carbonate diol)s with various diol species. Their detailed synthesis and characterization were reported by Mamiński et al. [21]. The synthesized oligocarbonate diols were then incorporated into polyurethane (PUR) coating formulations

as soft segment precursors. The influence of their molecular architecture on the resulting PUR coatings was examined in terms of hardness, flexibility, and adhesion, as well as color and gloss change after UV aging, providing valuable insights into the correlation between polycarbonate diol structure and coating performance.

Despite growing interest in sustainable polyurethane (PU) coatings, the existing literature on the specific role of oligocarbonate diols in these systems remains limited and fragmented. Most studies tend to focus broadly on polyol chemistry or model aliphatic and polyester diols, with relatively few systematic investigations isolating how variations in oligocarbonate diol molecular weight, functionality, and microstructure influence critical properties such as hydrolytic stability, mechanical performance, adhesion, and weathering resistance in final PU coatings [3,4,8]. Moreover, data on reaction kinetics with isocyanates and phase separation behavior are sparse or inconsistent across different studies [22–25]. To partially address these gaps, the present study was undertaken to investigate how blending of standardized coating formulations with oligocarbonate diols affects physical and mechanical properties of resultant coatings. Such work would enable clearer structure–property correlations and provide the polymer data to design oligocarbonate diol-based next-generation PU coatings.

2. Materials and Methods

The studied OCDs were synthesized according to the procedures described elsewhere, and their structure and physiochemical characterization were presented in the reference [21]. The OCDs selected as coating modifiers were cycloaliphatic (OCDs 01 and 02), aliphatic (OCDs 03 and 04) and aromatic (OCDs 05 and 06) (Figure S1). Hydroxyl numbers, L_{OH} , and molecular weights are shown in Table 1. L_{OH} was determined according to [26].

Table 1. Selected properties of the studied OCDs.

OCD	L_{OH} [mgKOH/g]	m.w. [g/mol]	Structure Type
01	131	860	cycloaliphatic
02	114	980	cycloaliphatic
03	35	4000	aliphatic
04	71	1600	aliphatic
05	62	1800	aromatic
06	38	3000	aromatic

Polyurethane 2-component transparent coating was purchased from a local wood product wholesaler. All liquid OCDs were added at 3%wt level based on total coating mixture weight and mixed until complete dissolution. All were found readily miscible with the other components. Ready-to-use mixtures were applied by paint spraying on solid beech wood sanded with 220-grit sandpaper in two layers with 4 hrs between drying.

The adhesion of the tested coating systems was determined in accordance with [27]. Test dollies with a diameter of 20 mm were bonded to the coatings using an epoxy adhesive. After 7 days of conditioning of the samples, circular cuts around the measuring dollies were made using an annular cutter. The pull-off test was carried out using a PosiTest AT-A (DeFelsko Corp., Ogdensburg, NY, USA) device. Ten tests were performed for each tested system at a pull rate of 0.2 MPa/s (Figure 1).

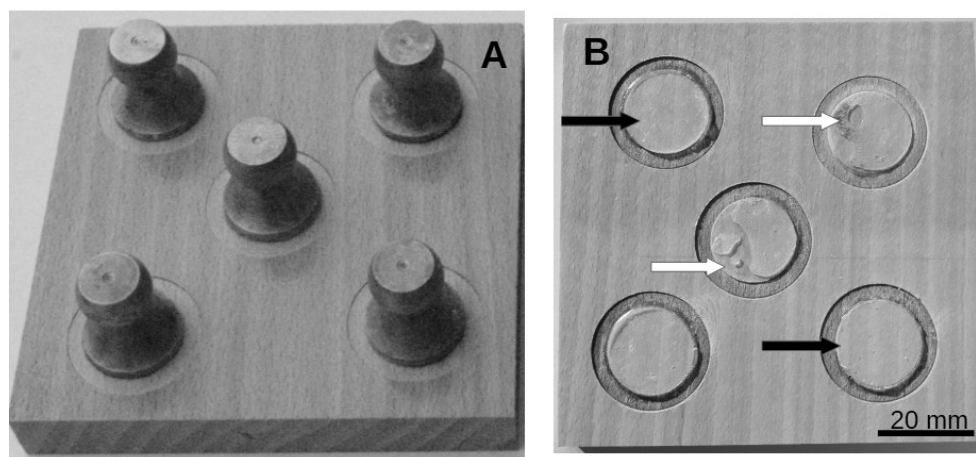


Figure 1. Specimens for pull-off adhesion testing: (A)—before testing, (B)—after testing. Arrows point adhesive/topcoat (white) or adhesive/dolly failure (black).

Additionally, the adhesion of the coating to the substrate was evaluated using the cross-cut test method in accordance with ISO 2409 [28]. The cross-cut method involves making a series of cuts with a circular cutting knife, forming a grid of lines intersecting at right angles, followed by the application and removal of an adhesive tape. The coating adhesion is assessed visually at the area of intersection, and the result is compared with the reference classification specified in ISO 2409.

The hardness testing of coating systems was conducted in accordance with ISO 1522 [29], which is based on counting the number of oscillations of a pendulum resting on the tested coating. The test was carried out on coatings applied to beech wood. Three replicates were tested in each series. A Persoz pendulum (AWS-9, POL-ZAF S.C., Wrocław, Poland) was used, intended for coatings with a hardness lower than 0.5 of glass hardness. The initial deflection angle was set to 12°.

Resistance of the coating to UV aging was performed as follows: the gloss and color were measured before and after exposure to UV radiation according to ISO 16474-3 [30]. Method B (ISO 16474): 24 h, 0.76 W/m²/nm at 340 nm, 50 ± 3 °C. Gloss was determined and reported in accordance with ISO 2813 [31] at a 60° angle along the fiber direction and expressed in gloss units (GU). The gloss of the coating was measured using a PICO GLOSS 503 glossmeter (Erichsen GmbH & Co. KG, Hemer, Germany) [31]. Provided values are means of ten measurements.

The color space CIE L*a*b* is a color model comprising three parameters: the lightness L* (from 0 to 100), the coordinate a* for determining color shift between red (+a) and green (−a), and the coordinate b* for determining the color shift between yellow (+b) and blue (−b). The coordinates L*, a* and b* were automatically measured by the spectrometer. Ten measurements were performed on each tested surface, and average values were used in calculations.

Color changes were determined in the CIE L*a*b* system as ΔE using a spherical spectrophotometer SP-60 (X-Rite Inc., Grand Rapids, MI, USA). Color changes were assessed in accordance with EN 722 [32] from Equation (1),

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}, \quad (1)$$

where ΔE—total color change; ΔL—lightening/darkening of the sample (L = 100 black, L = 0 white); Δa—shift toward red (+a)/green (−a); Δb—shift toward yellow (+b)/blue (−b).

The abrasion resistance test was carried out on 3 samples measuring 10 cm × 10 cm with a centrally placed hole of 7 mm diameter for mounting in the Taber Abraser 5130 testing device (Taber Industries, North Tonawanda, NY, USA). Measurements were performed according to the procedure specified in ISO 7784-1 [33]. The coating was subjected to the device arms loaded with 1 kg. The cleaned samples were weighed on an analytical balance with an accuracy of 0.001 g and then subjected to abrasion for 200 revolutions. The coating was dusted and weighed after completing 200 revolutions.

3. Results and Discussion

The effect of the studied OCDs on the modified mechanical and physical properties of PUR coatings was apparent and beneficial, which remains in accordance with general knowledge on the use of OCDs as modifiers in PURs [34,35]. Also, their positive influence on an increase in resistance to weathering and wear of coatings has been reported in the literature [4,5]. These enhancements are attributed to the ability of OCDs to interact at the molecular level with the polymer chains, improving the overall network structure and mechanical stability of the coatings. In addition to mechanical improvements, OCDs also demonstrated a beneficial effect on the durability and longevity of the coatings. Specifically, the presence of these modifiers contributed to increased resistance against environmental factors such as UV radiation [8,36]. Unlike the conventional approaches reported in the literature, where poly- or oligocarbonate diols (OCDs) act as stoichiometric components in PUR formulations, here they were introduced as additives.

3.1. Adhesion to Wood Substrate

The results of the coating adhesion measurements obtained via the pull-off test are presented in Table 2. No instances of coating detachment from the substrate, cohesive failure within the substrate, or cohesive failure within the coating were observed. In all cases, failure occurred either at the interface between the adhesive and the topcoat (-/Y) or between the adhesive and the test dolly (Y/Z), in accordance with the failure classification specified in ISO 4624 [27].

Table 2. Adhesion of the studied coatings to beech wood substrate in the pull-off test.

OCD	MPa	Delamination Locus	Cross-Cut Class Acc. ISO 2409
00 *	4.13 ± 0.48	50% -/Y; 50% Y/Z	II
01	2.73 ± 0.30	50% -/Y; 50% Y/Z	I
02	3.31 ± 0.13	80% -/Y; 20% Y/Z	II
03	4.58 ± 0.36	60% -/Y; 40% Y/Z	I
04	4.33 ± 0.23	100% -/Y	I
05	5.38 ± 0.22	90% -/Y; 10% Y/Z	I
06	4.90 ± 0.26	100% -/Y	I

* pure control coating.

As indicated by the data in Table 2, no topcoat adhesive delamination from the substrate or cohesive failure in the substrate was observed in any case, which seems rational due to the inherent strength of solid wood. Anyway, the results show that the weakest interface was adhesive/topcoat (white arrows in Figure 1B) or adhesive/dolly (black arrows in Figure 1B), while wood/topcoat interface adhesion remained intact and was proven to be sufficient and fully acceptable from the practical point of view. Pelit et al. [37] obtained pull-off strengths for polyurethane coatings on beech wood ca. 2.9–3.5 MPa, which values remain below our results from the present study. For comparison, the pull-off strengths of waterborne coatings on wood-plastic composites range between 1.4 MPa and 2.3 MPa [38], while cohesive failure in solid wood can reach

5.7 MPa [39]. It is also reported in the literature that solid beech wood strength in a pull-off test can reach 5.4 MPa [40]. Hence, the highest adhesion between the adhesive and the topcoat was found for OCDs 05 and 06, which bear aromatic moieties in the structure. The phenomenon can be explained by stronger intermolecular π - π interactions between aromatic subunits present in the epoxy adhesive and the investigated topcoat [41].

ISO 2409 [28] classifies the adhesion of a coating after a cross-cut test on a scale from 0 to 5. Class 0: no detachment of the coating. Class 1: Small flakes of the coating are detached at the intersections of the cuts (area $\leq 5\%$). Class 2: The coating has flaked along the edges and at the intersections of the cuts (area from 5% to $\leq 15\%$). Class 3: The coating has flaked along the edges of the cuts partly or wholly in large ribbons and/or at intersections (area from $>15\%$ to $\leq 35\%$). Class 4: The coating has flaked along the edges of the cuts in large ribbons, and/or some squares have detached partly or wholly (area from $>35\%$ to $\leq 65\%$). Class 5: Any degree of flaking that cannot be classified as Class 4, e.g., complete detachment.

The cross-cut test method according to ISO 2409 [28] proved and confirmed high adhesion to the substrate (Table 2). In all cases, neither Class IV nor Class V was observed (Figure 2).

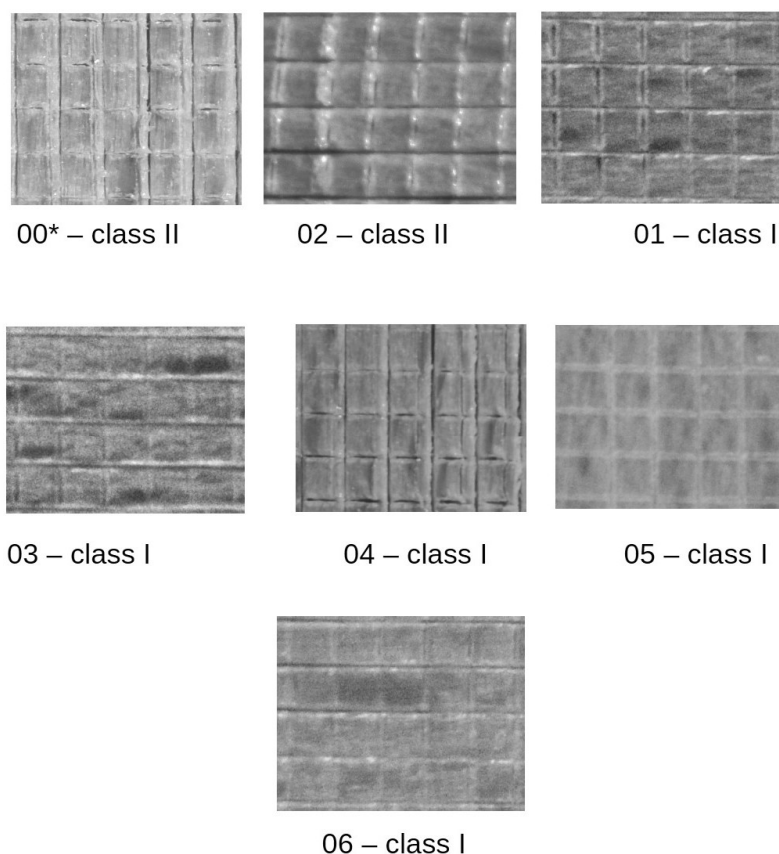


Figure 2. Specimens after cross-cut adhesion testing. * pure control coating.

3.2. Hardness of the Coatings

Coating hardness is a measure of a coating's resistance to mechanical deformation, such as scratching or indentation, and is an important indicator of its durability and protective performance. In practice, hardness reflects to what extent a coating can maintain its integrity and surface appearance as well as dissipate under mechanical stress during use [40,42]. Glass is often employed as a reference material due to its high and well-defined hardness. Relating coating hardness to that of glass enables the results to be presented on a

relative scale, facilitating the evaluation of whether a given coating exhibits lower or higher hardness than a standardized benchmark material.

Figure 3 presents the results of measurements of coating hardness relative to glass. The results indicate that the compositions doped with cycloaliphatic (OCDs 01 and 02) or aliphatic (OCDs 03 and 04) exhibit lower hardness than that for the pure commercial reference (0.40 ± 0.01). In this case, segmented polyurethanes were obtained in which the soft segments were derived from long-chain OCDs containing aliphatic moieties, resulting in enhanced flexibility and pronounced elastomeric properties. Such an effect of long-chain diols is commonly agreed [43]. But the results indicated increased hardness for OCDs 05 and 06 in comparison to the reference coating 00 *. It can be assigned to aromatic moieties, which are recognized as hard segments in polyurethanes. Intermolecular interaction via hydrogen bonds between aromatic and urethane moieties contributes to the formation of high cohesion energy of these hard segments at room temperature [44]. Zhang et al. investigated coatings comprising aromatic and cycloaliphatic subunits [41]. The observed enhancement in hardness was attributed to the incorporation of aromatic moieties within the polymer matrix, a reinforcement further amplified by the rigid segments derived from phthalic anhydride. Moreover, aromatic polyols were found to interact with urethane groups, promoting hard-domain cohesion. Concurrently, π - π stacking interactions contributed to an increased resistance of the polymer to mechanical deformation. Although the pendulum damping test showed 0.46 ± 0.01 hardness of glass for OCD 05, that value is still lower than 0.65–0.68 reported by Huang et al. [45] for hydroxyl-functional acrylic-based PUR coating. Due to the excellent repeatability of the results in each series, standard deviations were comparable, with the exception of beech wood, whose hardness was determined to be 0.24 ± 0.03 .

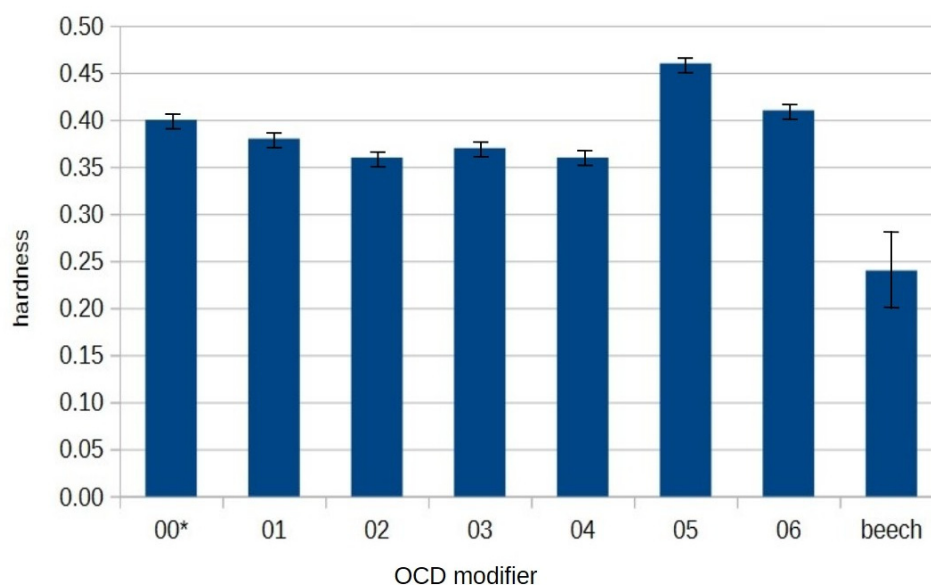


Figure 3. Glass-relative hardness of the coatings. Beech wood was used for comparison. 00 *—pure control coating. Error bars denote 0.01, with the exception of beech wood, 0.03.

3.3. The Effect of UV Aging on Color and Gloss of Coatings

Table 3 presents the total color change (ΔE) and the change in gloss (ΔGU) of the coatings after aging in a UV chamber. The observed ΔE values indicate moderate, distinct, or large color changes. Moderate color changes ($2 < \Delta E \leq 3.5$) were observed for the coating doped with cycloaliphatic OCD 02. Distinct color changes ($3.5 < \Delta E \leq 5$) were observed for the following coatings: reference 00 *, OCDs 01, 03 and 04. In contrast, large color changes ($\Delta E > 5$) were observed for aromatic OCDs 05 and 06. It should be noted, however, that

a large color change was also observed for uncoated beech wood ($\Delta E = 6.62$). Therefore, when the results are referenced to the color change in uncoated beech wood, they indicate that the beech/coating layer systems exhibit greater color stability than uncoated beech wood. This suggests that the coatings act as a protective barrier for the substrate against UV radiation, and that the observed changes should be attributed mainly to color changes in the beech substrate.

Table 3. Total color change (ΔE) and gloss change (ΔGU) before after UV aging.

Before UV Aging				After UV Aging			ΔE	Before UV Aging	After UV Aging	ΔGU
OCD	L	a	b	L	a	b		GU	GU	
00 *	64.77 ± 0.70	12.62 ± 0.22	25.21 ± 0.47	61.06 ± 0.96	14.05 ± 0.21	26.12 ± 0.37	4.08	73.9 ± 1.06	69.9 ± 2.04	4.0
01	70.61 ± 0.75	9.83 ± 0.15	25.10 ± 0.33	66.82 ± 1.04	11.29 ± 0.30	26.48 ± 0.42	4.29	99.5 ± 1.17	98.5 ± 1.80	1.0
02	67.03 ± 0.67	10.57 ± 0.11	25.71 ± 0.36	64.73 ± 0.77	11.41 ± 0.31	26.71 ± 0.19	2.64	84.9 ± 1.55	85.3 ± 1.33	0.4
03	69.79 ± 0.70	9.52 ± 0.10	23.70 ± 0.40	65.62 ± 0.74	10.86 ± 0.37	24.77 ± 0.85	4.5	81.5 ± 2.11	84.8 ± 2.60	3.3
04	70.31 ± 0.74	9.79 ± 0.13	24.11 ± 0.37	66.54 ± 0.97	11.63 ± 0.25	26.72 ± 0.64	4.94	81.6 ± 1.74	83.3 ± 1.92	1.7
05	69.08 ± 0.85	10.46 ± 0.18	24.35 ± 0.31	64.24 ± 0.83	12.87 ± 0.21	26.23 ± 0.44	5.72	84.4 ± 1.49	76.7 ± 2.07	7.7
06	71.77 ± 0.64	9.72 ± 0.23	24.59 ± 0.33	66.35 ± 0.80	12.16 ± 0.41	26.71 ± 0.55	6.31	73.2 ± 1.23	73.5 ± 1.88	0.3
beech	76.08 ± 1.11	6.73 ± 0.70	17.88 ± 0.67	72.05 ± 1.14	7.78 ± 0.62	23.02 ± 0.61	6.62	—	—	—

* pure control coating; GU—gloss units.

Gloss measurements of coatings after UV aging are shown below. Table 3 presents the gloss value change (ΔGU) of the tested coatings after UV exposure. Measurements were carried out at a 60° angle of light incidence. GU values in the range of 60–80 indicate gloss, while $GU \geq 80$ indicates high gloss. It is apparent that the highest loss in GU was found for pure control coating 00 * and the coating modified with OCD 05, but, in general, addition of the OCDs did not affect the glossy character of the coatings.

The presented results are in accordance with the literature data, where a color difference of $\Delta E = 7.7$ after UV exposure was found in uncoated beech, while the coated specimens exhibited significantly limited color change [46]. A comparable level of color change ($\Delta E > 8$) was observed by Li and co-workers for the uncoated wood; however, doping the coating with 1,4-butanediol:2-hydroxyethyl disulfide reduced total color change to $2.4 < \Delta E < 7.5$ [47]. Thus, it has been evidenced that our approach can be effective for color retention as long as cycloaliphatic or aliphatic modifiers are used.

3.4. Abrasion Resistance

According to the PN-ISO 7784-1 standard, the measure of a coating's abrasion resistance is the mass loss per measurement cycle. The abrasion resistance of the coatings is shown in Table 4. The mean values range from 0.006 g to 0.021 g. The highest mass loss after 200 revolutions (0.021 g) was observed for the reference 00 * coating. The results indicate that the efficiency of the OCDs is apparent since wear reduction ranged between 43% and 71% in comparison to the pure control 00 *. However, OCDs 05 and 06 bearing aromatic moieties in the molecule were less effective than aliphatic OCDs 03 and 04. That phenomenon is in accordance with Kwiatkowski and Nachman's results, who proved that the higher the content of the soft segments in a PUR, the higher the wear resistance that can be achieved [48,49]. Moreover, coatings doped with aromatic OCDs 05 and 06 exhibited the highest hardness (Figure 3). However, the relationship between hardness and wear resistance has not yet been fully explained and remains an open issue [50,51].

The literature data indicate that the addition of polycarbonate of 1,6-hexanediol and 1,5-pentanediol of molecular weight 500 Da can result in the reduction in mechanical properties after 15 days of water immersion at 70 °C by 40% vs. 70% for polyurethane without polycarbonate diol [8]. That can be explained by the polycarbonate diol carbonate group forming strong interactions between the soft segments in the polyurethanes.

Table 4. Weight loss after abrasion resistance testing.

OCD	Weight Loss [g]
00 *	0.021 ± 0.003
01	0.007 ± 0.001
02	0.012 ± 0.002
03	0.006 ± 0.002
04	0.007 ± 0.002
05	0.012 ± 0.002
06	0.011 ± 0.003

* pure control coating.

4. Conclusions

This study demonstrates that the chemical nature of oligocarbonate diols (OCDs)—aromatic, aliphatic, or cycloaliphatic—has a decisive influence on the mechanical and optical performance of polyurethane (PUR) coatings applied to wood substrates. Distinct structure–property effects were identified, confirming that the selection of OCD type is a critical parameter in tailoring coating performance.

Aliphatic soft segments were shown to provide the most favorable mechanical response—wear reduction ranged between 43% and 71% in comparison with aromatic- or cycloaliphatic-modified coatings—resulting in superior wear resistance among the investigated systems, while the highest hardness (0.46 and 0.41 that of glass) was found for the coatings bearing aromatic moieties. In parallel, the use of aliphatic and cycloaliphatic OCD modifiers proved effective in enhancing color retention, evidencing the suitability of this approach for applications where long-term optical stability is required.

Importantly, the adhesion at the wood/topcoat interface remained intact across all formulations. Pull-off tests confirmed that adhesion was sufficient and fully acceptable from a practical application standpoint, indicating that the incorporation of new OCDs does not compromise interfacial performance. Only cross-cut class I or II was observed.

Overall, the results clearly demonstrate that newly developed OCDs are effective modifiers of PUR coatings for wood. By appropriate selection of OCD structure, it is possible to balance mechanical durability, optical stability, and adhesion, thereby offering a versatile strategy for the design of high-performance wood coating systems.

Incorporation of OCDs in polyurethane coatings not only contributes to durability but also influences their sustainability and environmentally benign character. Involving greener monomers—like ethylene carbonate or dimethyl carbonate—highlights potential environmental benefits and aligns with green chemistry principles in production. The approach gives way to precise design of coating systems for specific end-use demands by oligocarbonate structure tailoring, resulting in its target technical properties. Additional benefits can be lower volatile organic compound (VOC) formulations and waterborne systems, contributing to improved environmental performance. As the coatings industry continues to prioritize sustainability and long-term performance, oligocarbonate diols are likely to play a pivotal role in next-generation polyurethane technologies.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/coatings16020155/s1>, Figure S1: Structures of the OCDs used in the studies.

Author Contributions: Conceptualization, P.G.P. and M.Ł.M.; methodology, M.M.-B. and P.G.P.; validation, P.G.P. and M.Ł.M.; investigation, M.M.-B., P.G.P. and M.Ł.M.; resources, M.Ł.M.; data curation, P.G.P.; writing—original draft preparation, M.M.-B., P.G.P. and M.Ł.M.; writing—review and editing, P.G.P. and M.Ł.M.; visualization, P.G.P. and M.Ł.M.; project administration, M.Ł.M.; funding acquisition, P.G.P. and M.Ł.M. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: Author Mariusz Ł. Mamiński was employed by Rejs Sp. z o.o. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

OCD Oligocarbonate diol
PUR Polyurethane

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