Surface Modification of PC and PMMA sheet for Enhanced Scratch Resistance

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(Received date: 03.10.2021 and Accepted date: 23.10.2021)

(DOI: 10.29228/JCHAR.52837)

REFERENCES: Iskender Ş., Işmar S., Evcin A., Surface Modification of PC and PMMA sheet for Enhanced Scratch Resistance, *Journal of Characterization*, (1)3 , 131-136, 2021.

Abstract

POLICAM PMMA (polymethylmethacrylate) and polycarbonates (PC) sheet used in many sectors such as furniture, decoration, building materials, lighting have optical properties. They are thermoplastic polymer sheets with a maximum usage temperature of 80 ° C. Thermoplastic polymer with amorphous structure is quite transparent and has the closest permeability to glass. Its density is half the density of glass and it is light. Fabrication applications are very easy. It is preferred instead of glass. Surface scratches are seen in areas of use in the environments where it is exposed. Surface improvement applications can be made with functional coatings. Sol-gel method is one of the most widely used methods because it is easy and useful in functional coating of ceramic, glass and plastic surfaces. In this study, the sol gel method was preferred for coating PMMA and PC plate surfaces. The prepared functional coating is applied to PC and PMMA sheet surface in certain thicknesses by means of an applicator. The improvements seen on the plate surface after the coating has cured have been controlled. Surface scanning with SEM, anti-scratching of the surface with pencil hardness test, and permanent properties on the surface were determined by artificial aging.

Keywords: Polycarbonate, Polymethylmethacrylate, Coating, Sol-gel, Silane.

Gelişmiş Çizilme Direnci için PC ve PMMA levhaların Yüzey Modifikasyonu

Öz

Mobilya, dekorasyon, yapı malzemeleri, aydınlatma gibi birçok sektörde kullanılan POLİCAM PMMA (polimetilmetakrilat) ve polikarbonat (PC) levhalar optik özelliklere sahiptir. Maksimum kullanım sıcaklığı 80°C olan termoplastik polimer levhadır. Amorf yapıya sahip termoplastik polimer oldukça şeffaf ve cama en yakın geçirgenliğe sahiptir. Yoğunluğu camın yoğunluğunun yarısıdır ve hafiftir. Fabrikasyon uygulamaları çok kolaydır. Cam yerine tercih edilir. Maruz kaldığı ortamlarda kullanım alanlarında yüzey çizikleri görülür. Fonksiyonel kaplamalar ile yüzey iyileştirme uygulamaları yapılabilmektedir. Sol-jel yöntemi seramik, cam ve plastik yüzeylerin fonksiyonel kaplanmasında kolay ve kullanışlı olması

nedeniyle en yaygın kullanılan yöntemlerden biridir. Bu çalışmada, PMMA ve PC plaka yüzeylerinin kaplanması için sol jel yöntemi tercih edilmiştir. Hazırlanan fonksiyonel kaplama, bir aplikatör vasıtasıyla PMMA sac yüzeyine belirli kalınlıklarda uygulanır. Kaplama kürlendikten sonra plaka yüzeyinde görülen iyileştirmeler kontrol edilmiştir. SEM ile yüzey taraması, kalem sertlik testi ile yüzeyin çizilmemesi ve yüzeyde kalıcı özellikler suni yaşlandırma ile belirlendi.

Anahtar Kelimeler: Polikarbonat, Polimetilmetakrilat, Kaplama, Sol-jel, Silan..

1. Introduction

Poly(methyl methacrylate) (PMMA) and Polycarbonates (PC) are high performance amorphous engineering thermoplastics with extremely superior impact strength, optical properties, heat resistance and dimensional stability [1-5]. It is used in many areas, especially in the automotive, aerospace and aviation sectors, due to its high impact resistance and moisture / UV rays resistance [6]. However, it also has different applications such as golf ball, tennis racket, CD packaging, automotive headlights, lenses, helmets, vinyl coatings [7]. Although PC and PMMA have superior optical properties, they are generally used in various cleaning materials as well as scratching and abrasion caused by dust in the atmospheric environment. They are also adversely affected by the chemicals and abrasives they contain and may lose their unique optical properties over time. By using the UV-curable sol-gel coating method, the surface of such materials can be minimally affected by external factors [8].

2. Material and Method

3 different solutions were prepared in this study. Solution-1 was prepared with 3-Glycidyloxypropyl) trimethoxysilane, GLYMO (C₉H₂₀O₅Si, 99.8%, Sigma Aldrich), purity water, Isopropyl alcohol, IPA (C₃H₆OH, purity 99.7%, Supelco) and Diisopropyl ether, IPE (C₆H₁₄O, 99.7%, Sigma Aldrich). Solution-2 was prepared with 3-(Trimethoxysilyl)propyl methacrylate, TMSPM (C₁₀H₂₀O₅Si, 98%, Sigma Aldrich), purity water, Isopropyl alcohol, IPA (C₃H₆OH, purity 99.7%, Supelco) and Diisopropyl ether, IPE (C₆H₁₄O, 99.7%, Sigma Aldrich). Solution-3 prepared with Titanium(IV) butoxide, Ti(Ob)₄ (C₁₆H₃₆O₄Ti, 97%, Sigma Aldrich) and Methyl methacrylate, MMA (C₅H₈O₂, 99%, Sigma Aldrich) Solution-3 was divided into two and added slowly to solutions 1 and 2. It was stirred for 24 hours and left to age for 15 days.

The characterization of PC and PMMA surfaces were obtained by using KSV Attension Theta Lite TL 101 Optical Tensiometer, Leo 1430 VP model scanning electron microscope (SEM) BYK-Gardner haze gard dual Light Transmittance / Haze Meter, and Konica Minolta Multi Gloss 268 Gloss Pencil hardness test was made to determine the hardness of coated samples. The cross-cut test was performed to determine the resistance of coatings to separation from PC and PMMA substrates by utilizing a tool to cut a right angle. Chemical resistance test was used to determine PC and PMMA surface's resistance to chemical attack, which can include, acid, alkali, hydrocarbons. Artificial Ageing test method covers the monitoring of the time-dependent performance of environmentally. Coatings were characterized by Perkin Elmer FT-IR Spectrometer Spectrum Two. Digital photos of PC and PMMA substrates were taken with Inskam-315 (7 Inch IPS High Definition Screen Industrial Digital Microscope). Taber Abrasion Test was made to determine the relative strength of materials against a mechanical abrasive effect such as friction, rubbing or erosion.

3. Results and Discussion

As a result of the characterization tests, the data in Table 1 were obtained. As can be seen from Table 1, a slight decrease was observed when compared to uncoated PC and PMMA sheets. No significant effect of coating thickness on light transmittance was observed. The Haze value is expected to be less than 1. This

was achieved in the coatings in our study. Gloss value showed a significant increase with coating. These values for PC and PMMA are 144-144 and 160-158, respectively.

Table 1. Test results

No	Tests & Analysis	Uncoated PMMA	PMMA surface		Uncoated PC	SOLID PC surface	
			Coating Thickness			Coating Thickness	
			25 mic	50 mic		25 mic	50 mic
1	Light transmittance (%)	92±2	91,6	91,6	89±2	87,9	87,9
2	HAZE (%)	<1	0,52	0,92	<1	0,86	0,84
3	Gloss (20-60-85°)	86	144	144	85	160	158
4	Pencil Hardness	2B	2B	B	3B	B	B
5	Cross-cut	-	OB	OB	-	OB	OB
6	Chemical Resistance						
7	ethanol	1	1	1	1	1	1
8	acetone	1	1	1	1	1	1
9	0,1M HCl	5	5	5	5	5	5
10	cologne	1	1	1	1	1	1
11	Cyclo hexane	5	5	5	5	5	5
12	Artificial Ageing test(200h)	0,9	1,03	0,82	6,6	5,6	5,66
13	Coating Thickness (dry film)	-	24 µm	49 µm	-	23 µm	50 µm
14	Contact Angle	60,87°	74,38°	73,27°	84,15°	67,65°	83,40°
15	Taber50 cycle	35 mg	5,7 mg	12 mg	32 mg	15 mg	20 mg

In the pencil hardness test, the uncoated surface with 2B and 3B (PC and PMMA) hardness was measured as 2D-B (PMMA) and B-B (PC) for 25 and 50 µm thicknesses, respectively. In the cross-cut experiment, OB values were obtained for 25 and 50 µm on PMMA and PC sheets. In the chemical resistance table, it was observed that it was resistant to other solvents (ethanol, acetone, cologne) except 0.1 M HCl and Cyclo hexane. The artificial aging test results were 0.9 and 6.6 for uncoated sheets, 1.03 and 0.82 for coated 25 and 50 µm PMMA sheets, and 5.6 and 5.66 for PC sheets, respectively.

Coating thicknesses from the section measured with a digital microscope are 24 and 49 (PMMA) and 23 and 50 µm (PC) for 25 and 50 µm film thickness.

When the contact angle of the coatings was measured, it was observed that the coating increased the contact angle for PMMA and decreased for PC. Hydrophilic surfaces were obtained for all coatings.

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Figure 1. Cross section of PC and PMMA sheets.

Figure 3. Contact angle of PC and PMMA sheets.

Figure 4. FTIR analysis of PC and PMMA sheets.

The strong band appearing at 1680 cm^{-1} in the spectrum (see Figure 4) of the PC and PMMA samples can be attributed to the carbonyl ($\text{C}=\text{O}$) group [9]. It shows C–O stretch absorption at 1195 cm^{-1} . The peak at 3226 and 1300 cm^{-1} corresponds to hydroxyl groups (OH) [10].

For PMMA, the band around 2744 cm^{-1} (symmetric) is assigned to C–H stretching vibrations. The bending vibration band of the methyl ($-\text{CH}_3$) group appeared at 1474 cm^{-1} in the FTIR spectra, the sharp and intense band at 753 cm^{-1} are attributed to the stretching and out-of-plane-bending vibrations of the carbonyl ($\text{C}=\text{O}$) group [11].

4. Conclusions

In the study, the surfaces of PC and PMMA sheets were coated with a film applicator to form different film thicknesses. In order to improve the properties of the surface, silane-based coating solutions have been successfully applied to the surface.

The light transmittance, haze and brightness values were within acceptable limits. It was observed that the coating thicknesses (25 and 50 micrometers) did not have much effect on the gloss. Likewise, it was noted that the resistance to chemicals was not related to the coating thickness. In the Taber abrasion test, it was observed that the coating had a significant effect on the scratch-proof property of the surface, and the increase in the coating thickness negatively affected the improvement in the scratch-resistance property.

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