Adhesion of TPEs on Polycarbonates for Medical Wearables

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Abstract

Thermoplastic elastomers and polycarbonates offer an interesting combination of rigid and soft materials for housings and interfaces in wearable applications. This study examines adhesion and chemical resistance for medical-grade resins that are candidates for wearable applications. Peel strength measurements on overmolded test pieces of Makrolon®, Bayblend® and Makroblend® alloys showed strong adhesion to various grades of Medalist® TPE. All specimens showed cohesive failures during peel tests. Slightly higher peel strengths were obtained for direct 2-shot overmolding than with insert molding. Chemical resistance tests for these materials against suntan lotion and isopropyl alcohol suggest that Medalist MD-36975 and Makrolon 2458 are excellent choices of candidate materials for wearable devices.

Introduction

Polycarbonates (PC) are well known in healthcare applications owing to their outstanding combination of physical properties and processability. Medical-grade resins that meet criteria for skin-contact biocompatibility are often the first choice in materials by designers of wearable devices, where the assurance of suitability for patient contact has already been confirmed. Thermoplastic elastomers, or TPEs, are also available as medical grades and are ideal for components such as gaskets, seals, grips and handles or soft components to provide comfort for a wearable device. Together, PC and TPEs are often combined by overmolding, either 2-shot or insert molding, where the two materials can be quickly joined in a molding machine to avoid adhesives or secondary assembly steps.

Strong adhesion between PC and TPE materials is critical to achieve durable devices which can withstand repeated use. In this study, we evaluated the adhesion of newly introduced TPE grades designed specifically for overmolding (including PC), on various medical-grade polycarbonate substrates. The adhesion was examined in the context of 2-shot molding by measuring the force required to pull apart the PC and TPE layers. Excellent chemical resistance is also a must-have for wearable devices, where repeated cleaning or contact with skin creams or lotions has been known to cause chemical attack on plastics. This study also examines the chemical resistance of the TPE and PC substrates to isopropyl alcohol and suntan lotion.

Experimental

Various polycarbonate-based resins were used as substrates in this study, including medical-grade polycarbonate and medical-grade polycarbonate alloys (PC+ABS, FR-PC+ABS, PC+Polyester). Basic characteristics of these engineering resins are given in Table 1. All resins are part of the portfolio of resins for Healthcare by Covestro.[1]

TABLE 1 - Physical properties of polycarbonate-based resins used in this study.

Property	Unit (Conditions)	Makrolon® 2458	Bayblend® M850XF	Bayblend® M301FR	Makroblend® M525
Tensile Modulus (ISO 527)	MPa (RT)	2400	2500	2600	2000
Notched Izod Impact Strength (ISO 180-A)	kJ/m^2 (RT)	75*	48	40	60
Vicat Softening Temperature (ISO 306)	°C (B/120)	146	131	105	122
Barrel Temperatures	°C	287	260	250	250
Mold Temperature	°C	85	77	77	65

* Tested at 3.2mm.
Supplier-recommended drying and injection-molding conditions were followed for molding the substrates.[1]

Thermoplastic Elastomers (TPE)

Several Medalist medical-grade TPEs were evaluated. The Medalist MD-34900 series of compounds, available in 50, 60, and 70 Shore A, are formulated for general medical overmolding applications, while the MD-36975 grade is a 75 Shore A TPE designed specifically for overmolding in wearable devices, with improved chemical resistance. Table 2 summarizes the key properties of these materials.

TABLE 2 - Physical properties of Medalist® thermoplastic elastomers (TPEs) studied in this report.

Property	Unit (Conditions)	MD-34950	MD-34959	MD-34969	MD-36975
Hardness ASTM D2240	Shore A (5 sec delay)	50	59	69	75
Melt Flow Rate ASTM D1238	g/10min (200°C/5 kg)	1.5	1.0	2.0	8.0
Tensile Strength ASTM D412	MPa	7.6	6.9	6.2	4.1
Tensile Elongation ASTM D412	%	793	750	560	200
100% Modulus ASTM D412	MPa	1.5	2.3	4.5	3.8
Tear Strength ASTM D624	N/m	19	22	37	20
Processing Conditions					
Melt Temperature for Overmolding	°C	230	230	230	230
Mold Temperature	°C	38	38	38	38

Overmolding

Overmolding was done with a Battenfeld HM300/1330H/525V two-shot injection molding machine equipped with a rotating mold that permitted a continuous process to mold the substrate and then overmold the soft component. Figure 1 illustrates a Medalist TPE material overmolded on a clear Makrolon PC substrate.

FIGURE 1 - Overmolded specimens for peel force measurements

The adhesion to TPE was tested with two approaches to overmolding: either direct 2-shot, or by insert molding, where the substrates were pre-molded. Direct 2-shot employed a continuous process with a rotating mold in the molding machine and alternated between injection of the substrate and the TPE overmold. The approach with pre-molded substrates entailed pre-molded substrates that were conditioned for at least 24 hours at ambient conditions before being manually inserted in the mold cavity for overmolding.

Adhesion Testing

Peel strength was measured at 50 mm/min pulling rate according to ASTM D429. Average peel force and peak peel force were recorded from four replicates. Values were converted from imperial to metric units (N/mm).

Chemical Resistance Testing

Assessment of chemical resistance of polycarbonate resins was done by a method which included exposing a material to a chemical while under an applied stress and subsequently testing for resulting changes. Injection-molded tensile bars were exposed to either 70% isopropyl alcohol (in water) or suntan lotion (Banana Boat Sport Performance SPF 30) while subjected to 1% flexural strain for 24 hours. The test bars were in constant exposure to the test liquid. After exposure, the materials were visually inspected for cracks and the tensile properties were measured. More details on assessment of chemical resistance are reported elsewhere.[2]

The chemical resistance of the TPE materials was evaluated by retention of tensile properties after a repeated wipe protocol with 70% isopropyl alcohol and suntan lotion. The wipe procedure entailed a cycle where 20 back-and-forth wipes of the chemical on the material within a 30 minute period were done. Each cycle was repeated for a total of 10 cycles. The tensile properties were then tested 24 hours after the first wipe cycle.

Results and Discussion

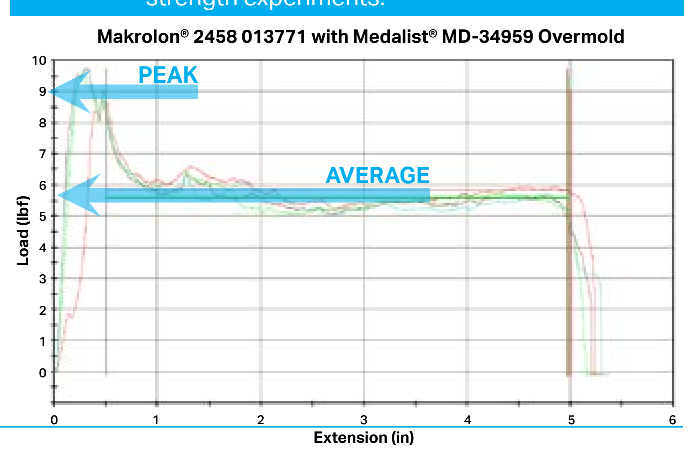
Adhesion Testing

For all resin combinations tested in this study, the separation of the polycarbonate was by cohesive failure, where a substantial amount of the TPE was still adhered to the substrate after the peel experiment (see Figure 2, below). Cohesive failure occurs when the TPE material breaks before it peels from the substrate (indicating that peel strength > material strength). It is usually the more desired mode of failure versus adhesive failure, where the TPE may be completely peeled off from the substrate. However, adhesive failure paired with a high peel strength is also favorable in most overmolding applications.

FIGURE 2 - Example of cohesive failure observed between the polycarbonates studied in this report and Medalist TPE.

The average and peak peel strengths were determined from two distinct regions of the data curves collected during the test. Figure 3 illustrates a typical force vs. distance profile, which was collected for Makrolon 2458 013771 as a substrate and Medalist MD-36975 as an overmold.

FIGURE 3 - Force vs. distance measured during peel strength experiments.



Various polycarbonate substrates were studied with Medalist MD-36975. Figures 4a-b summarize the individual average peel strength results along with the peak peel strength recorded from each (overlaid in gray).

The average and peak peel forces showed good consistency across all polycarbonate resin types. Side-by-side comparison of direct 2-shot and pre-molded substrates showed that direct 2-shot gave slightly better adhesion values. The strongest adhesion was observed on Makrolon 2458, a high-productivity medical-grade polycarbonate. The consistent peel strength and consistency in cohesive failures suggest the adhesion between the TPE and polycarbonates is excellent and as strong as the TPE.

FIGURE 4a - Average peel strength for direct 2-shot over-molded Medalist MD-36975 on various polycarbonate substrates. Peak peel strength is indicated in the background in light gray.

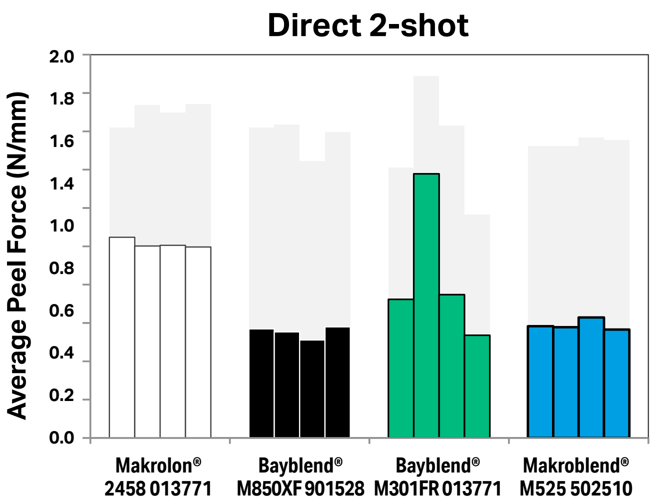
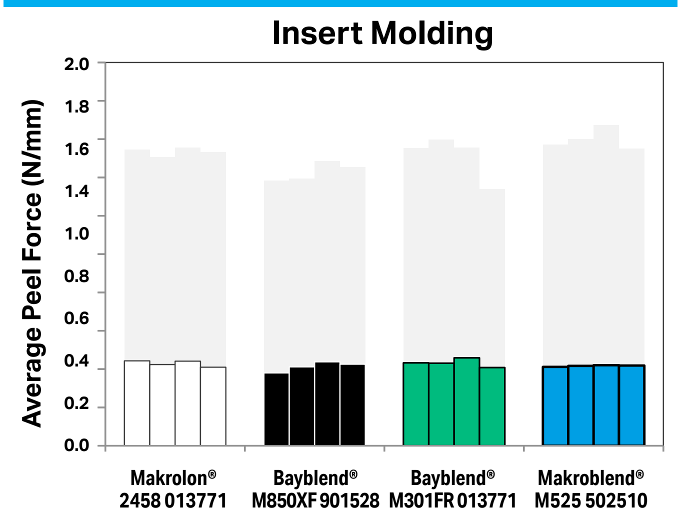


FIGURE 4b - Average peel strength for samples made by insert molding substrates with Medalist MD-36975. Peak peel strength is indicated in the background in light gray.



Additional adhesion testing was done with Makrolon 2458 with Medalist MD-34950, MD-34959 and MD-34969. The results of average and peak peel strength are summarized in Figure 5a-b.

FIGURE 5a - Average peel strength for direct 2-shot Medalist MD-34950, MD-34959 and MD-34969 overmolded on Makrolon 2458.

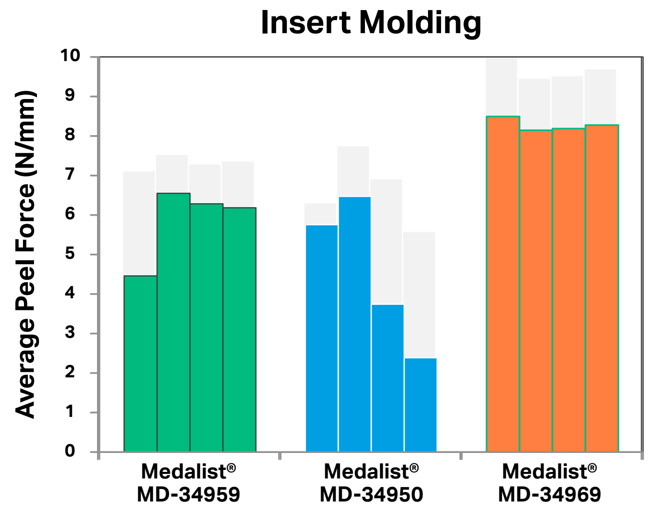
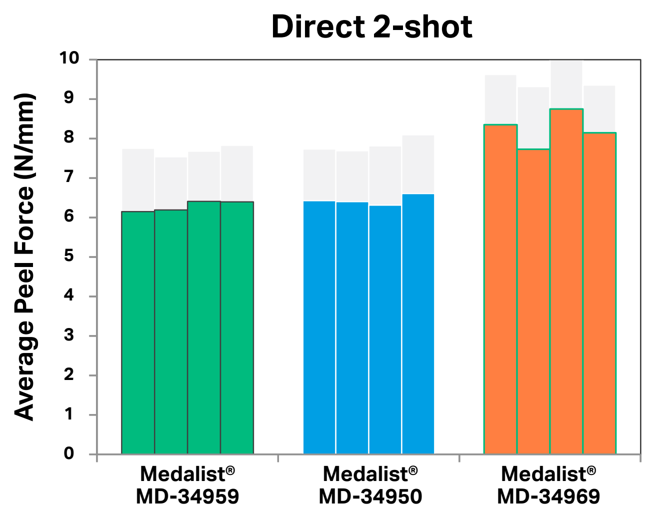


FIGURE 5b - Average peel strength for samples made by Insert Molding Makrolon 2458 with Medalist MD-34950, MD-34959 and MD-34969.



Chemical Resistance Testing

Table 3 summarizes the resistance of the substrate materials studied in this project to suntan lotion and 70% isopropyl alcohol. Suntan lotion is known to present a particular challenge to polymers due to either oils which hydrate skin or UV absorbers for protection that are believed to contribute to chemical attack of plastics. Among the substrates tested, Bayblend M301FR, a flame-retardant PC+ABS alloy was most susceptible and PC and PC+Polyester showed better resistance. In the case of 70% isopropyl alcohol, Makrolon 2458 showed the best resistance. Makroblend M525, a PC+Polyester, has superior chemical resistance against a wide range of chemicals due to its polymer matrix containing a semi-crystalline polyester.

For both TPE and polycarbonate materials, a change in tensile elongation at break and tensile strength of 5% or less after chemical exposure (and strain, in the case of polycarbonates) meant excellent retention of properties such that a material is considered "Resistant." For polycarbonates, a loss of either tensile strength or elongation at break of greater than 50%, or breaking on the strain fixtures, is considered indicative of a material being "Not Resistant" to a chemical after exposure. Thus, results that lied between "Resistant" and "Not Resistant" were categorized as "Limited Resistance."

TABLE 3 - Assessment of chemical resistance of materials studied in this project.

Material	Suntan Lotion	70% isopropyl alcohol
PC, PC+ABS, PC+Polyester Substrate		
Bayblend® M301FR	Not Resistant	Limited Resistance
Bayblend® M850XF	Not Resistant	Limited Resistance
Makroblend® M525	Limited Resistance	Limited Resistance
Makrolon® 2458	Limited Resistance	Resistant
TPE		
MD-34969	Limited Resistance	Limited Resistance
MD-36975	Resistant	Resistant

Alcohols, however, present a special challenge to polyesters in terms of chemical resistance, which likely explains the similarity in isopropyl alcohol resistance between Makrolon 2458 and Makroblend M525.

Medalist MD-36975 was formulated for better chemical resistance than Medalist MD-34969. This grade employs unique raw materials that are more resistant to oils and alcohols than standard TPEs, while still providing good adhesion to the PC substrates.

Conclusions

Peel strength measurements on overmolded test pieces of Makrolon, Bayblend and Makroblend alloys showed strong adhesion to various grades of Medalist TPE. All failures during peel tests showed cohesive failures. Slightly higher peel strengths were obtained for direct 2-shot overmolding than with insert molding. Chemical resistance tests for these materials against suntan lotion and isopropyl alcohol suggest that Medalist MD-36975 and Makrolon 2458 are excellent choices of candidate materials for wearable devices.

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References

1 Product datasheets are available for download at www.solutions.covestro.com

2 Chemical Resistance Testing of Polycarbonates and Blends with Hospital Disinfectants and Cleaners, P. J. Nowatzki, Proceedings SPE ANTEC 2020.

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