# NOVEL THERMOPLASTIC ELASTOMERS FOR UNIVERSAL OVERMOLDING ON DISSIMILAR THERMOPLASTICS

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## Abstract

Overmolding thermoplastic elastomers (TPEs) onto rigid thermoplastics has been an explosive trend in the last decade. Thermoplastics are used in various applications, including PP, PS, ABS, copolyester, SAN, PC etc.. Recently, many TPEs have been uniquely developed to bond to specific substrate materials based on surface energy or polarity match between the elastomer and the thermoplastics. However, these TPEs are usually not capable of bonding to different thermoplastics with dissimilar surface energy, i.e., PP and copolyester. A new class of TPEs has been developed with the ability to bond to dissimilar thermoplastics, including PP, copolyester, ABS etc. This paper covers the varied aspects of this technology.

## Introduction

A hard/ soft combination of TPEs and rigid thermoplastics provides differentiations of a product in various applications (1). This hard/soft combination design has been driven by an escalating market trend pushing toward enhanced ergonomic feel and touch, gripping feel, aesthetics, cushioning against impact, vibration isolation or dampening and insulation. Overmolding technology facilitates such a combination. Although overmolding requires a new tool and sophisticated equipments, the demand in TPE materials overmoldable onto various substrates has significantly increased since the 1990s. This is because overmolding eliminates the traditional bonding process which requires adhesives and primers for bonding and instead allows the surface of an article of complicated design to be conveniently covered. As such, overmolding presents an opportunity to design articles that have not been possible with the traditional bonding process.

Over the years, many rigid thermoplastics have been utilized with this hard/soft design in order for specific performance and additional value. Rigid thermoplastics include both commodity thermoplastics and engineering thermoplastics, such as polypropylene (PP), polystyrene (PS), high impact polystyrene (HIPS), polycarbonate (PC), acrynitrile-butadiene-styrene (ABS), poly(ethylene terephthalate) (PET), poly(methylmethacrylate) (PMMA), styrene acrylonitrile (SAN), poly(phenylene oxide) (PPO), polyamide (PA), PC/ABS blend and PPO/PS blend etc..

Demands for TPEs that would bond to countless rigid thermoplastics substrates have propelled the development of numerous novel TPEs in recent years. Most of the new TPEs are designed based on the concept of matching the surface energy between the TPEs and the substrates. Figure 1 shows the surface energy match of various thermoplastic elastomers with rigid thermoplastics. These TPEs usually have good adhesion on substrates with similar surface energy. However, their adhesion on other substrates is poor. For example, a TPE that can bond to PC does not bond to PP, vice versa. Thus, one of the limitations for most of the existing TPE overmolding technology is that one needs to develop and use different TPE materials for different substrates.

Venkataswarmy et al. (1) introduced a general guideline of overmolding and a choice of material with respect to the substrates employed for the applications. Novel TPE materials that can overmold onto various engineering plastics also were reported elsewhere (2-4). This paper concentrates on a new class of TPEs that can bond to a number of substrates with dissimilar surface energy or polarity, such as PP, ABS, PC and COPE, etc., called "universal overmolding TPE." This new technology opens up unprecedented opportunities for new designs where the TPEs need to bond to dissimilar substrates. Also, this new technology can reduce cost by reducing the number of TPEs needed for different applications.

## Experimental

### Material

Two classes of "universal overmolding TPEs" have been developed and used in this study. TPE-1 and TPE-2 have a hardness of 45 and 50-55 Shore A, respectively.

### Injection Molding of Plaques

A Milacron injection molding machine was used to prepare plaques for the measurements of physical properties and adhesion. Plaques for the measurement of adhesion were prepared by injection molding TPE materials onto cold inserted rigid thermoplastic substrates. The barrel temperature of the injection molding machine was set from 180°C to 220°C (360°F to 430°F) and the injection velocity from 0.7 inch/sec to 2.0 inch/sec.

### Physical Property

Both TPEs were characterized for Shore A hardness (ASTM D2240), specific gravity (ASTM D792), tensile strength (ASTM D412), elongation at break (ASTM D412) and tear strength (ASTM D624).

### Adhesion

The adhesion between the TPE and rigid thermoplastics substrates was measured by a "90 degree peel test" which is a modified ASTM D903 method. Figure 2 shows a schematic diagram of the test. This test is done on overmolded plaques with TPE on top of rigid thermoplastic substrates. A 25 mm wide strip of TPE is cut and pulled at a $90^o$ angle toward the substrate using an Instron tensile tester. The substrate is locked in its place on wheels in order to maintain the $90^o$ angle as the elastomer is pulled. The adhesion strength, i.e., peel strength, is measured by the force required to pull the elastomer from the substrate and is reported as an average or a maximum strength over 50 mm of pulling. The adhesion is also categorized based on a visual observation of the failure mode, i.e., an adhesive failure if no TPE residue is left on the substrate or a cohesive failure if the failure is in TPE.

### Rheology

The viscosities of both TPE-1 and TPE-2 at different shear rates were measured using a capillary rheometer at $200^oC$ by a method prescribed in ASTM D3835.

## Results and Discussion

### TPE-1

TPE-1 is a translucent material of 45 Shore A. Table I gives the physical properties of TPE-1, including tensile strength, tear strength and elongation at break. Table II lists the substrates employed for the overmolding of TPE-1 and the corresponding adhesion strength on the different substrates. As given in Table II, TPE-1 demonstrates good adhesion on all ten substrates with very different surface energy and polarity; from the low like PP to the high like PC and ABS. The failure mode is cohesive on PP and adhesive on all other substrates.

### TPE-2

TPE-2 materials are opaque and their base chemistries are different from TPE-1. The substrates materials employed for overmolding were PP, ABS, PC/ABS, polyester, Nylon and POM. Each formulation was designed to selectively bond to a substrate based on the functionality of the substrate material. The properties of TPE-2 are given in Table III. The bonding characteristics of TPE-2 materials to all the substrates were adhesive in nature. As the formulation was altered, bondability of TPE-2 to a substrate varied. TPE-2B exhibits a relatively strong bond to all the substrates employed in this study irrespective of surface energy and/or polarity of a TPE and a substrate. Compared to other substrates, Nylon and polyacetal, i.e., POM, appear to be difficult to bond. Figure 3 shows the capillary viscosity of TPE-1 and TPE-2 at 200$^{o}$C. They have good flow characteristics suitable for injection molding applications.

## Conclusion

Two classes of TPE formulations have been developed and studied for rigid thermoplastics overmolding applications. Their physical properties and adhesion properties were measured and compared. These TPEs have exhibited good adhesion on various substrates including PP, PS, HIPS, PMMA, PC, PET, ABS, PC/ABS and Copolyester. These TPEs also possess good flow properties suitable for injection molding applications. These results confirm that TPE-1 and TPE-2B are truly the "universal overmolding TPEs."

## Acknowledgment

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## Bibliography

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**Figure 1**
**Surface energy of various thermoplastic elastomers with rigid thermoplastics**

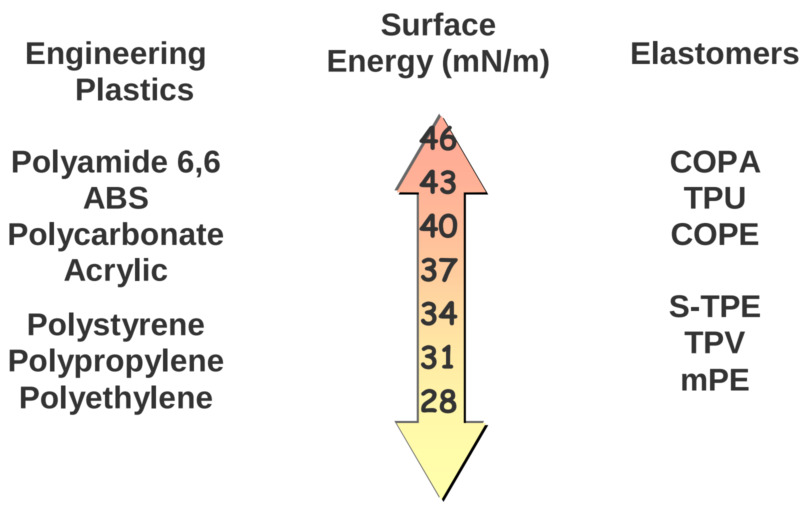


**Figure 2**
**Schematic diagram of the peel test**

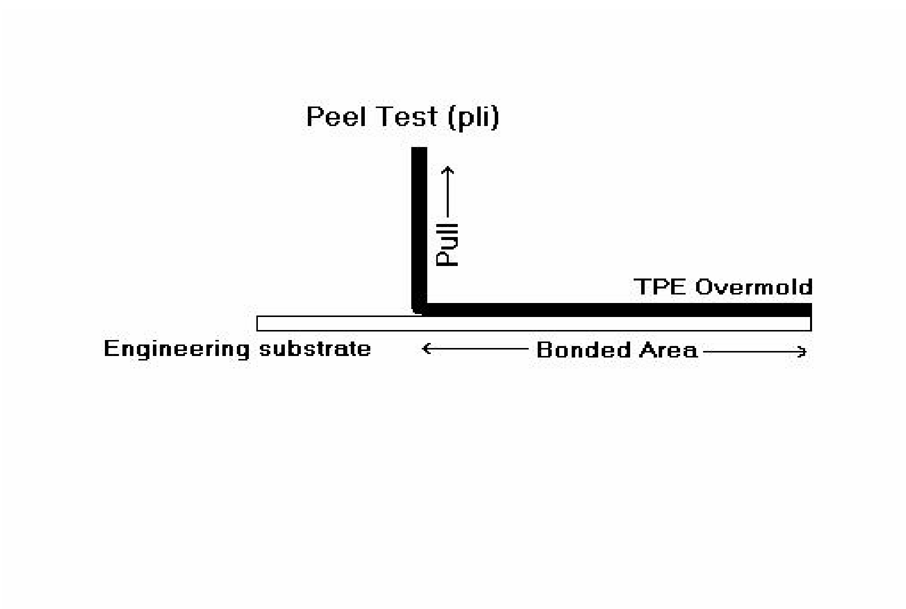

**Table I**
**Physical property of TPE-1**

| | |
|---|---|
| Shore A Hardness (10 second delay) | 44 |
| Specific Gravity (g/cm$^3$) | 0.90 |
| Color | Natural |
| 300 % Modulus (PSI) | 348 |
| Tensile Strength (PSI) | 603 |
| Elongation at Break (%) | 598 |
| Tear Strength (lbf/in) | 110 |

**Table II**
**Adhesion value of TPE-1 on different substrates**

| Substrate | Average Peel Strength (lbf) | Failure Type |
|---|---|---|
| PP | 17 | Cohesive |
| Copolyester | 13 | Adhesive |
| PET | 13 | Adhesive |
| PPE/HIPS | 18 | Adhesive |
| PMMA | 15 | Adhesive |
| PS | 18 | Adhesive |
| PC | 17 | Adhesive |
| PC/ABS | 14 | Adhesive |
| HIPS | 13 | Adhesive |
| ABS | 13 | Adhesive |

**Table III**
**Properties and peel strength of TPE-2 materials**

| | A | B |
|---|---|---|
| Hardness: | 51 | 56 |
| Tensile Strength (psi): | 1010 | 1081 |
| Tensile Elongation (%): | 721 | 713 |
| Peel Strength (PIL) | | |
| PP | 28 | 20.8 |
| ABS | - | 24.5 |
| PC/ABS | 19 | 22.6 |
| Polyester | 7 | 22 |
| Nylon | 7 | 15.3 |
| POM | 6.5 | 11.1 |

**Figure 3**
**Capillary viscosity of TPE-1 and -2 at 200°C**