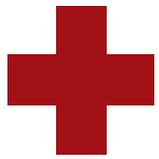


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HELPING OUT HEALTH CARE FILM RECYCLING

Recovering plastics in a hospital setting is one thing, recycling the recovered materials is another. Our authors offer a detailed, scientific assessment on the best blends – and the best applications – for recovered plastic film from health care facilities.

BY ANTHONY MOTT, ANNE MUSGRAVE AND THERESA HERMEL-DAVIDOCK

Health care facilities in the U.S. generate approximately 6,600 tons of waste per day. It is estimated that between 20 and 25 percent of that 6,600 tons can be attributed to plastic packaging and plastic products. In addition, 85 percent of the waste generated is non-infectious. These statistics, coupled with growing sustainability aspirations, increasing incineration costs and decreasing landfill space, inevitably point to the prospect of increasing diversion at the doctor's office.

However, one of the largest challenges of recycling health care plastics is finding viable reuse applications for the recycled material. To better understand the potential recycling value of polymeric packaging materials from the hospital waste stream, the Healthcare Plastics Recycling Council (HPRC), in collaboration with Plastics Engineering students at Penn State recently concluded a study that tested and analyzed the physical properties associated with various blends of recycled plastics and virgin resin. This article is a summary of the application, results, interpretation and conclusions of the study.

Application and process

The materials collected for this study included multilayer and woven films comprised of low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), nylon and other plastics most commonly used in medical packaging applications. These materials were representative of the recyclable plastics that are typically found within hospital areas which generate the highest volumes of packaging waste – the operating room, general floor and loading dock. However, each of these areas generates a slightly different packaging waste profile. For example, Tyvek (HDPE) and blue sterilization wrap (PP) are primarily found in the operating room; multi-layer ethylene and nylon-based plastic films are most common in the general floor; and stretch wraps (LDPE) and shrink wraps (PE and PP) are prevalent in the loading dock.

The breakdown of materials used for this study is detailed in Table 1. The percentage of each material represents the total amount of packaging films from each specific area of the hospital, as determined largely by studies championed by HPRC.

For this experiment, the operating room, general floor and loading dock were assumed to all have equal contributions of material.

Table 1 | Summary of material breakdown

Operating room	Percent used	General floor	Percent used	Loading dock	Percent used
Blue wrap (PP)	75.00 percent	Bags	75 percent	Stretch wraps	75.00 percent
Multi-layer films	18.75 percent	Multi-layer films	18.75 percent	Shrink wraps	25.00 percent
Tyvek (HDPE)	6.25 percent	Tyvek (HDPE)	6.25 percent	---	---

The Tyvek and multilayer films had to be reduced in size with a micro-cut shredder before mixing with the other materials. This produced small pieces of the plastic that could be used to produce tensile bars in each specific blend. The other recycled material components were received in pellet form from a polymer recycler.

Once collected, these materials were blended with virgin polypropylene pellets at different ratios and evaluated through tensile, flex, impact and differential scanning calorimetry (DSC) tests to find the optimum ratio for final applications. The blend ratios created were as follows: (virgin PP: recycled material) 100:0, 90:10, 80:20, 70:30, 60:40, 50:50, 30:70 and 0:100.

Impact testing results

It is seen in Figure 1 on page 42 that the impact strength of the blends has a slight increasing trend from the 100:0 through the 60:40 blend. However, based on the error bars, the differences between the impact strengths of this blend are relatively insignificant.

The properties of the blends with smaller portions of recycled materials are largely influenced by the virgin PP. The slight incline in properties is caused by the greater amount of polyethylene from the recycled component increasing the toughness of the material. The first significant change in the impact strength occurs with the 50:50 blend which decreased to 1.2 ft.lb./inch, from the 100:0 value of 4.5 ft.lb./inch. The 50:50 blend shows a severe decline in impact properties, which can be attributed to immiscibility (the inability to be mixed) of the polymers in the blend. The 50:50 and 30:70 blends have a mixed matrix of PE and PP materials and the energy imposed during testing is not efficiency transferable between the different polymer phases. The 30:70 and 0:100 blend show large error bars, which can be attributed to a large variation in the material's solid-state macromolecular morphology. A large increase in impact strength is seen for the 0:100 blend because the properties of the samples are dominated

by the large polyethylene component in the recycled material.

Tensile test results

Figure 2 displays the extension at break versus the blend compositions. An increasing trend can be seen between the 100:0 and 60:40 blends. An increase in the amount of polyethylene from the recycled component in the blends enhances the deformation capabilities of the samples. The 50:50 and 30:70 blends show a decrease in properties, though not statistically significant. This could be attributed to the immiscibility of the polymers in the blend inhibiting that ability for stresses to be transferred between the different polymers phases present. Statistically, 0:100 is also not different from the 50:50 and 30:70 blends due to the large variance in data, which can be attributed to the variability of the phase morphologies present in the test specimens.

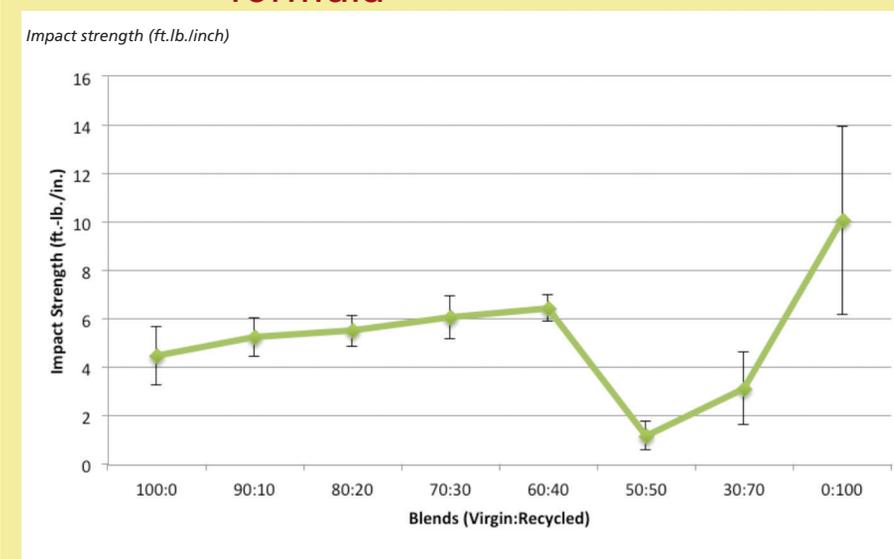
Flex testing results

The flex properties are displayed in Figure

3. Even though the maximum occurred at the 90:10 blend, the graph shows a general decrease in modulus as the percentage of recycled content is increased. The Young's modulus (a measure of the stiffness of an elastic material) was also measured as part of the tensile testing and showed a similar trend as that of the flex modulus data. The decreasing trend in the measured moduli is due largely to the increasing amount of PE, especially very elastomeric ethylene-copolymers, in the recycled content being inherently less stiff than a homo or random PP.

DSC results

In Table 2 on page 44, guidance as to the composition of the recycling components' majority compositions can be roughly determined based on the melt properties. The virgin PP had a melt temperature of 148 degrees Celsius, which is consistent with a PP copolymer. The PP blue wrap had a melt temperature of 165 degrees Celsius, consistent with a PP homopolymer. The PE stretch wrap had a melt temperature of 124 degrees Celsius, so it is likely a blend

Figure 1 | Impact strength versus blend formula

of LDPE with either a LLDPE or MDPE. The multilayer film had four different melting peaks, indicative of a composition comprised of at least four different materials. The melt temperature of 106 degrees Celsius indicates the film has a LDPE portion. The film also included a double peak with melt temperatures at 114 and 121 degrees Celsius, and these peaks are indicative of LLDPE and an additional ethylene-based copolymer, such as EVA. The last melting point in the multilayer film was at 194 degrees Celsius, which denotes a nylon portion of the film, which is used to improve mechanical properties such as stiffness. The PE bag component had a broad peak at 126 degrees Celsius, suggesting it is a miscible mixture of LDPE and LLDPE. The shrink-wrap component included three melting points. The first melting of the material was a double peak at 110 and 123 degrees Celsius. These melt temperatures indicate the shrink-wrap included LDPE and an additional ethylene-based copolymer, such as EVA. The third melt temperature of the shrink wrap was at 162 degrees Celsius, which indicates the shrink wrap also has a PP portion. The final component of the blend was Tyvek, which had a wide melt temperature at 137 degrees Celsius. This melt temperature indicates the Tyvek is composed of HDPE. The Tyvek samples used in this study were coated with a thin layer of an ethylene-based co-polymer sealant. The sealant portion of this film did not have a distinct melting peak within the overall melt phase of the sample.

Table 3 displays the melt properties of the recycled blends. The 90:10 blend produced a single broad melt energy, with two highly overlaying peaks identifiable. This suggests some degree of co-crystallization of the PE into the PP dominate matrix occurred. While some PE crystallization occurred, the overall crystallization of the small amount of PE present from the recycled content portion of the blend was suppressed. All of the blends consistently had two identifiable melting peaks, and as the blend ratio increased the distinction between the two melting peaks increased. The first melt temperature was at about 123 degrees Celsius, which can be attributed to the PE from the recycled component. The second melting peak occurred generally at 150 degrees Celsius, which is consistent with a mixing of the PP portions of the blends including the virgin PP copolymer, PP blue wrap and the PP component of the shrink wrap. While those portions of

Figure 2 | Extension at break versus blend formula

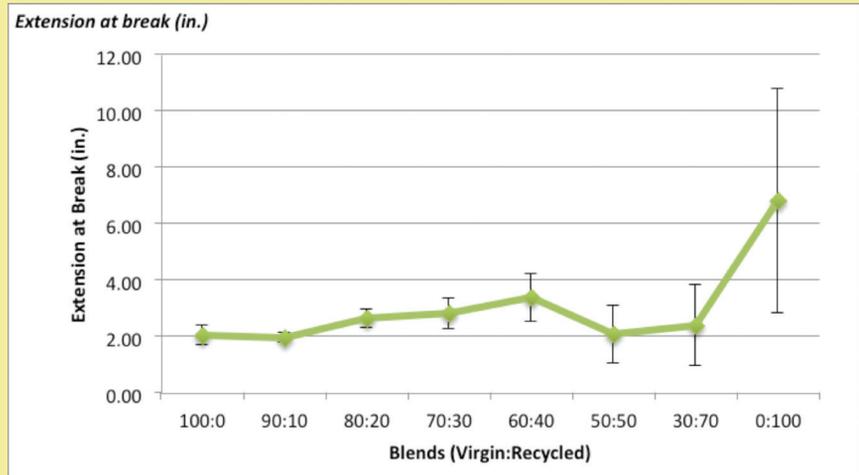
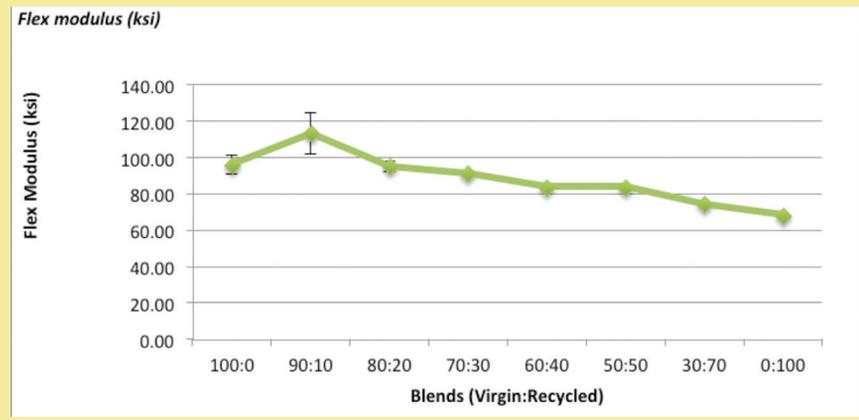


Figure 3 | Flex modulus versus blend formula



the blends were miscible, the entire blend system was overall immiscible. As the recycled content is increased, the PE dominate component of the recycled portion and the PP components, both from the virgin PP and PP components in the recycled portion, can form two morphologies which can more readily and more independently crystallize.

Conclusion

From this research the point where the amount of recycled content significantly changes or reduces the original properties of the virgin PP was determined to be at a 50:50 blend ratio. The 60:40 blend was found to be the optimal blend to retain the bulk of the original polypropylene properties while maximizing the amount of recycled content utilized.

The transition to the 50:50 blend is where there is no longer a dominate composition of the PP. While PE and PP, especially those containing some level of ethylene copolymer, are compatible they are not full miscible and the disruption of a continuous semi-crystalline PP matrix results in the observed degradation of the physical properties. At increasing levels of recycled content the PE from the comingled film packaging becomes the dominate composition of the blend and likewise the physical properties demonstrate a trend toward more PE-like properties.

This PP material, which incorporates recycled packaging films, could be used in future commodity and household applications. The blends with 40 percent recycled content retained a significant amount of the bulk PP mechanical properties to be used in

lower tolerance, non-critical applications, where one would still want to mimic PP properties. The 100 percent recycled blends material could be used in low tolerance, non-critical applications where lower modulus and more ductile PE-like properties are required.

For more information on this study, contact the Healthcare Plastics Recycling Council at www.hprc.org.

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Table 2 | DSC melt properties of blend components

Components of blends		
	Tm(°C)	Melt energy (j/g)
Virgin PP	148	64.9
PP blue wrap	165	82.1
PE stretch wrap	124	83.4
Multilayer file	106	18.3
	114	11.6
	121	11.6
	194	13.7
PE bag and wrap	126	103.6
PE and PP shrink wrap	110	62.4
	123	62.4
	162	11.4
Tyvek	137	129.4

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Table 3 | DSC melt properties of blends

Blends		
	Tm(°C)	Melt energy (j/g)
90:10 Blend	125	
	149	64.8
80:20 Blend	123	4.5
	151	35.5
70:30 Blend	123	5.5
	152	37.1
60:40 Blend	123	2.6
	149	22.6
50:50 Blend	123	22.4
	155	32.0
30:70 Blend	123	35.1
	159	27.4
0:100 Blend	124	56.5
	163	20.2