

Blends from Reprocessed Coextruded Products

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Synopsis

Numerous film and sheet products are formed by coextrusion of polymer pairs such as ABS/HIPS or nylon/ionomers. Any practical attempt to reprocess scrap from such operations will be blends of the component polymers, and the value of these reprocessed materials will be a function of the properties of the resulting blends. Blends of the above-mentioned pairs were formed by extruder compounding followed by injection molding and were tested for mechanical properties. ABS-HIPS blends showed near additivity of modulus, strength, and elongation at break and should have adequate mechanical properties for many uses. Nylon/ionomer blends showed excellent mechanical properties including higher elongations at break for some blends than either pure component. The effect of moisture on mechanical response was also examined. Blends of this pair should prove to be quite valuable for many applications.

INTRODUCTION

Over the past two decades, technology has been developed to coextrude two or more polymers into film or sheet. This has led to numerous commercial products that combine desired features of each component of the composite.¹ Examples include laminated sheet of ABS and HIPS for refrigerator door liners and film of nylon 6 and ionomers for packaging. Obviously, these components cannot easily be separated from one another in the scrap generated from these processes or products, and this introduces additional considerations into reprocessing such scrap compared to single component systems. One approach is to reprocess this scrap as a blend of the two components, and the feasibility of this, of course, depends on the properties of the blends so generated. Often, blends of immiscible polymers have mechanical properties which are poorer than the weighted average of those for the pure components.^{2,3} Thus, the purpose of this article is to evaluate the mechanical properties of polymer blends that might be generated from coextrusion operations, and the two examples mentioned above were chosen for study. Blends were made from the pure components rather than directly from coextruded scrap so that the blend composition could be varied over the entire range.

EXPERIMENTAL PROCEDURES AND MATERIALS

The polymers used in this study are described in Table I. Each polymer was dried at 80–90°C for 24 hr prior to any processing. Mixtures of the desired composition were compounded in a Brabender laboratory extruder, pelletized, and injection molded into test bars (ASTM D638 type 1) on a Van Dorn ram machine using process conditions approximately optimized for each system. The

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TABLE I
Polymers Used in Blend Preparation

Polymer	Product designation	Description	Manufacturer
ABS	Abson 89120	Injection molding grade	Abtec Chemical Co.
HIPS	825E	Used for refrigerator door liners	Cosden Oil and Chemical Co.
Ionomer	Surlyn 1650	Zinc ionomer for coextrusion	E. I. du Pont Co.
Nylon	XPN 1132	Nylon 6 used for coextrusion with ionomers	Allied Chemical Corp.

mold was gated from one end so that the test bars contained no weld line. These bars were then pulled on an Instron at a crosshead speed of 0.2 in./min. Modulus values were determined with an extensometer for the nylon-ionomer blends.

RESULTS FOR HIPS-ABS BLENDS

Figure 1 shows the response of the various mechanical properties to blend proportion. It is interesting to note that all of these properties lie very near the simple additive line connecting the properties of the pure components. This type of response is somewhat unusual for immiscible blends especially for parameters indicative of toughness such as the elongation at break.

The property responses shown in Figure 1 would suggest that HIPS-ABS blends generated from reprocessed scrap from coextrusion sources ought to be adequate for some potential applications. However, the incompatibility of these two polymers is apparent upon examination of broken test bars. Figure 2 is a photomicrograph of a fractured end of a bar made from a blend containing 50% of each component. Component migration during flow in the molding process is evident.^{4,5} The less ductile ABS has formed a skin around the bar. Generally, such phase segregation during processing is detrimental to practical use of in-

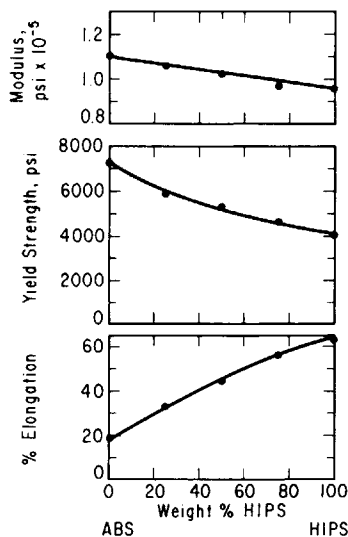


Fig. 1. Mechanical properties of ABS-HIPS blends.

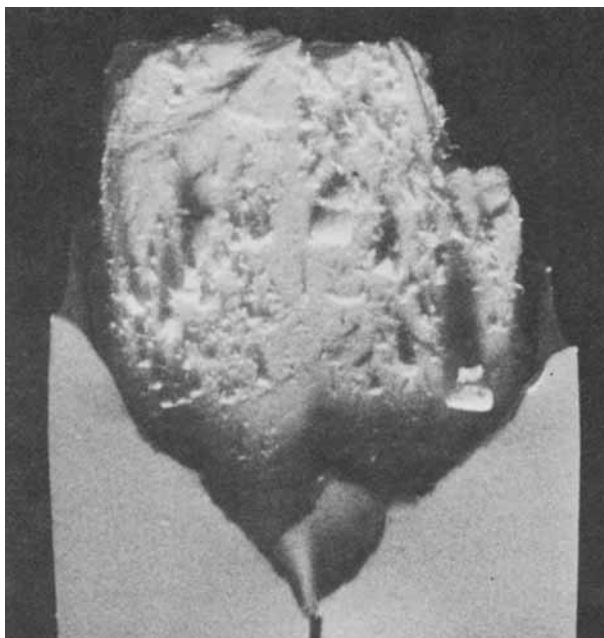


Fig. 2. Photomicrograph of fracture bar molded from 50/50 ABS-HIPS blends.

compatible blends. However, skins of this type could be beneficial in some instances. For example, ABS is well known for its superior chemical resistance compared to HIPS, and, in fact, it is for this reason that an ABS skin is coextruded over the cheaper HIPS for refrigerator door liners. It could be that skins of ABS formed on blends would serve to endow the molded part with the chemical resistance of ABS.

RESULTS FOR NYLON 6-IONOMER BLENDS

Blends of nylon 6 and ionomer were fabricated into test bars in the same manner as for the previous system; however, the program of mechanical testing was more extensive owing to the effect water has on nylon. It is well known that water plasticizes nylon and dramatically alters its mechanical behavior.⁶ Thus, to a degree, similar effects should be anticipated for blends of nylon. The molded bars were quite dry as produced; however, to assess the effects of water, some of the bars ($\frac{1}{8}$ in. thick) were immersed in pure water for periods up to five days. Figure 3 shows the percent water gain by the various bars as a function of immersion time. At any immersion time, the water gain by a blend compared to pure nylon is less than the fraction of nylon in the blend owing presumably to kinetic features of the water diffusion process in blends of complex phase morphology.

Figure 4 illustrates the dramatic effect of the presence of water on the mechanical response of pure nylon. Prior to any immersion, the nylon exhibits a very high modulus and yield strength and an elongation at failure of about 65%. However, upon sorbing moisture for various periods of time, both the modulus and yield strength decrease and the elongation at failure increase as one might expect. Interestingly, some of the specimens showed a dual necking phenome-

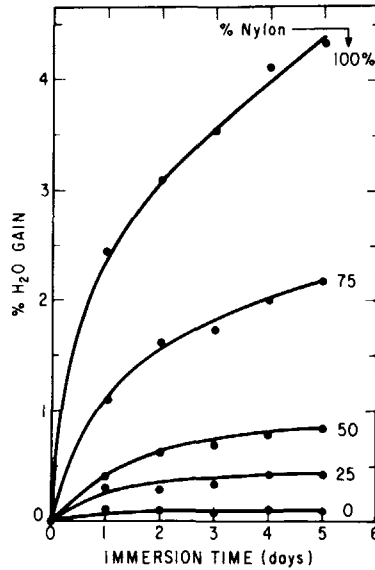


Fig. 3. Water uptake by nylon-ionomer blends. Immersion is in pure water; bars are $\frac{1}{8}$ in. thick.

non. After the first neck had propagated through the entire gauge section, a new neck was initiated and gave rise to a peak in the otherwise flat portion of the stress-strain diagram. Figures 5 and 6 show respectively how the modulus and yield strength for nylon and its blends with the ionomer change with immersion time in water. Since the mechanical behavior of the ionomer is relatively unaffected by water, these changes diminish in magnitude as the fraction of ionomer in the blends increases. It is clear from Figures 3, 5, and 6 that even after five days of immersion, the nylon is not fully saturated with water.

Figure 7 shows the stress-strain diagrams for the various blends after molding and prior to immersion in water. As expected, addition of the weaker and softer ionomer to nylon reduces the modulus and yield strength. However, it is very interesting to note that the blends containing 75 and 50% nylon exhibit elonga-

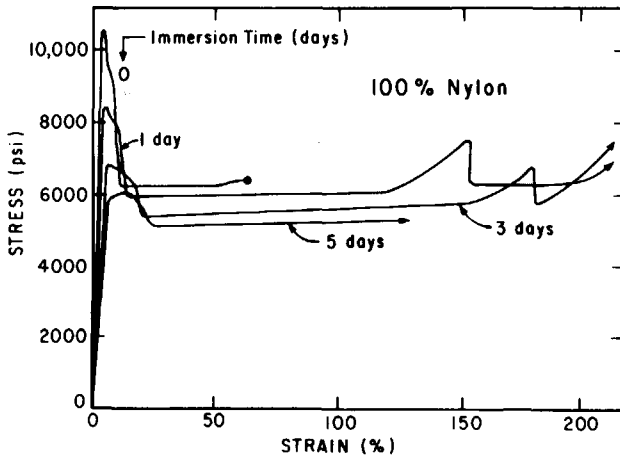


Fig. 4. Stress-strain diagrams for pure nylon after various immersion periods in water.

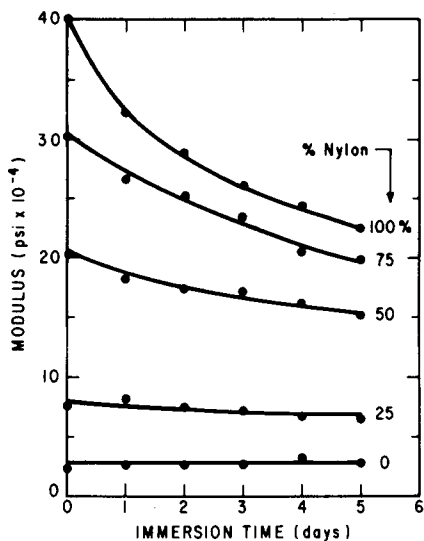


Fig. 5. Effect of water immersion time on modulus of nylon-ionomer blends.

tions at break that are larger than for either pure component. This synergism of ductility is not commonly seen in blends and suggests some unusual aspects of this system. Figure 8 shows the response of these same blends after three days of immersion in water. Owing to plasticization of the nylon, all stress levels have been reduced to those seen in Figure 7 except for the pure ionomer which effectively did not change.

Figures 9 and 10 show, respectively, the moduli and yield strengths of the blends as a function of nylon content at various immersion times. The shape of the modulus curves is most interesting. If the components were immiscible and the minor phase were present as a dispersion in a continuous phase of the major component, then one would expect a sigmoidal-shaped response in contrast to what is seen.⁷ Clearly, it would be most interesting to examine in detail the phase thermodynamics and morphology for these blends. Figure 10 shows that the yield strength becomes nearly a linearly additive function of composition as the nylon phase becomes plasticized by water.

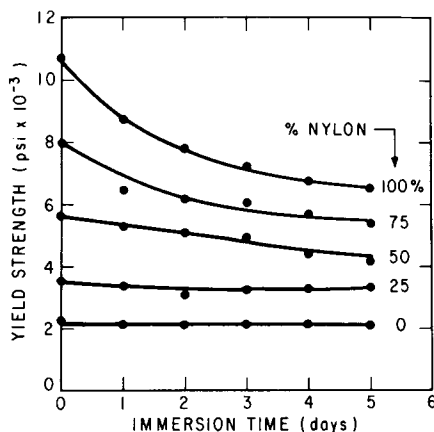


Fig. 6. Effect of water immersion time on yield strength of nylon-ionomer blends.

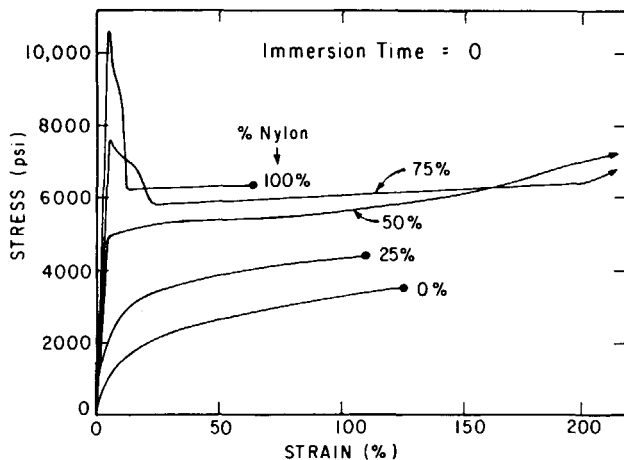


Fig. 7. Stress-strain diagrams for various blends prior to immersion in water.

The nylon-ionomer blends show remarkably good mechanical properties including some synergism of ductility in the dry state. Blends produced from reprocessed scrap from this source should be quite useful.

SUMMARY

Generally, blends of most immiscible polymers have inferior properties. Typically, their tensile strengths, elongations at break, or impact strengths possess less than additive contributions from each component. Indeed, in many cases these properties show minima for certain blend compositions. This precludes reprocessing mixed scrap plastics in many cases.⁸ Scrap from coextrusion processes or products will be mixtures of generic types of polymers in nearly all cases. However, the current results demonstrate that the problems of incompatibility generally expected are minimal for ABS-HIPS and nonexistent for nylon-ionomer. Thus, reprocessing of scrap of these types does not appear to be precluded for these reasons at all.

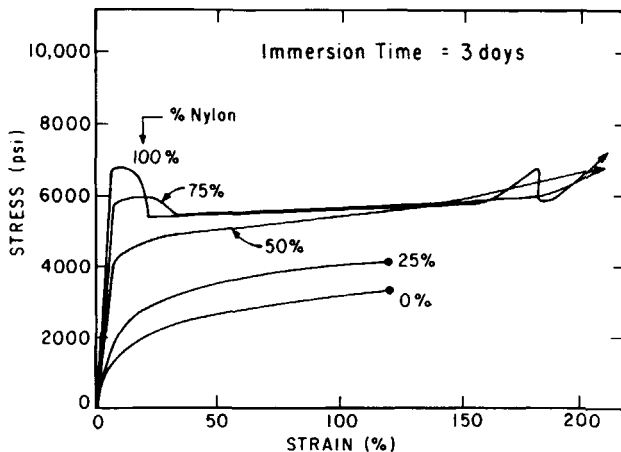


Fig. 8. Stress-strain diagrams for various blends after immersion in water for three days.

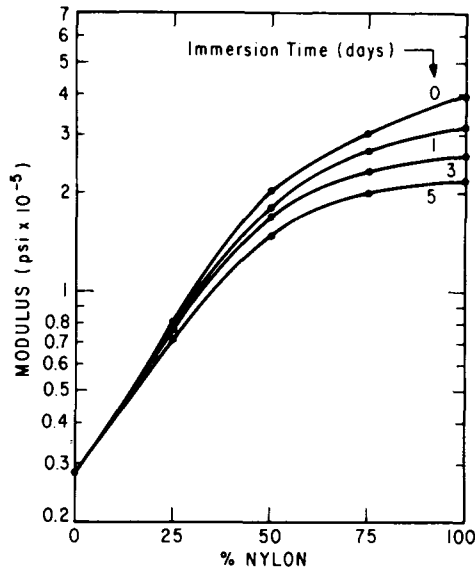


Fig. 9. Blend modulus as a function of nylon content for various periods of immersion in water.

We believe that component adhesion is responsible in part for the better-than-expected mechanical response observed in these systems. It is well known that lack of adhesion leads to poor performance in blends just as it does in composites. It has not yet been demonstrated fully; however, one might anticipate that components which adhere well to one another ought to form blends with more nearly additive mechanical responses.³ In most cases, some degree of adhesion between components is a prerequisite for forming a successful coextrusion process from two polymers. To the extent that both of these lines of reasoning are valid, blends formed from coextrusion systems ought to have reasonably good mechanical properties. Thus, reprocessing ought to be more attractive in these cases than for the mix of incompatible polymers generated from most other sources.⁸

Apparently, the nylon-ionomer case involves issues other than just good ad-

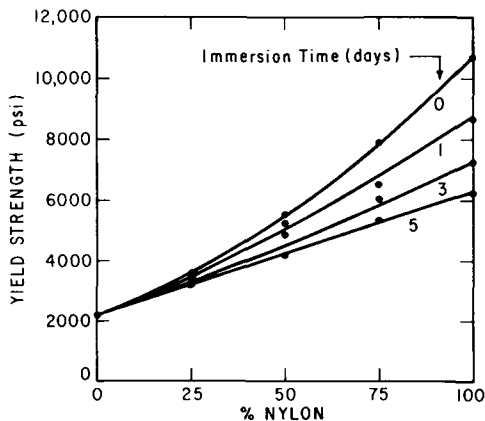


Fig. 10. Blend yield strength as a function of nylon content for various periods of immersion in water.

hesion, and a thorough, fundamental investigation of this system should be highly rewarding.

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