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Analysis Method

The use of FTIR mapping to assess phase distribution in mixed and recycled WEEE plastics

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ABSTRACT

Attenuated total internal reflection FTIR mapping was used to examine the coarse microscopic two-phase structure seen with some blended and recycled polymers. The blends studied were virgin and recycled ABS, HIPS and polycarbonate, typical of waste electrical and electronic plastics. The method was compared to optical microscopy both before and after etching with chromic acid. It was found that while optical microscopy showed up phase separation on a scale of tens of microns, the FTIR mapping allowed compositional details to be investigated. The phase structure could be quantified by using the standard deviation of band ratios and this correlated well with mechanical performance. The effects of processing method were more significant than whether material was recycled or not. Longer, less intensive processing produced more phase separation than shorter more intensive processing.

1. Introduction

Increasing amounts of waste plastics from many sectors are being recycled. Although some of this is economically viable, much is being driven by legislation on end-of-life vehicles (ELV) and waste electrical and electronic equipment (WEEE). For instance, in the EU, the ELV and WEEE Directives have challenging requirements for the amount of plastics requiring recycling. For plastics from WEEE in particular this has posed a number of challenges given that there is a range of plastic materials used, many of which are co-polymers and blends which are often difficult to separate from each other. Studies of the composition of WEEE plastics [1,2] have found the major constituents are ABS, HIPS, PC, PPO/HIPS blends, PC/ABS blends as well as PE and PVC from cable insulation. Some acrylic polymers, polyolefins and polyamides are often found as minor components. Given this mix, it is not surprising that there has been considerable attention given to the combined recycling of selected mixtures without complete separation.

Studies on mixtures of recycled ABS and HIPS [2,3] have found that the strength and stiffness are reasonably well-maintained across the composition range but the ductility and impact properties are reduced. It was found that the composition was more significant than whether the materials were recycled or not. Lui and Bertilsson [4] found that blends of recycled ABS and PC/ABS gave good mechanical performance across the composition range. They found that small amounts of PMMA as a contaminant gave slight improvements in properties, while nylon (PA) contaminants gave poorer performance. Rybnicek et al. [5] found similar effects with blends of ABS and PC with PMMA contaminants. They also found that the blend composition was more important than whether material was virgin or recycled. Balart et al. [6] however found poorer mechanical performance in blends of recycled PC and ABS, which they attributed to limited compatibility as seen by DSC results showing two separate Tg's. They concluded that poor bonding at the PB surface (possibly due to degradation) was responsible. The potential use of compatibilisers has also been studied with Elmaghor et al. [7] showing that

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Table 1
The materials use to produce mixed polymer blends.

vHIPS (SA)	Virgin HIPS, from Sigma Aldrich
vHIPS (Em)	Virgin HIPS, Empera 622N/W from Ineos Nova
rHIPS (1)	Recycled post-consumer HIPS, manually sorted from a representative range of WEEE
rHIPS (2)	Recycled post-consumer HIPS, manually sorted from computer keyboards
vABS (SA)	Virgin ABS, from Sigma Aldrich
vABS (Te)	Virgin ABS, Terluran GP35 from BASF
rABS (1)	Recycled post-consumer ABS, manually sorted from a representative range of WEEE
rABS (2)	Recycled post-consumer ABS, manually sorted from (fixed-line) telephones
rABS (3)	Recycled post-consumer ABS, manually sorted from computer casings
rPC/ABS (1)	Recycled PC/ABS, manually sorted from game consoles
rPC/ABS (2)	Recycled PC/ABS, manually sorted from a representative range of WEEE
rPC (1)	Recycled PC, manually sorted from game consoles
rPC (2)	Recycled PC, manually sorted from a representative range of WEEE

blending of recycled ABS and PC was improved with the use of maleic anhydride, which was linked to changes in phase morphology. Lui et al. [8] also found that compatibilisers were required to give reasonable properties in blends of PA and ABS.

In various studies, it is clear that there is some variation in results with mixed recycled materials and this has been one of the major barriers to the successful market penetration of recycled materials. In a commercial recycling operation, it will never be possible to control all the input materials, and so methods of adjusting blends and processing conditions will need to be utilised. For instance, it has been found that some materials produce volatile emissions during processing which can lead to void formation and property reductions, although appropriate vented processing can overcome

Table 2
The compositions and processing methods for all the blends produced.

Sample	First material	Second material	Third material	Processing
#1	100% vABS (SA)			TR & CM
#2	75% vABS (SA)	25% vHIPS (SA)		TR & CM
#3	50% vABS (SA)	50% vHIPS (SA)		TR & CM
#4	25% vABS (SA)	75% vHIPS (SA)		TR & CM
#5		100% vHIPS (SA)		TR & CM
#6	50% vABS (Te)	50% vHIPS (Em)		TR & CM
#7	50% vABS (Te)	50% vHIPS (Em)		Ex + IM
#8	50% vABS (Te)	50% vHIPS (Em)		IM
#9	50% vABS (Te)	50% vHIPS (Em)		IM x2
#10	50% vABS (Te)	50% rHIPS (1)		Ex + IM
#11	50% rABS (1)	50% vHIPS (Em)		Ex + IM
#12	50% rABS (1)	50% rHIPS (1)		Ex + IM
#13	50% rABS (2)	50% rHIPS (2)		TR & CM
#14	50% rABS (3)	50% rHIPS (2)		TR & CM
#15	47.5% vABS (SA)	47.5% vHIPS (SA)	5% PP	TR & CM
#16	47.5% vABS (SA)	47.5% vHIPS (SA)	5% PC/ABS	TR & CM
#17	47.5% vABS (SA)	47.5% vHIPS (SA)	5% Nylon	TR & CM
#18	100% rABS (2)			Ex + IM
#19			100% rPC (1)	Ex + IM
#20		100% rPC/ABS (1)		Ex + IM
#21	50% rABS (2)	50% rPC/ABS (1)		Ex + IM
#22	50% rABS (2)		50% rPC (1)	Ex + IM
#23		50% rPC/ABS (1)	50% rPC (1)	Ex + IM
#24	33% rABS (2)	33% rPC/ABS (1)	33% rPC (1)	Ex + IM
#25	60% rABS (1)	30% rPC/ABS (2)	10% rPC (2)	TR & CM

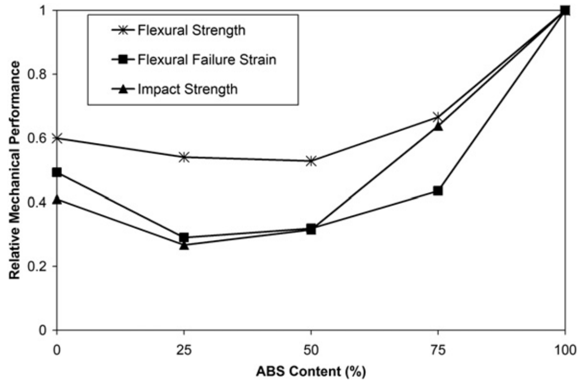

Fig. 1. The mechanical properties of virgin ABS/HIPS blends, relative to the properties of the 100% ABS material.

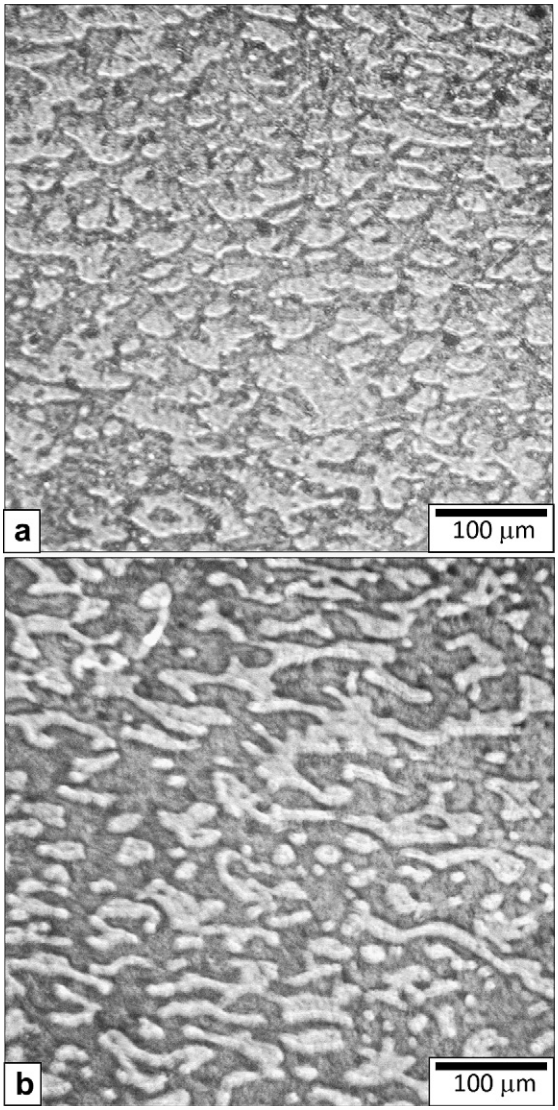

Fig. 2. Optical micrographs of 50% vABS/50% HIPS blend: a) unetched; b) after chromic acid etching.