RECYCLING OF LATEX BASED PAINT AS POLYMER FEEDSTOCK MATERIALS

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Abstract

This work investigates the recycling of used latex paints into non-paint products. Waste latex paint was collected, dried, and prepared for mixing as polymer feedstock. This feedstock was melt-blended with high-density polyethylene (HDPE) and polymethylmethacrylate (PMMA) at various composition ratios by injection molding. Tensile mechanical properties and thermal properties of paint/HDPE and paint/PMMA polymer blends were determined. Thermal analysis revealed that these blends are immiscible.

Introduction

According to the USEPA, unwanted paint is the largest component of residential household hazardous waste in the country. It is estimated that 34 million gallons of left over consumer paint is generated annually in the United States.[1] However, this estimate does not include significant amounts of waste paint generated by contractors, retailer mis-tints, paint manufacturers, private corporations or other businesses, schools, and public agencies.

The primary component of paint retailers' waste stream consists of unused full containers of paint that are returned as a mis-tint or other retailing errors. The cost of final disposition, a per container cost for either recycling or hazardous waste disposal, is very high for the retailer. Much of this paint, particularly the lighter shades of paint in unopened containers, can be re-blended and converted into new paint for use by either government or private entities. However, markets for re-blended paint have been slow to develop and have not yet proven to be profitable.

Currently, latex paint is the most popular paint on the market. In 1997, $270,000 was spent collecting and recycling 1.3 million pounds of latex paint. The amount of post-consumer latex paint has grown each year, and in 2003, the quantity of latex paint collected increased to two million pounds.

This high volume of waste or unwanted latex paint in the municipal solid waste stream makes it an attractive material to recycle. Moreover, many jurisdictions prohibit waste paint disposal in a liquid state due to its propensity to spill on route to the landfill or incinerator, resulting in equipment contamination.

On average, latex paint is composed of 59.3 % water, 15.7 % latex polymer concentration, 12.5 % titanium dioxide concentration, 12.5 % extender pigments, and 1.1 % ethylene glycol concentration.[2] However in the 1980s and earlier, mercury was used as a preservative in latex paint. Thus, liquid waste paint collected at recycling facilities must be tested for mercury and other contaminants prior to deciding its fate: recycled for reuse or use in non-traditional products, landfill, or hazardous waste. Latex paint manufactured after the 1980s may be legally disposed of in a dried, solid form without going to a hazardous waste landfill. Drying waste paint releases only water and fractional amounts of safe, non-organic volatiles into the environment. However, drying the paint is either energy intensive as in the case of spray drying or similar methods, or time consuming and weather dependent as in the case of natural evaporation. Naturally, the latter can be economical and practical in arid locations, although these conditions do not typically occur near major consumer markets.

Thus, there is a need to develop a proactive, voluntary recycling program and technology for reusing this material while simultaneously creating financial benefits. Such a program must be successful in removing a large percentage of unused paint from the waste stream to negate the need for a mandatory or special taxation program.

The National Council on Paint Disposition, NCPD, focuses on issues that arise due to retail and post-consumer waste paint. The NCPD, with assistance from the Solid Waste Policy Group at Rutgers University and funding from Benjamin Moore, initiated a project with the AMIPP Advanced Polymer Center at Rutgers University. In this study, dried latex paint was melt-blended with HDPE and with PMMA. HDPE was selected because it is a commodity plastic, one of the most inexpensive plastics, plentiful in the post-consumer recycling stream, and easy to process by most methods. PMMA was selected due to the similarity of its chemical nature with many of the polymers used in latex paints. PMMA is easy to process and recently has become fairly inexpensive.

[1] Paint Product Stewardship: A Background Report for the National Dialogue on Paint Product Stewardship, Section 6.1, Product Stewardship Institute Draft Issues and Potential solutions Document, April 8, 2003.

[2] Private communications with Marv Goodman of the National Council on Paint Disposition.

Experimental

Thirteen cans of post-consumer paint were collected, separated by gloss content, and labeled gloss or flat. Both high-gloss and semi-gloss paint were categorized as *gloss*, and the flat paint labeled *flat*.

A small sample was collected from each can, weighed, and weighed again after five days to determine changes in mass. Following this preliminary experiment, samples of both gloss and flat paint were poured into 25 by 55 cm Teflon baking sheets, dried under room temperature conditions over night to form a thin solid layer at the surface, and then placed in a Precision Mechanical Convectional Oven at 85 °C for a period of twelve hours. The twelve-hour period was repeated for each sample until the paint could be peeled off of the tray neatly. The total drying time varied due to gloss content. The flat paint total drying time was three to four days, while the gloss paint total drying time was five to seven days.

The resulting solid sheets of gloss paint were then cut into ten 5 x 9 cm sections and labeled A – J. The initial mass of the rectangular samples was recorded. The samples were dried further in a Fisher Scientific Isotemp Oven at a temperature of 85 °C for twenty-four hour periods, and the mass was recorded after each increment. Samples were dried until the change in mass after each period was minimal. The length, width, and height were measured and the density calculated for each sample.

The second phase of experiments involved blending various compositions of the dried, solid latex paint with two types of plastics, HDPE and PMMA forming dried Paint/Polymer blends. Composition ratios of 20/80, 30/70, and 35/65 % of Flat/HDPE, Gloss/HDPE, Flat/PMMA, and Gloss/PMMA blends were prepared, as well as 100 % HDPE and 100 % PMMA. The mixes were extruded using a Brabender Intelli-Torque Plasti-Corder® extruder operating at 50 RPM and 180 °C. Once cooled, the extrudate was ground in a Nelmor grinder. Each blend was injection molded into tensile specimens using a Negri Bossi V55-200 injection molding machine operated at 205 °C.

Tensile mechanical properties were determined using a MTS QTest/25 Elite Controller, according to ASTM D 638. Modulus, ultimate stress, and percent strain at fracture were calculated. The average results of five specimens are reported for each composition.

Thermal properties were determined using a TA Instruments Q 1000 Differential Scanning Calorimeter in modulated DSC mode (MDSC) under an atmosphere of dry nitrogen. Approximately 8 mg specimens of 35/65 Gloss/HDPE and 35/65 Gloss/PMMA were encapsulated in standard aluminum pans and sealed by crimping. DSC scans for each sample were conducted at 3 °C/minute while simultaneously modulating at 2 °C every 40 seconds. The Gloss/HDPE specimen was scanned over a temperature range of -20 – 200 °C, and the Gloss/PMMA specimen was scanned over a temperature range of -20 – 160 °C. Each specimen was heated, cooled, and reheated over the respective temperature range.

Results

The preliminary study for determining average weight loss of the gloss and flat paints resulted in average weight losses of 48.2 % for gloss paint and 47.0 % for flat paint. Table 1 shows the weight loss of the thirteen samples of paint collected after a five-day drying period. The standard error at 95% confidence of the weight loss means was 1.7%, indicating that no significant difference exists between the average moisture content of the gloss and flat paint samples.

Table 2 shows the calculated density of ten specimens of gloss paint, labeled A-J. The average density of the gloss sample is 1.45 g/cm^3. Figure 1 depicts the mass loss as a function of drying time for two of the specimens, A and B, over a period of 180 hours. As expected, the curve decreases at a decreasing rate until it levels off asymptotically and subsequent weight changes are minimal.

Table 3 shows the average tensile mechanical properties (modulus, ultimate stress, and strain at fracture) of Gloss/HDPE, Flat/HDPE, Gloss/PMMA, and Flat/PMMA paint/polymer blends. Most samples were not strained to failure but rather the testing was terminated after a certain level of strain was achieved. The maximum measured strain is reported and the status of the specimens after the test is noted, i.e. integral or fractured. Of the 16 sample groups with five specimens each, only the neat PMMA specimens and some of the Flat/PMMA specimens at 20/80 and 30/70 fractured, as noted in the table. A particularly interesting outcome of this work is that the Gloss/PMMA blends have a higher percent strain to failure than neat PMMA.

Figures 2 and 3 graphically depict a comparison of the tensile modulus as a function of paint content between Gloss/HDPE and Flat/HDPE blends and Gloss/PMMA and Flat/PMMA blends, respectively. The modulus of 100 % HDPE (720 MPa) increases dramatically with the addition of 20 % flat or gloss paint but then decreases with further additions such that the modulus is near or below initial values when the paint concentration is 35%. As shown in Figure 3, any addition of flat paint to PMMA up to 35% increases the modulus of the composite over that of 100 % PMMA (3,480 MPa), although a maximum modulus may be achieved near 25%. However, gloss paint has the opposite effect, and the modulus decreases from 3,480

MPa with any addition of gloss paint. Clearly the gloss paint contains a component that plasticizes PMMA.

Figure 4 depicts a comparison of the tensile ultimate strength as a function of paint content between Gloss/HDPE and Flat/HDPE blends and Gloss/PMMA and Flat/PMMA blends. The ultimate strength increases slightly from 14.5 MPa for neat HDPE with gloss paint content but is fairly constant with the addition of flat paint. The ultimate strength of PMMA decreases linearly from 65.0 MPa with the addition of gloss paint and approximately linearly with the addition of flat paint.

Figures 5 and 6 present the stress-strain curves for the gloss and flat Paint/HDPE and Paint/PMMA blends, respectively. It is evident that the gloss and flat Paint/HDPE blends behave in a similar manner as neat HDPE. This result suggests that Paint/HDPE blends can potentially replace HDPE in some applications. The gloss and flat Paint/PMMA blends have greatly increased toughness values compared with neat PMMA, as is evident by the area under the stress-strain curves limited by the strain at failure. The enhanced toughness of Paint/PMMA blends is an astonishing result that provides an enhanced alternative to neat PMMA. Furthermore, the 20/80 Flat/PMMA composite, which contains a significant percentage (~12% by weight) of fully dispersed nanoparticles (TiO_2, $Al_2O_3 \cdot 2SiO_2$, and $CaCO_3$), demonstrates performance nearly identical to PMMA with the remarkable feature that the strain to failure is at least several fold greater. Additional tests are needed to explore the actual strain to failure of this composition.

Figures 7 and 8 present DSC reheat scans of 35/65 % Gloss/HDPE and Gloss/PMMA, respectively. The total heat flow and the derivative of the reversing heat flow are plotted against temperature for both samples. In Figure 7, the Gloss/HDPE sample, a glass transition of the paint component occurs at 14 °C, and a melting transition of the HDPE component occurs around 130 °C. In Figure 8, the Gloss/PMMA sample, a glass transition of the paint component occurs at 14 °C, and a glass transition of the PMMA component occurs at approximately 104 °C.

Summary & Conclusions

Flat and gloss latex paint was collected, dried to a solid form, melt-blended with HDPE and PMMA, and injection molded into mechanical test specimens resulting in immiscible polymer blends of paint/HDPE and paint/PMMA. The paint/HDPE blends produced have mechanical properties similar to neat HDPE. The paint/PMMA blends have properties similar to PMMA in stiffness and strength, but the Gloss/PMMA blends have enhanced or higher toughness. The significant result of this work is that latex paint can be recycled and re-used in non-paint products, such as a polymer feedstock with HDPE or PMMA without sacrificing the mechanical properties of neat HDPE or neat PMMA. In one particular composition, 20/80 Flat/PMMA, properties were measured that substantially exceeded those of the neat polymer.

Acknowledgements

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Table 1. Percent weight loss after 5-days drying time

Sample	Weight % Loss	Type
1	47.72	Gloss
2	36.68	Flat
3	49.25	Gloss
4	60.97	Gloss
5	48.15	Gloss
6	48.27	Gloss
7	46.75	Gloss
8	57.60	Flat
9	39.61	Gloss
10	46.76	Flat
11	43.86	Gloss
12	49.12	Gloss
13	48.00	Gloss

Table 2. Density of dried gloss paint

Sample	Mass (mg)	Volume (cm^3)	Density (g/cm^3)
A	14.55	0.010	1.44
B	13.91	0.008	1.68
C	12.31	0.009	1.33
D	13.69	0.009	1.45
E	12.78	0.008	1.57
F	11.13	0.008	1.45
G	8.92	0.008	1.15
H	12.41	0.009	1.32
I	12.51	0.008	1.47
J	14.45	0.009	1.60
Average			1.45

Table 3. Average tensile properties of Gloss and Flat Paint/HDPE polymer blends and Gloss and Flat Paint/PMMA polymer blends at various compositions.

Sample	**Young's Modulus (MPa)**	**Ultimate Stress (MPa)**	**Maximum Measured Strain (%)**	**Specimen Status After Test** [integral unless noted]
0/100 % Gloss/HDPE	720	14.5	20.0	
20/80 % Gloss/HDPE	850	18.3	20.0	
30/70 % Gloss/HDPE	750	14.8	20.0	
35/65 % Gloss/HDPE	715	15.2	10.0	
0/100 % Flat/HDPE	720	14.5	20.0	
20/80 % Flat/HDPE	840	14.8	25.0	
30/70 % Flat/HDPE	715	13.7	22.0	
35/65 % Flat/HDPE	615	12.6	14.0	
0/100 % Gloss/PMMA	3480	65.0	2.5	Fractured
20/80 % Gloss/PMMA	3200	54.8	6.0	
30/70 % Gloss/PMMA	2750	48.1	6.0	
35/65 % Gloss/PMMA	2745	44.3	6.0	
0/100 % Flat/PMMA	3480	65.0	2.5	Fractured
20/80 % Flat/PMMA	4395	54.7	5.0	Some fractured
30/70 % Flat/PMMA	4330	53.2	2.9	Some fractured
35/65 % Flat/PMMA	4030	50.1	5.0	

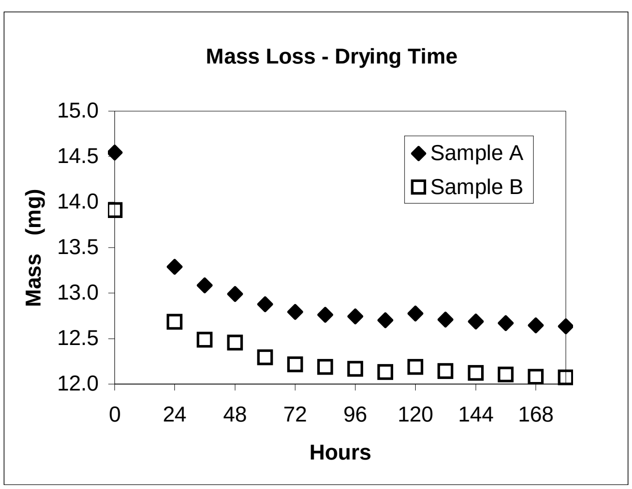

Figure 1. Mass as a function of drying time

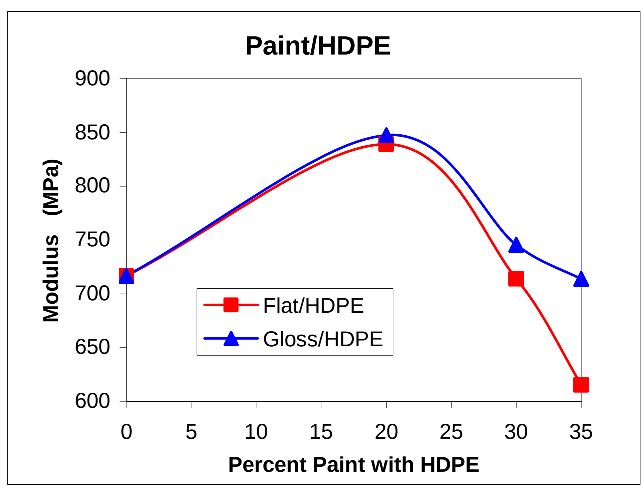

Figure 2. Tensile modulus versus Dried Paint/HDPE

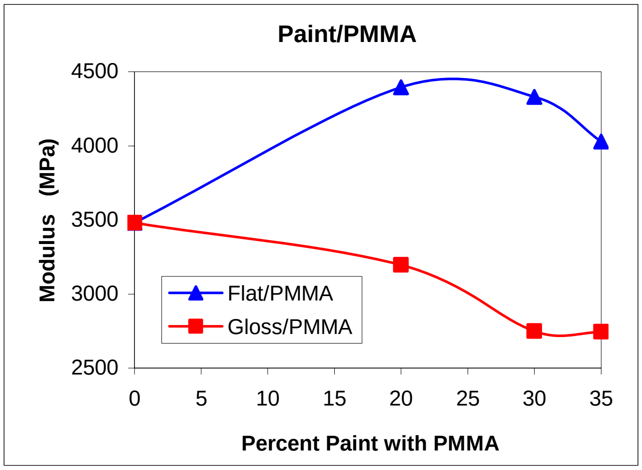

Figure 3. Tensile modulus versus Dried Paint/PMMA

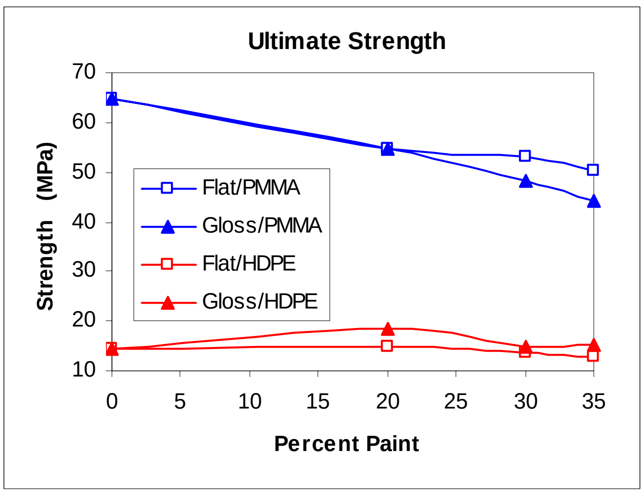

Figure 4. Tensile ultimate strength

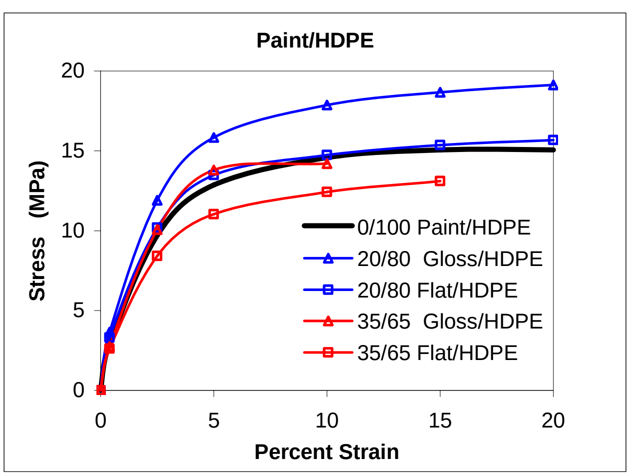

Figure 5. Stress-Strain curves for Paint/HDPE

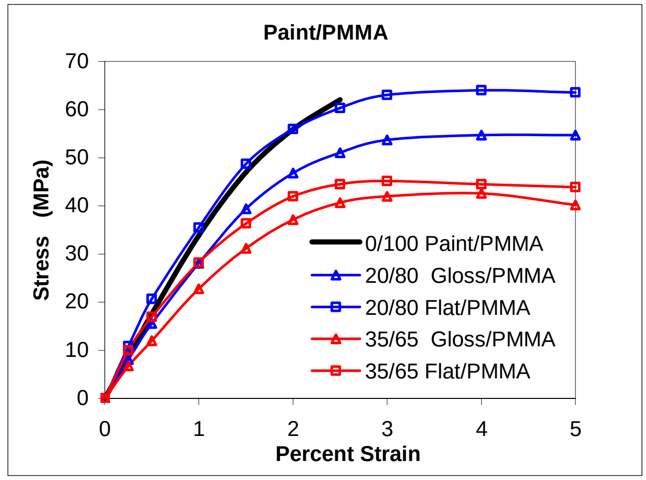

Figure 6. Stress Strain curves for Paint/PMMA

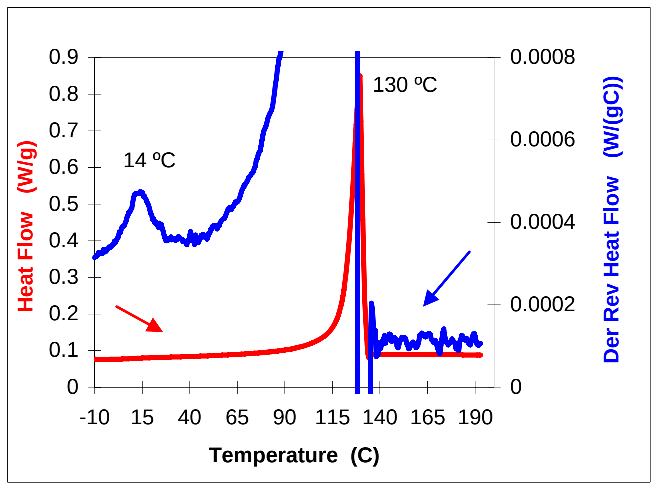

Figure 7. Reheat DSC scan of 35/65 Gloss/HDPE

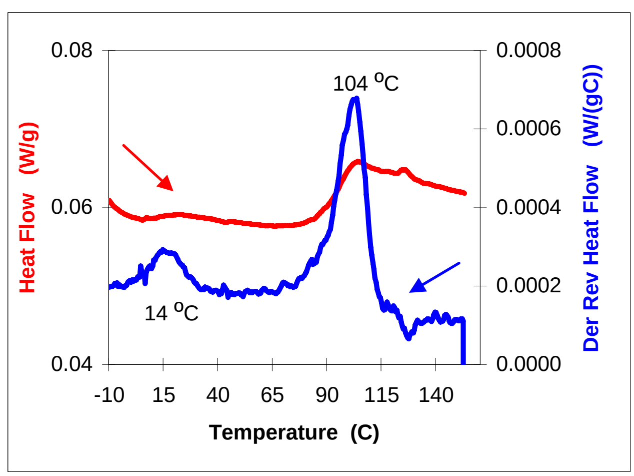

Figure 8. Reheat DSC scan of 35/65 Gloss/PMMA