The Recycling Of Amber Glass through Decolorization

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Summary

The recycling of glass is limited by color control and foaming encountered when remelting mixed "cullet" (waste glass frit), which consists of a mixture of amber, green, and colorless glasses. Small amounts of amber glass in the recycled waste stream cause unacceptable brown streaks in the product and foaming of melts due to changes in the redox of sulfur. Since foaming can shut down a commercial glass tank, resulting in the loss of millions of dollars, the industry will not use cullet containing amber glass.

This study determined if amber glass can be successfully recycled by eliminating the problems of color. The first objective of this study is decolorization of amber glass by addition of float glass cullet, which contains tin from its production process. SnO has already been proven to decolorize amber glass [1,2]. The second objective is to determine the effects of tin-less window glass, clear bottle glass, green bottle glass, and champagne green glass. The final objective is to determine the effects of SnO on a mixed cullet.

The first two objectives are very effectively met at a 50 weight percent level addition. All additions decolorized the amber glass to a certain degree at weight percents of 25 and 12.5 as well. The tin-less window glass was the most successful at the 50 weight percent range. At levels less than 50%, the decolorization was much less consistent, with areas of clear or green and areas of amber color. For the mixed cullet, doping with SnO had no effect on the glass.

Introduction

Previous work sponsored by CEER demonstrated that small addition of SnO to amber cullet completely decolorizes the glass [1,2]. Since SnO is expensive, a cheaper source of tin is needed to promote recycling of amber glass by this method. No tests have been made regarding the effect of other recycled glasses, including window glass, on the decolorization of amber. The effects of clear container glass, green container glass, and champagne glass as well as window glass and tin-less window glass additions to an amber cullet were observed in this study.

Methods

All of the glass used in this experiment was crushed from commercial glass. The amber cullet was from Coors Light bottles, the clear bottles were manufactured by Owens Illinois, the green bottles were from Heineken, and the window glass was a typical float glass produced by PPG. The tin-less float glass was made by polishing the tin layer off of the glass.

The amber glass and window glass were ball milled with zirconia media for varying amounts of time and sifted with a 120 mesh sieve. The other glasses were crushed with a hammer or mortar and pestle and sifted with a 120 mesh sieve. All batches weighed 15 grams, with varying weight percents of the components. The dopant was added in addition to the 15 grams at 0.15g SnO. All batches were melted at 1500°C in an air atmosphere for 30 minutes in a preheated electric furnace in an open Pt/Au crucible. The glass transition temperature(T_g) was measured for each sample, which was then annealed by holding at the T_g for 30 minutes and then cooled at a rate of 3K/min to room temperature.

Ultraviolet and visible spectra were measured using a Perkin-Elmer Lambda 40 spectrometer. Infrared spectra were measured using a Thermo Nicolet Avatar FTIR spectrometer. The glass transition temperature was determined using a differential scanning calorimeter (DSC) with a heating rate of 20K/min. Densities were measured using the Archimedes Method with kerosene as the immersion fluid. The dilatometer is a single push-rod vitreous silica used to determine the T_g of the glass and the softening point(T_d) using a heating rate of 4K/min.

Results

Results of the T_g, T_d, density, and color measurements are listed in Table I. Window glass, tin-less window glass, clear glass, green glass, and champagne glass were all successful in decolorizing the amber glass at 50wt% additions. Effectiveness of the addition decreases with decreasing weight percents of each type of glass. Spectral Uv-Vis data was used to compare the original amber glass to the spectra for 50wt% additions of the window glass, tin-less window glass, clear glass, and green glass. Clear glass was used as a standard to for comparison of the degree of decolorization. The goal would be to have spectrum that matches or nearly matches that of the pure clear glass.

Doping the amber glass with 12.5wt% of green, tin-less window, and clear glasses did not successfully decolorize the amber glass. The glasses still show more than a desirable amount of amber color. The equally mixed cullet of amber, clear, and green are green because of the dominating effect the green glass has on the overall glass. Using the SnO to dope this same, 1:1:1 ratio, glass caused a shift in the color to a darker green with brown at the bottom of the melt.

The T_g, T_d, and density for all of these glasses did not vary much with the composition of the glasses. This behavior is due to the fact that all of the bottle glasses are soda lime silicate glasses and therefore the composition of the resulting glasses did not change significantly. The dopant lowered the density for those glasses but not by more than 0.07 g/cm^3. Only a few dilatometer measurements were made because of the similar compositions of the glasses. Data from IR measurements are not shown because the glasses did not show a significant change over the range of compositions.

Discussion and Conclusions

Previous research has found that an absorption band at 400 nm in amber glass is the result of a charge transfer process. It is believed that the ferric and sulfide ions present are what is necessary to produce the amber color. Suggestions for decolorization aim towards either eliminating sulfide ions by oxidizing the melt or eliminating ferric ions by reducing the melt. Another possibility exists where the ferric ion is replaced by another ion[1]. It is unclear which way this experiment decolorized the melt. This would be one area of possible future work.

It was found that a 50 weight percent addition of window glass, tin-less window glass, clear container glass, green bottle glass, and champagne bottle glass will all decolorize amber bottle glass. Doping with SnO did not affect the mixed cullet. This finding suggests that, if a manufacturing plant were to add less than 50% by weight amber to a cullet of any of these glasses, streaking would not occur. Further work may include finding an exact weight percentage that can be added to amber to decolorize it.

Table I. Density, Glass transition temperature, Softening Temperature, and observed Color for all glasses. (S) represents swirls of color in the glass.

Sample	Density (g/cm^3)	T_g (°C)	T_d (°C)	Color
As Received	2.4882	550	608	Amber
50wt% Window	2.4876	571		Clear/Blue
25wt% Window	2.4722	568		Amber with Clear Edges (S)
12.5wt% Window	2.4703	575		Light Amber (S)
50wt% Sn-less Window	2.4887	574		Clear/Blue
25wt% Sn-less Window	2.4832	573		Amber with Clear Edges (S)
12.5wt% Sn-less Window	2.4923	567		Light Amber (S)
50wt% Clear	2.4632	589		Clear/Blue
25wt% Clear	2.4519	569		Blue/Amber (S)
12.5wt% Clear	2.485	571		Light Amber (S)
50wt% Green	2.485	571		Green
25wt% Green	2.488	571		Amber/Green (S)
12.5wt% Green	2.4782	576	600	Light Amber with Clear Edges (S)
50wt% Champagne	2.4961	569		Dark Green
25wt% Champagne	2.4768	566		Light Amber with Clear Edges (S)
12.5wt% Champagne	2.4495	569		Amber with Clear Edges (S)
12.5wt% Clear Doped	2.4893	574	607	Amber/Green (S)
12.5wt% Green Doped	2.4902	577	620	Amber/Green (S)
12.5wt% Sn-less Doped	2.4681	568		Amber/Green (S)
Amber Doped	2.4132	579	608	Green with Brown in bottom
Green Doped	2.5009	582		Medium Green
33% GAC	2.4721	590	612	Light Green
33% GAC Doped	2.4583	585		Darker green with Brown in the bottom
Pure Clear	2.4684	584	610	Clear
Pure Green	2.4508	577	608	Green

References

[1] Rapp, Douglas B. Melissa A. Dorsey, Melissann M. Ashton-Patton, and James E. Shelby, "Decolorization of Amber Glass." Advances in Fusion and Processing of Glass III, Ceramic Transactions Vol. 141, pp. 323-330 (2004).

[2] Ashton-Patton, Melissann M. Douglas B. Rapp, and James E. Shelby, "Effect of SnO Additions on Decolorization of Amber Glasses," accepted by Phys. Chem. Glasses.