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Direction of CRT waste glass processing: Electronics recycling industry communication ☆

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ABSTRACT

Cathode Ray Tube, CRT, waste glass recycling has plagued glass manufacturers, electronics recyclers and electronics waste policy makers for decades because the total supply of waste glass exceeds demand, and the formulations of CRT glass are ill suited for most reuse options. The solutions are to separate the undesirable components (e.g. lead oxide) in the waste and create demand for new products. Achieving this is no simple feat, however, as there are many obstacles: limited knowledge of waste glass composition; limited automation in the recycling process; transportation of recycled material; and a weak and underdeveloped market. Thus one of the main goals of this paper is to advise electronic glass recyclers on how to best manage a diverse supply of glass waste and successfully market to end users. Further, this paper offers future directions for academic and industry research. To develop the recommendations offered here, a combination of approaches were used: (1) a thorough study of historic trends in CRT glass chemistry; (2) bulk glass collection and analysis of cullet from a large-scale glass recycler; (3) conversations with industry members and a review of potential applications; and (4) evaluation of the economic viability of specific uses for recycled CRT glass. If academia and industry can solve these problems (for example by creating a database of composition organized by manufacturer and glass source) then the reuse of CRT glass can be increased.

1. Introduction

Video screen technology has advanced at a fevered pace, but advances in technology are quietly burying parts of the world in a growing supply of toxic electronic waste, particularly Cathode Ray Tubes (CRT). Electronic waste recycling is not yet fully automated and remains labor intensive. This means cheap third world labor easily underbids the cost of first world recycling efforts. One result of this is the export of waste to third world countries for a positive or increased profit margin. Unfortunately, third world countries are not equipped, nor governed, to handle the dismantling and recycling of electronic waste in an environmentally safe and responsible manner. Prohibiting e-waste export to third world countries (Basel Action Network, 2012) is an idealistic attempt that will only result in illegal transport (EIA, 2011). First world countries must advance their recycling efforts by making the retention and processing of electronics more profitable than export. This will require increasingly flexible high-rate automation at low cost, the continuous dissemination of information and the creation of new products or processes made from recycled (electronic) materials instead of virgin materials.

CRT glass was essential to old-tech televisions and computer monitors and is now approximately 35% of known electronic waste (Townsend et al., 1999). IBM estimated 294 million CRTs were discarded in the US in 2008 alone (Mizuki et al., 1997). The peak in CRTs to be recycled is projected to occur between 2015 and 2020 (Gregory et al., 2009; private communication with glass recycling industry contacts); the time range for CRT accumulation was

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expected to continue until 2028 in the UK (ICER, 2003) and a small survey of large-scale private US recyclers estimates a slightly lower year for the US, 2026 (private communications with industry contacts). These figures are debatable. The time over which CRT glass will be recycled and available to market is separate from accumulation peaks and ranges. Current recycling techniques are unable to recycle at the rate of accumulation and electronics recyclers often have dry warehouses back stocked with CRTs waiting to be recycled.

The historic economic trend in CRT recycling reflects the fact that CRT glass is a bulky, nearly worthless material with a complex mixture of heavy metals and oxides. The introduction of the LCD screen made the direct reuse of most CRT glass unrealistic (Gregory et al., 2009), though post consumer waste accumulation was already a problem. Industrial closed-loop CRT glass recycling had a documented negative return in 1998 (Menad, 1999) and the US market was past its saturation point in 2001 (Monchamp et al., 2001). World supply exceeded demand at the end of 2009. Since that time, the remaining CRT manufacturers, all in Asia, will only take funnel and lead-free panel glass free on board in large, regular shipments. Although the cost of shipping to Asia is lowered by the need to fill cargo containers on their way back to manufacturers, the loss to electronics recyclers is too great to sustain and, as manufacturers do not require as much material as is freely available, this outlet is additionally unreliable. The cost of transport for open-loop reuse eliminates all but the closest outlets. Electronics recyclers have thus been seeking domestic markets for continuing business partnerships.

Academia has long assisted recyclers in examining potential uses for CRT glass. The approaches have often been to mimic current products that use recycled cullet and prove the viable substitution of CRT waste glass. Glass foams have been produced (Mear et al., 2006a, 2007; Yot and Mear, 2009, 2011; Bernardo and Albertini, 2006), which serve as sound and heat insulation similar to those already on the market. Glass matrix composites (Bernardo et al., 2003), glass ceramics (Bernardo et al., 2006; Andreola et al., 2005), a range of glazes (Andreola et al., 2007), and concrete applications with (Chen et al., 2009) and without (Kim et al., 2009) lead extraction (Yot and Mear, 2009; Goforth et al., 1994) have been demonstrated. The viability of current and novel applications is examined here. Highlighted are the most readily marketable endeavors and the most promising applications, though not all successful applications are listed.

Drawing on experience gained working for a large electronics recycler and interviews with industry members, this paper offers a summary of CRT glass recycling practices (see additional review Herat, 2008; Menad, 1999) and useful facts about CRT glass, with specific focus on lead content. This paper aims to advise glass recyclers and academics on how to manage a diverse supply of glass, create pseudo sustainable management of materials and successfully market to end-users.

2. Materials and methods

The processing heuristics of CRT glass were determined using the data and samples of a large-scale electronics recycling facility (>100 tonnes per month) in the midwest United States. Televisions and computer monitors of all kinds were accepted from Ohio and its surrounding states. The customer base included corporate decommission and regular public drop off, drop off augmented by recurring countywide recycling drives.

CRTs are recycled as standard procedure in electronic recycling; however, CRTs are not worth enough to merit testing and resale. Even if a market could be found, the vast majority of used CRTs become inoperable after transport even though ~30% were listed as functional at drop off. In any event, reuse would only delay, not eliminate the need to eventually deal with the waste.

The CRT Heaven Angel machine with a dry diamond saw (CRT Heaven, Angel) was used for tube separation, followed by phosphor removal for the panel glass and dry tumbling of the funnel glass (CRT Heaven, Devil), to remove the aquadag, or dag, coating. The company produced an average of 113 short tons of panel glass a month and 61.3 short tons of funnel glass a month, giving a ratio of about 2:1 panel to funnel by continuous processing. This did not include co-mingled and black and white CRTs (12 short tons a month), which consisted primarily of closed circuit televisions. Pre-sorting separated the CRTs by TV versus monitor, monochrome versus color, general size and apparent age. According to process data, the ratio of CRTs was 68% monitors and 32% TVs. The common monitor size was 17″, followed by 21″ and 19″. The common TV size was 27″ followed by 32″. Monitors have slightly thicker panel glass than TVs of the same size, since viewers were expected to be closer to the screen.

The historic trends in CRT glass chemistry were determined using industry communications, cross-referenced with inventory testing. For cross-referencing specific manufacturers, whole CRTs were individually processed and their funnel and panel glass collected. For bulk cullet trends, cross cut samples of the funnel glass stream were taken on a regular schedule, adjusting for retention time, from the dry tumbling hopper. Panel glass was checked, per batch, for lead fluorescence. Chemical analysis of the collected samples was performed using X-ray Fluorescence, XRF, and short wave, 250 nm, UV-light fluorescence; greater utility and ease of use was provided by the UV-light technique.

3. Results and discussion

3.1. Historic trends in leaded-glass

There is an understandable misconception in reference to a WEPSI communication (Corcoran, 2001; Mear et al., 2006b; Andreola et al., 2005) that color panel glass ceased to be leaded after 1995. This is incorrect. The German Electrical and Electronic Manufacturers Association, ZVEI Faschverband, began an industrial working group on TV CRT recycling to increase the recycle rate of the glass (ZVEI, 1996). Their effort succeeded in nearly all CRT manufacturers voluntarily eliminating lead from panel glass in 1995. Three US manufacturers continued to use lead in their panel glass: Thompson RCA, Corning Asahi Video, and Corning. After 1998, Thompson RCA converted production to non-leaded panel glass, Fig. 1.

3.2. Process efficiency and development

Though only a few companies continued using lead oxide in their glass after 1995, glass recyclers are almost certain to have leaded panel glass among their stock due to the quantity processed and the range in unit ages. For instance, the ratio of leaded panel glass present in processing was found to be ~10% for large-scale electronic glass recycling (*measured in-house and gleaned during conversations with other CRT glass recyclers*). It is important to note that each open-loop glass use has different tolerances in terms of chemical content and most demand 100% lead-free cullet. Therefore, a simple, fast, and cost effective method for sorting the leaded panel from non-leaded panel glass will make the resulting streams immediately more marketable.

Short wave UV light fluorescence is that efficacious method. Leaded glass fluoresces purple under UV, so an entry-level worker, or an optical sensor, can easily distinguish leaded from non-leaded glass. Additionally, residual coatings on the glass are not known to