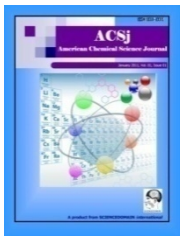

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Processing of Electronic Glass Scrap Recycling

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Author's contribution

This whole work was carried out by the author BE.

Review Article

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ABSTRACT

Among the diverse types of waste, glass is one of the most adequate recycling materials because it can be revived and recycled completely and hardly decomposes. The glass recycle process basically involves collecting, sorting, then crushing and grinding after which glass cullet is produced as the secondary raw material. Removing of the contaminants from the glass cullet, and then melting are the next steps. LCD glass, PCBs and CRT are recycled to fabricate new products. In this study, recent developments in the recycling of glass, are discussed in terms of glass production processes. It was concluded that CRT, LCD and PCBs are popular resources of glass recycling and they can be used in different applications.

Keywords: Scrap; electronic glass; processing; glass recycling; waste glass.

1. INTRODUCTION

Among the diverse types of waste, glass is one of the most valuable recycling materials because it can be revived and recycled completely and hardly decomposes. On average, one out of two glass bottles coming on to the market is provided by recycling processes in Europe. Glass recycling has been started by the early of 1970s in Turkey, and the recycling amount has been reached to 70 thousand tons recently, while 4.2 million tons which represents only 25 percent of total glass manufactured, is the amount of glass collected annually for recycling in the world. The glass recycle process basically involves collecting,

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sorting, then crushing and grinding after which glass cullet is produced as the secondary raw material. Removing of the contaminants from the glass cullet, and then melting are the next steps [1,2].

End-of-life electronics consists of computers, cell phones, televisions, and batteries, and ATM machines, and large phone machines etc. These electronic parts requires safe disposal and recycling. A large number of second hand electronic parts can be used again or can be manufactured into new products. Many electronic products contain hazardous substances, which must be carefully handled. Rapid growth in the electronics industry results in a large number of second hand products, which are depicted in Fig. 1. Several valuable substances are utilized to manufacture these products, which needs to be regained [6].

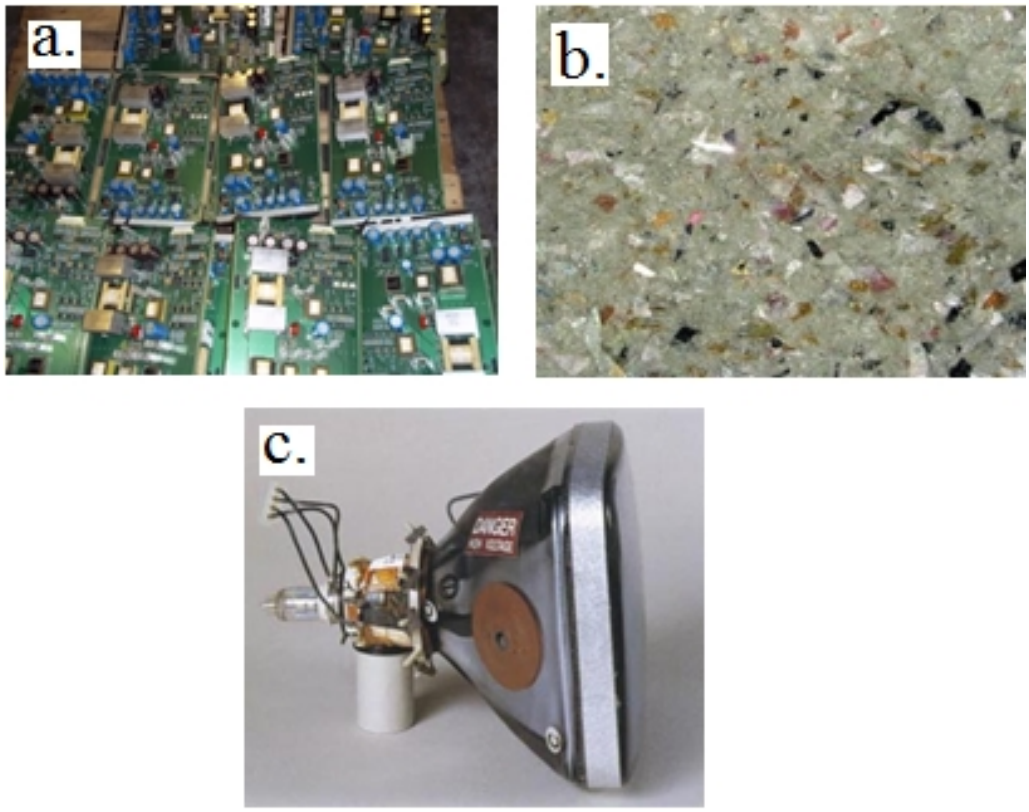

Fig. 1. Mostly recycled electronic products a. Printed circuit boards [3] b. LCD glass cullet [4] and c. CRT device [5]

2. THE RECYCLING OF LIQUID CRYSTAL DISPLAY (LCD) GLASS

Since LCD monitors are popularly used nowadays, the amount of waste LCD is increasing dramatically [7]. The estimated amount of LCD monitor sale reaches eighty billion dollars by 2012. This high amount of sales leads to huge waste generation as end-of-life products. When these electronic wastes are stored, not only they will be harmful for the environment but also valuable resources will be lost [8,9]. Therefore a new alternative technology for treating waste LCDs needs to be proposed immediately [10].

The glass substrate has compact sandwich structure which mainly contains front polarizing film, front glass covered with indium tin oxide (ITO) film, liquid crystal, back glass covered with ITO film and rear polarizing film [10].

The waste LCDs were initially dismantled by Wang et al. to recover the independent materials. After removing the liquid crystal, the polarizing film was separated from the glass substrate of waste LCDs and then pyrolyzed while the rest of the glass substrate was immersed in the acid to recover indium. In the end, the residual glass after acid immersion can be used as construction materials [10]. Fig. 2 indicates the technique developed by Sharp with Aqua Tech. Co. Ltd. This method takes advantage of the unique properties of indium. LCD panels are first crushed into glass cullet (small chips) and then dissolved in an acid solution. It is a simple process using common chemicals that eliminates the need for large energy expenditures, such as those required to achieve high temperatures or high pressures [11]. Most of the researches in the literature focus on the winning of indium and recycling glass [12,13].

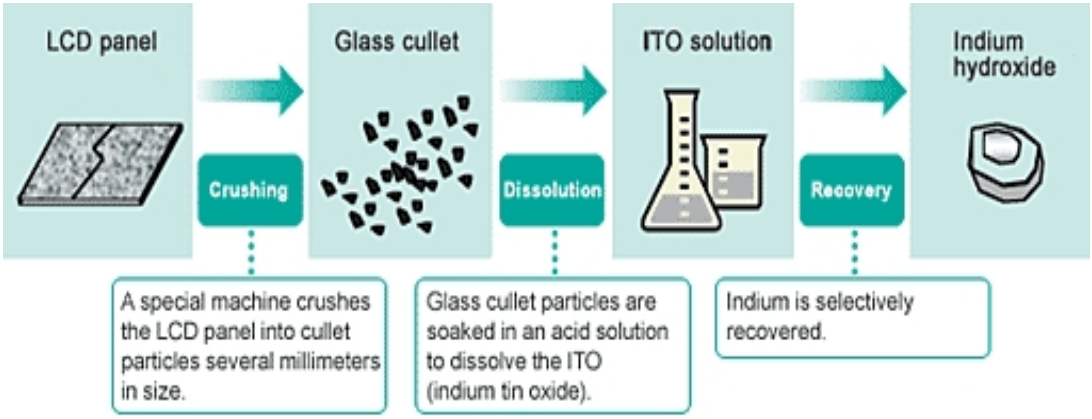

Fig. 2. The technique developed by Sharp with Aqua Tech. Co. ltd [11]

There have been many suggestions on how to recycle waste LCD glass. Almost all of them were to use the collected glass in the production of new LCD glass or some of them were to reuse. One of them was to use feed materials for production of tile. And some case of them was to use the waste glass as lining materials to prevent the corrosion of incinerator walls or as partial additives or substitutes for melting, metallurgy or incineration processes. However, the concepts of these processes are about retrieving materials rather than recycling them [14].

Wang studied the recycling of discarded liquid crystal display (LCD), glass into concrete. The specimens with glass sand replacement developed a better splitting tensile strength at the longer curing age, when the durability of concrete is improved. The addition of LCD glass sand can improve the resistance to sulfate attack for concrete. The addition of LCD glass sand can produce a denser internal concrete structure [13]. In a study of Wang and Chen, controlled low-strength concrete (CLSC) is mixed with waste glass and also includes Portland cement and fly ash. The findings reveal that using waste liquid crystal display, LCD glass in place of sand can meet design requirements [15]. Also, Lin and colleagues recycled LCD waste glass and produced glass-ceramics [16].

3. THE RECYCLING OF PRINTED CIRCUIT BOARDS (PCBS)

Printed circuit boards (PCBs) are used to mechanically support and electrically connect electronic components using conductive pathways, tracks or signal traces etched from copper sheets laminated onto a non-conductive substrate, employed in the manufacturing of business machines and computers, as well as communication, control, and home entertainment equipment. PCBs are essential parts of almost all electric and electronic equipment, and its rapid development has revolutionized the electronics industry. A large quantity of obsolescent electronic products has rapidly led to considerable waste generation, even in the developing countries [17].

The amount of PCBs in electronic waste is 3% [18,19]. PCBs contain various heavy metals and hazardous substances such as Pb, Cd and flame retardants [20,21]. The non-metals of PCBs are plastics, resins, glass and fibers [22].

It can be clearly seen that except the hazardous substances, a lot of valuable materials contained in PCBs make them worth being recycled. Therefore, developing a non-polluting, efficient and low cost processing technology for recycling of PCBs can not only avoid environmental pollution, but also help to recycle valuable resources, which has a great practical significance for continuous improvement of the human living environment and resources recycling. Mechanical and hydrometallurgical methods have been the traditional methods of recycling PCBs. Many researchers have used various mechanical methods to separate metals and non-metals from PCBs, such as multi-crushing, grinding, electrostatic separation, gravity separation, density-based separation and magnetic separation [23].

Hydrometallurgical and mechanical methods have been the traditional methods of recycling PCBs. High chemical reagent consumption, high cost and long process, a large amount of waste water and sludge production are the disadvantages. The mechanical methods include crushing, grinding, electrostatic separation, gravity separation, magnetic separation, density-based separation etc. Dust, noise and harmful gas emission, need for complicated equipments are the disadvantages. Noble metals of PCBs may lose as they usually adhere to the resin powder in the crushing and grinding processes. In addition, the resin powder obtained from crushing and grinding processes can only be used as low-value products (paints, building materials, plastic filling materials, etc.) [24].

Guo et al., used glass-nonmetals, a byproduct of recycling waste printed circuit boards (PCBs), to replace wood flour in production of phenolic moulding compound (PMC) [25]. Quan and co-workers carried out the pyrolysis of PCB waste on a fixed-bed reactor [26]. Zhou et al. made the recycling of organic materials and solder from PCBs by vacuum pyrolysis-centrifugation coupling technology [24]. Long and co-workers' study demonstrated the feasibility of vacuum pyrolysis and mechanical processing for recycling PCB. And the glass fiber could be obtained by calcinations in a muffle furnace at 600°C for 10 min. The main components of the non-metal materials of waste PCBs are glass fibers and thermoset resin matrix [27]. According to Zheng, a fluidized bed process can be used to recover glass fibers [28].

4. THE RECYCLING OF CATHODE RAY TUBES (CRTS)

Cathode ray tubes are a major item in electronic recycling due to their volume, recycling costs and disposal restrictions. A CRT consists of two major parts. One is the glass

components (funnel glass, panel glass, solder glass, neck) and the other is the non-glass components. CRT glass consists of SiO_2, Na_2O, CaO, and other components for coloring, oxidizing, and protecting from X-rays (K_2O, MgO, ZnO, BaO, PbO). Because CRTs contain lead (Pb), proper handling is necessary to avoid contamination of air, soil and ground water [29].

Glass-to-glass and glass-to-lead recycling are two technologies that could be used for CRT recycling. In glass-to-glass recycling, collected CRTs are sent to recycler where the whole glass is ground into cullet without separation of panel and funnel glass. Then the recycler sends these cullets to manufacturers for making new CRTs. The metallic lead and copper are separated and recovered from CRT glass through a smelting process in case of glass-to-lead recycling. The recovered CRT glass goes on to lead smelter and CRT glasses act as a fluxing agent in smelting process [30]. The third option has been developed recently in Hong Kong and it involves a process of crushing, acid washing and water rinsing. The recycling process of CRT panel glass mainly involves the removal of fluorescent powder on the inner surface by vacuum, and then using a mechanical crusher to break it down into smaller particle size in a safe manner. Then the crushed panel glass can be used directly as glass aggregate in construction products due to its low lead content. The crushed CRT funnel glass was surface-treated by immersing it in a bath of 5% nitric acid (HNO_3) solution for 3 h to extract lead from the surface of the crushed glass. After that, the acid-treated crushed glass was removed from the nitric acid bath and was thoroughly rinsed by using tap water to remove the remaining acid [31].

CRT glass can be used in brick manufacturing. In the process, ground glass is pressed in a mould with a binder. The products obtained can be used as decorative products in building or highways. Another potential use is foam glass. The product obtained can be marketed as loose fill aggregate replacement for concrete products. Coloured table ware glass can be produced using 97 wt.% of panel glass waste into the batch. The production of insulating fibre glass by adding about 10 wt.% of panel glass to a typical batch composition is another possibility. CRT glass can also be utilized in porcelain stoneware bodies [32].

According to Andreola and co-workers, cathode ray tube, CRTs are used in brick manufacturing (ground glass is pressed in a mould with a binder and then fired). The products will be used as decorative products in building or highways [32]. Mear et al. created foam glasses from cathode ray tube, CRTs (screen and funnel) using a reducing agent [33]. Bernardo et al. produced Al_2O_3 platelet-reinforced glass matrix composites from glasses coming from dismantled cathode ray tubes [34]. In another study of Bernardo and co-workers, Al-reinforced lead silicate glass matrix composites were fabricated using CRTs [35]. Andreola and co-workers stated that CRT glass is used to produce coloured tableware glass. The production of insulating fibre glass by adding about 10 wt.% of panel glass to a typical batch composition is also possible. CRT glass is also used in porcelain stoneware bodies. Andreola et al. proposed feasibility of CRT glass recycling in ceramic field using it into a base glaze formulation as substitute of “ceramic frits”. Andreola et al. developed glass-ceramics from panel or funnel glass with dolomite and alumina [32].

5. CONCLUSION

Recycling raw materials from end-of-life electronics is the most effective solution to the growing e-waste problem. LCD glass was added into concrete instead of sand and was used to make glass-ceramics. The pyrolysis of PCB waste on a fixed-bed reactor, using vacuum pyrolysis and mechanical processing or using a fluidized bed process were carried out.

CRTs were used in brick manufacturing, for creating foam glasses, glass matrix composites, coloured tableware glass, porcelain stoneware bodies or as the substitute of ceramic frits. It was concluded that CRT, LCD and PCBs are popular resources of glass recycling and they can be used in different applications.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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