Determining The Optical and Radiation Characteristics of the Glass of Cathode Ray Tubes (CRTs) and the capability to produce Radiation Shielding Glass

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Abstract

A new method for recycling the glass of Cathode Ray Tubes (CRTs) is presented in this paper. The glass from CRTs is suggested to be used as row materials for producing radiation shielding glass. Cathode ray tubes glass contains considerable amounts of environmentally hazardous toxic waste namely heavy metal oxides such as lead oxide (PbO). This makes CRTs glass a favorable choice to be used as row material for Radiation shielding materials, as heavy metal oxides increases its density, which make the produced glass nearly equivalent to commercially available shielding glass. CRTs glasses have been characterized to determine the heavy oxides content, density, refractive index, and radiation shielding properties for different gamma rays energies empirically by using the source Co-60 and theoretically by using the code XCOM. The measured and the calculated values were in a good compatibility. The effect of irradiation on the transparency for each part of the CRTs glass has been studied. Results showed that some parts of CRTs glass are more resistant to radiation than others. The study has shown that the glass of cathode ray tubes can be recycled as a radiation shielding glass at least in some applications.

1 Introduction

The generated amount of waste electrical and electronic equipment (WEEE) or e-waste in the world is growing rapidly see Fig.1. The content of hazardous components in electrical and electronic equipment (EEE) is a major concern during the waste management phase. Ideally, the materials in electronic products should be re-used when the products reach the end of their service life.

In the European Union (EU), WEEE represents about 7.5 million tons each year, where computer monitors and TV sets containing cathode-ray tubes (CRTs) represent about 80 % of the total electronic waste [1].

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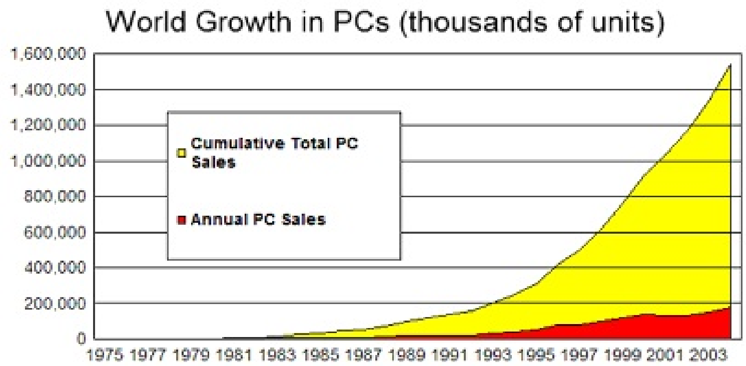

Figure 1: The exponential increase of the production of personal computers in the world [2].

The Table.1. Shows the annual energy needs, costs, and CO_2 emissions for the production one personal computer [3]. These huge amounts of toxic wastes (for example lead compounds) affect the environment. The total amount of lead in 315 million of personal computers exhausted between 1997 and 2004 in the united states is about 600 000 tons. Additionally, these amounts of personal computers contain about 151.2 tons of gold and 1786.1 tons of silver [4],[5].

Table 1: Annual energy needs, costs, and CO_2 emissions for the production of one personal computers [3].

EfficientProducts.org: US Operational Energy Cost per Computer per Year

Computer Type	Annual Energy Use (kWh)	Electricity Cost (USD)*	CO2 Emissions (lbs.)**	US PCs in Use (millions)	US Total Annual Energy Use (gWh)	US Total Annual CO2 Emissions (millions of lbs)
Desktop	200 - 400	$16 - $32	268 - 536	150	30,000 - 60,000	40,230 - 80,460
Laptop	80 - 140	$6 - $11	107 - 188	50	4,000 - 7,000	5,364 - 9,387
Server	1500	$120,00	2012	10	15,000	20,115

The aforementioned statistics indicate to the need to the development of new methods to recycle these costly (both economically and environmentally) products. The glass of cathode rays tubes (CRT) can be classified according to its chemical composition into 3 types; the panel glass, the funnel glass, and the neck glass. The glass constitute between 50 % and 85 % of the total weight of a computer monitor or a television set [1].

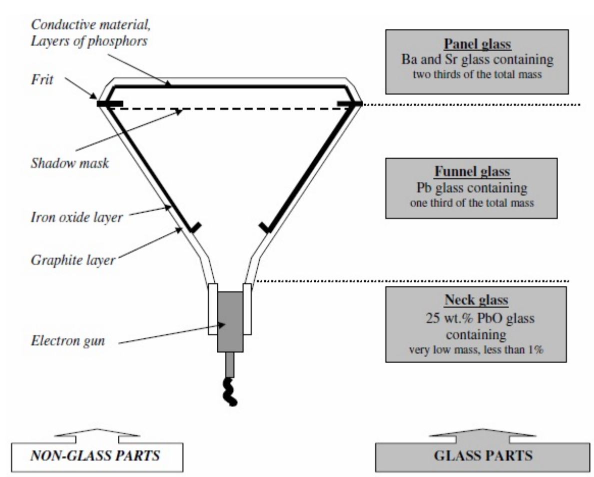

Figure 2: The glass and non glass parts of typical cathode ray tube (CRT) [1].

All the three types of CRT glass contain hazardous heavy elements (i.e. lead, strontium, antimony, barium, europium, selenium etc. . .). Collected monitors are dismantled and treated, and the CRT glass generally ends up in a special landfill licensed for hazardous waste. Hence, in Europe almost 90 % of the end of life (EOL) electronic goods is disposed of in landfills [1].

As the lead content in these waste products represents as much as 80 % of the toxic metals in discard electronics, CRTs represent a clear potential pollution danger to the environment [1]. Therefore, many researches have been carried out to explore new methods for recycling CRTs [5].

2 Materials and Methods

Cathode ray tubes made by Hitachi Co. (after year 2000) were used in this research. The CRTs were dismantled, the glass parts were separated and cleaned very well, first by water and then by ethanol. The phosphorus deposited layer, and other foreign layers were etched out. The three types of glass in each CRT were separated.

The average ratio for each type of glasses in the studied samples were Panel = 65 %, Funnel = 34 %, Neck = 1 % (by wt.).

Samples were analyzed using scanning electron microscopy SEM-EDX technique to estimate their main component and their content of heavy metals. The densities of the samples were measured using Archimedes principle. Refraction indexes were measured using laser source (wavelength between 655 nm ± 25 nm) and by using Snell relation:

$$n_0 \cdot \sin\theta_0 = n \cdot \sin\theta$$

Attenuation coefficients of the tested samples were measured experimentally using Co-60 source, and calculated theoretically using the code XCOM [6]. Transmission of light were investigated in the visible range of spectrum (between 400–800 nm) using UV- visible photo-spectrometer made by Cecil instrument limited, model No. 2021. The samples were prepared for the transmission test by polishing on lapping machine and SiC polishing papers up to 1200 grits.

The samples were crashed and grinded, and mixtures were made from the different types of glass in the same ratios as in the original CRTs. The grinded glass was melted in electric box type furnace using Pt crucible, and have been cast in simple stainless steel moulds. The resulted samples were characterized in the same way as above mentioned.

The radiation resistance properties of the original as well as the new prepared samples were studied against different irradiation doses using Co-60 source. The glass were irradiated by using the source Co^{60} to three doses: 1 kGy, 3 kGy and 5 kGy. The used irradiation dose rate was 1 kGy/h. samples were stored for 16 hours before measuring the transmission spectra, to get rid of the effect of that fast fading in the recently irradiated samples.

3 Results and Discussion

The Table.2 shows results of the analyses of the tested samples as oxides. it can be noticed that funnel and neck parts of CRT contains relatively high content of lead oxide, while the panel contains relatively high content of barium and strontium oxides. This result is in accordance with the data in literatures.

Table.3 shows the results of the density and refraction index measurements. The three tested types of glass are heavier than ordinary alkali lime silicate glass (density about 2.4 g/cm^3). As the attenuation efficiency of materials is related to its density, the last result support the suggestion for the use of the new glass as radiation shielding material.

The Table.4 and Table.5 show the linear attenuation coefficients, the half-value layers and the tenth value layers for the tested samples. The calculated and measured values are in a good compatibility.

Table 2: Ratios of the oxides in each part of the CRT and the Mix.

Oxide	Funnel	Panel	Nick	Mix
B_2O_3	6.90	7.53	5.37	6.21
Na_2O	5.86	6.78	1.58	6.15
MgO	1.71	0.07	0.18	0.76
Al_2O_3	4.89	1.98	2.45	2.74
SiO_2	45.92	54.72	43.21	52.20
K_2O	6.08	5.65	7.11	6.59
CaO	3.47	0.94	1.30	1.55
SrO	1.47	9.48	2.27	6.89
ZrO_2	0.82	2.44	0.37	2.04
Sb_2O_3	0.06	0.25	0.69	0.14
BaO	0.00	7.88	0.42	5.70
CeO_2	0.42	0.41	0.44	0.37
PbO	20.03	0.00	33.15	6.50
SnO	0.06	0.00	0.11	0.62
TiO_2	0.47	0.33	0.21	0.43

Table 3: The density and the refraction index of the tested samples: the funnel, the panel and the Mix.

Glass Type	Density(g/cm^3)(±0.01)	Refractive Index N_d at (655±25)(±3.5%)nm
Funnel	3.01	1.561
Panel	2.77	1.541
Mix(Mixture)	2.88	1.505

Table 4: The attenuation coefficients for the tested samples.

Glass Type	Density (g.cm^{-3})	Measured Attenuation Coefficients (cm^{-1}) At Energy Co-60 (keV)	Attenuation Coefficients Calculated by XCOM (cm^{-1})			
			At Energies (keV)			
			X-Ray	Cs-137	Co-60	
			100	661.6	1173.24	1332.5
Funnel	3.01	0.19	3.60	0.25	0.18	0.17
Panel	2.77	0.16	1.09	0.21	0.16	0.15
Mix	2.88	0.17	1.92	0.23	0.17	0.16
Neck	3.25	-	6.07	0.28	0.19	0.18

Table 5: The half value and tenth value layers for the tested samples.

The Glass	Half Value Layers At Isotope's Energies (cm)		Tenth Value Layers At Isotope's Energies (cm)		
	Cs-137	Co-60		Cs-137	Co-60
Funnel	2.77	3.85	9.21	12.79	
Panel	3.30	4.33	10.96	14.39	
Mix	3.01	4.08	10.01	13.54	
Neck	2.48	3.65	8.22	12.12	

The Fig.3 shows the optical transmission spectra for the three studied samples; funnel, panel, and the mix of them. These spectra are for 1 cm thick samples.

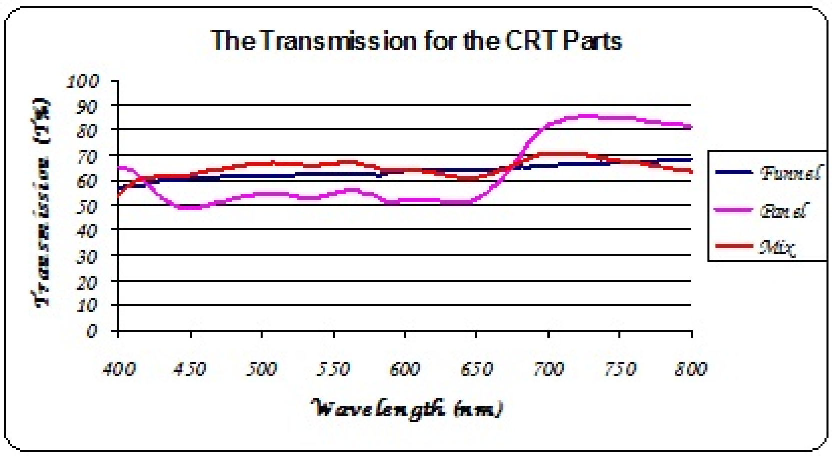

Figure 3: The transmission for the Funnel, Panel and Mix.

The optical losses are less for funnel and the mix glasses are between 30 to 40 % for most of the visible wavelength range, while it vary between 50 to 15% for panel glass, which suggests the use of longer wavelength light sources to decrease the losses. Figures 4, 5, 6 show the changes in transmission for the three investigated glass, against different irradiation doses.

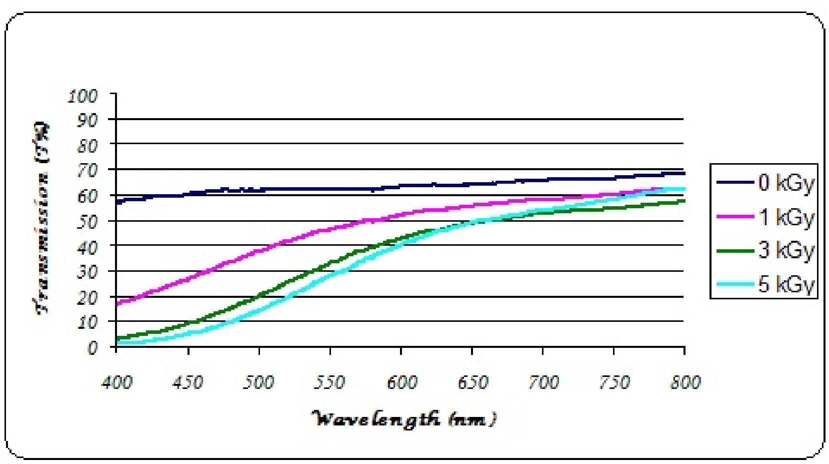

Figure 4: The effect of irradiation on the transmission spectrum of funnel glass.

In funnel glass, the transmission decreases with increasing of the irradiation doses. The loss is more in the shorter wavelength range.

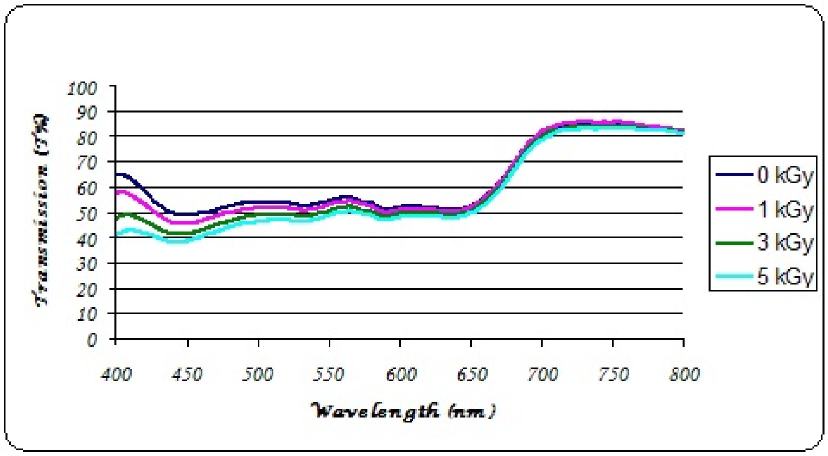

Figure 5: The effect of irradiation on the transmission spectrum of panel glass.

Fig.5 shows that CRTs panel glass doesn't affect much by irradiation; and the maximum loss of transmission in the spectra is about 20%. This radiation resistance of panel glass can be explained by the high content of Strontium oxide. Some oxides have been used to stabilize glass [7].

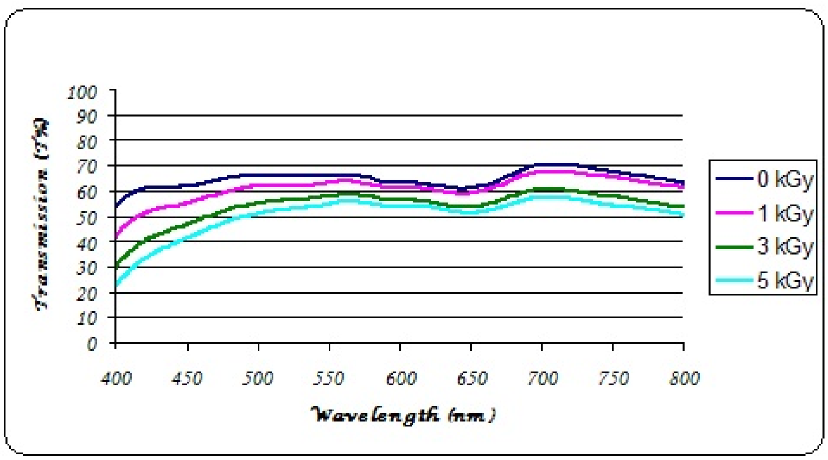

Figure 6: The effect of irradiation on the transmission spectrum of mix glass.

The behavior of the mix glass is an average for the behavior of two types of glass, it is made of. It is affected moderately by irradiation, and the effect is more in the range of the shorter wavelengths. To estimate the radiation resistance of the studied glasses, their behavior after irradiation can be compared to the behavior of a well known type of glass with a good resistance for radiation effects i.e. BK7 produced by Schott Co [8],[9]. The Fig.7 shows the transmission spectra before and after irradiation, for BK7 glass samples (1 Gy = 100 rad). The samples were irradiated by gamma radiation from Co^{60} source at dose rate of 24 Gy/h.

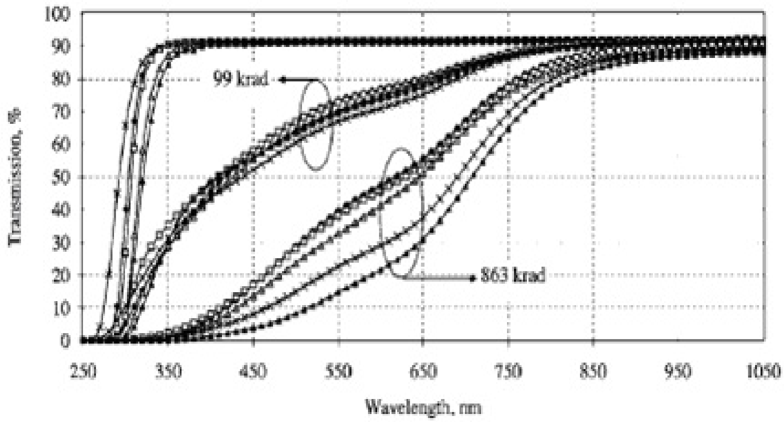

Figure 7: The transmission spectra for the glass: BK7 before and After irradiation (thickness = 0.5 cm) [9].

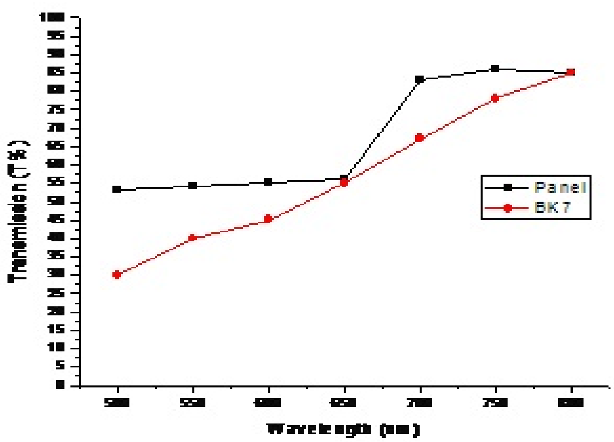

Figure 8: Comparison transmission between two glasses: panel and BK7 at dose of 8.63 kGy.

This figure shows a comparison between panel glass and BK7 at dose of 8.63 kGy. Panel glass has a less transmission losses, and the maximum difference between values is about 25%.

4 Conclusion

The glass of cathode ray tubes can be recycled to obtain radiation protection glass: Panel glass, funnel glass, and the mixture of them are all recyclable. The resulted glass have good attenuation properties and suitable stability against irradiation effects.

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