Pyrolysis as a recycling method of polymeric blends and plastics collected from WEEE in a fixed-bed reactor

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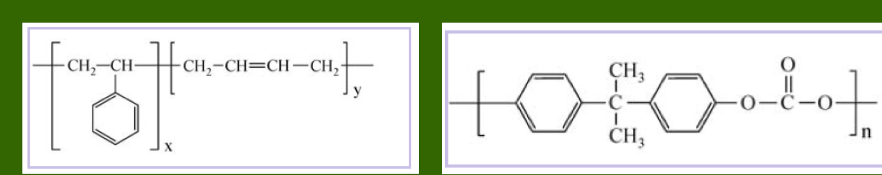
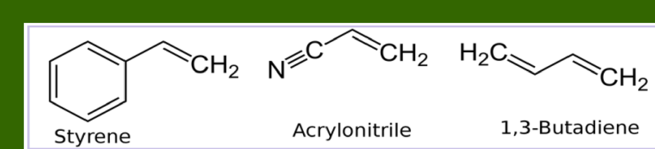
Introduction

The production and consumption of electric and electronic devices have increased over the last years leading to large amounts of waste electric and electronic equipment (WEEE). Plastics in WEEE represent a big percentage, almost 30% of WEEE; and the most commonly used are acrylonitrile-butadiene-styrene (ABS), high-impact polystyrene (HIPS), polycarbonate (PC), etc. (Ma et al. 2016). A difficulty in the recycling of plastics from WEEE is the fact that they often contain various, toxic additives, such as pigments, plasticizers and brominated flame retardants (BFR). BFR are added into plastics in order to reduce their flammability, but during the recycling of brominated flame retarded plastics careful handling is required, in order to avoid environmental contamination (Charitopoulou et al. 2021).



HIPS PC



Monomers in ABS

Pyrolizer /GC-MS

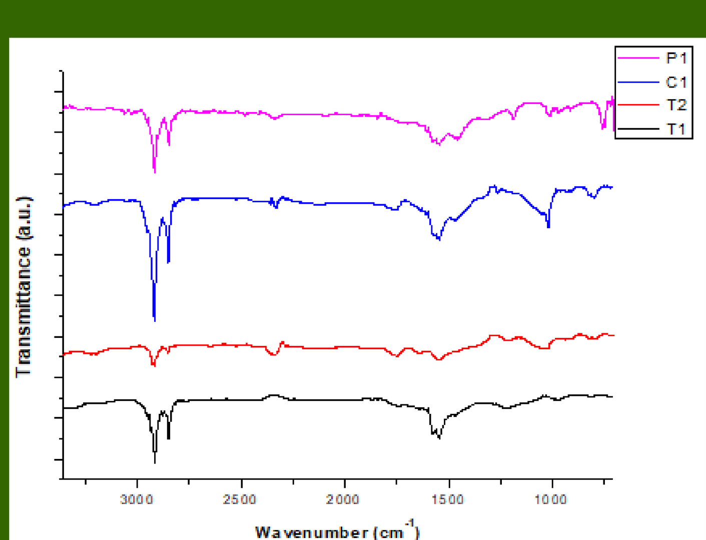
The disposal of WEEE occurs via landfilling, energy recovery, mechanical recycling and chemical recycling. Among them, chemical recycling and especially pyrolysis has many advantages and is often selected by many researchers as an environmentally friendly method. During pyrolysis the monomers can be recovered and secondary valuable materials can be produced. It takes place in an inert atmosphere, medium to high temperatures (300–600 °C) and in the absence or presence of catalysts. During pyrolysis, plastic waste is converted into liquids, gases and solid residues (chars) (Miandad et al. 2016).

This work investigated the thermal pyrolysis of polymeric blends with composition similar to that found in WEEE, as well as of several plastic materials gathered from real WEEE, aiming in recovering secondary valuable products and monomers. The blends consisted of ABS, HIPS, PC and/or PP along with tetrabromobisphenol A (TBBPA), which is a very common BFR. The plastic fractions coming from WEEE, included television, computer and printer samples. All of them were subjected to Fourier transform infrared spectroscopy (FTIR) and Evolved Gas Analysis (EGA). Thermal pyrolysis was also conducted at 440 °C, using a bench-scale fixed bed reactor; and the liquid, solid and gaseous products were analysed.

Materials and methods

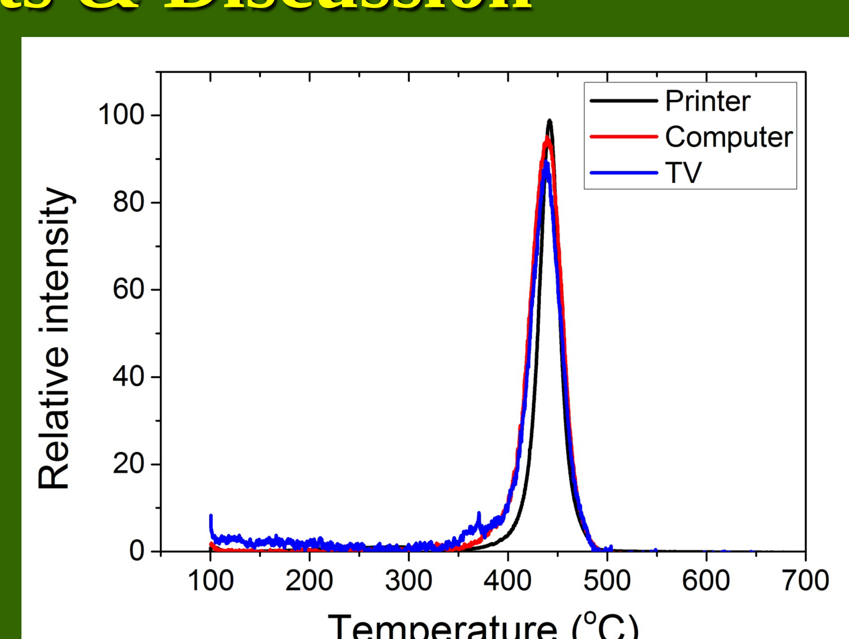
Blends were prepared using a twin-screw extruder at 210°C and 30 rpm. The extrudates were further processed into thin films by hot pressing at 200°C.
The plastic materials coming from WEEE were collected from a recycling plant or from household appliances and included parts from waste televisions (T1 and T2), computers (C1) and printers (P1).
Both the blends and the plastic samples were analysed according to their chemical structure using Fourier transform infrared spectroscopy (FTIR).
EGA analysis was applied in order to receive information about the decomposition temperature range of the samples and was carried out on a Pyrolizer (EGA/PY-3030D Frontier Laboratories), with purge gas He, heating in the range of 100–700°C with a rate of 20°C/min, under satisfactory vacuum.
Pyrolysis experiments were performed at 440 °C, in a bench-scale fixed bed reactor heated by a 3-zone electrical furnace. A specially designed piston system was used to introduce the feedstock into the reactor and a constant stream of N_2 was fed from the top of the reactor for the continuous withdrawal of the products and the maintenance of inert atmosphere during pyrolysis.

Results & Discussion



FTIR spectra of plastics from WEEE

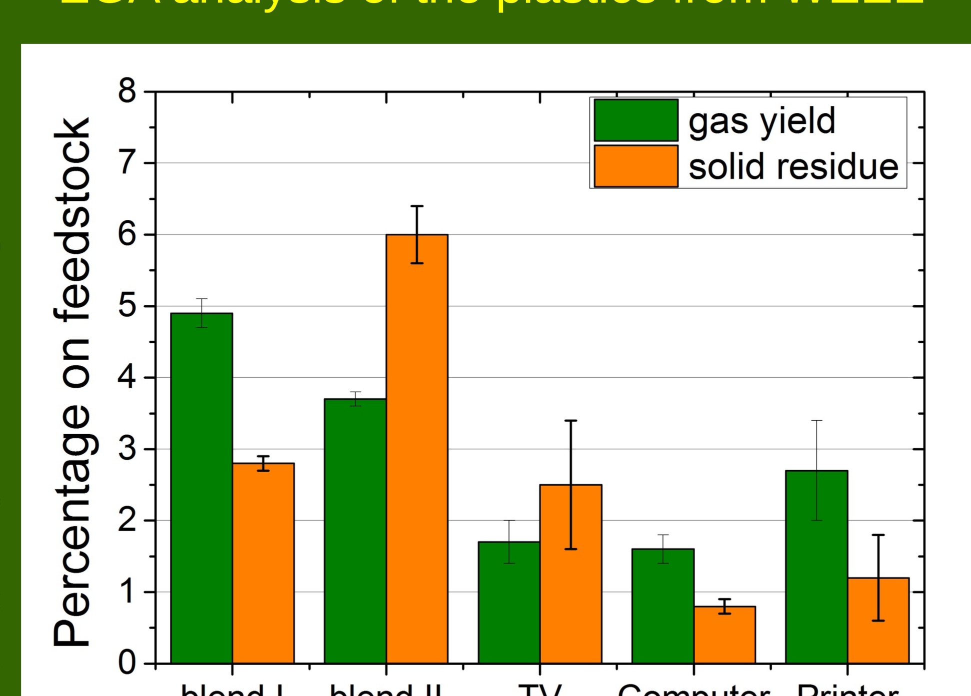
From FTIR measurements of the unknown plastics from WEEE, two strong peaks, within the range: 2840-3000 cm^{-1}, were identified. These peaks are attributed to C-H bond and are indicative of styrenic polymers (ABS or HIPS).



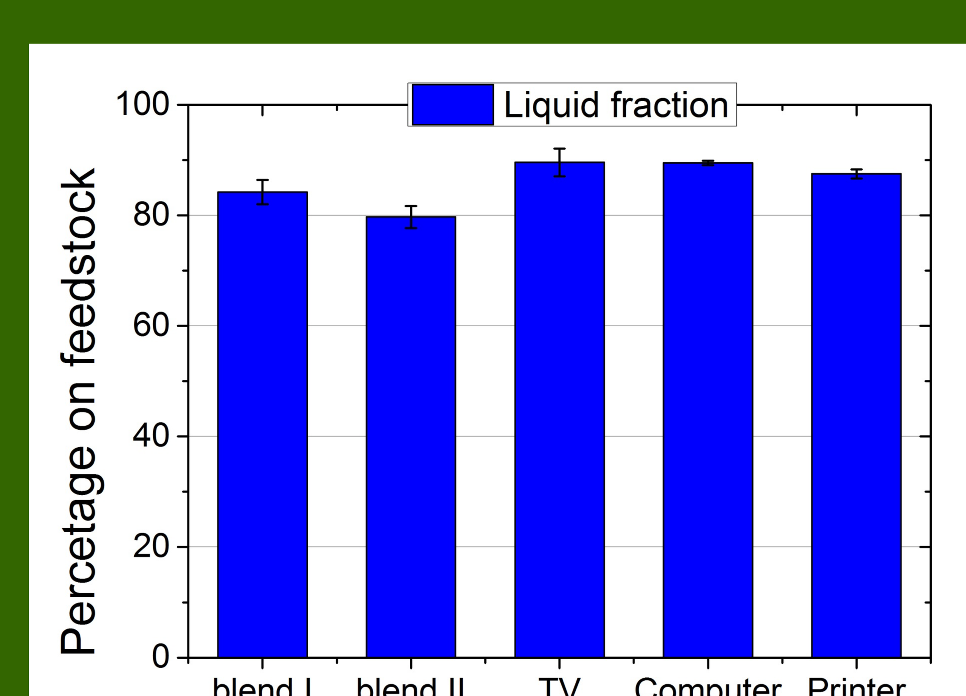
EGA analysis of the plastics from WEEE

According to the EGA analysis the thermal degradation of the blends was quite similar, since the degradation started, became maximum and ended at very close temperatures; and seemed to follow a one-step mechanism.
As for the plastic samples, again the degradation followed a one-step mechanism, since one strong peak was observed, with temperature at the peak equal to 440 °C.

Pyrolysis in a Fixed Bed reactor at 440 °C.
The degradation products fall under three main categories: total liquid product, gas and solid:
► In all materials the liquid fraction after pyrolysis varied between 80 and 90 %.
► A small gaseous fraction was received: 2-5%
► The solid residue varied from 1 to 6%
► The gaseous fraction included mainly hydrocarbons from C_1–C_6 small amounts of CO, CO_2.
► The liquid fraction of the WEEE wastes included aromatic compounds such as the monomer styrene, the dimer and trimer, as well as ethyl benzene, xylene and compounds with two or three aromatic rings.



Gas and solid fraction obtained after pyrolysis



Liquid fraction from pyrolysis

Conclusions

Both blends and plastics from WEEE were subjected to thermal pyrolysis for their recycling
Thermal degradation of the blends and WEEE plastics followed a one-step mechanism with peak at 440 °C and a high percentage of a liquid fraction.

References

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