The Materials Content of WEEE – Plastics

Professor Martin Goosey

IeMRC Industrial Director

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The vision of the IeMRC is to be the UK's internationally recognised provider of world-class electronics manufacturing research. It will focus on sustaining and growing high value manufacturing in the UK by delivering innovative and exploitable new technologies through its highly skilled people and by providing strategic value to the electronics industry.
Overview of the IeMRC

- Established 2004 with a £16M research budget over 10 years
- By 2013 had funded
  - research in >30 UK institutes
  - 100 investigators
  - 42 research associates
  - 30 research students
- Various themes including ‘Sustainability’
- Funding to March 2015
Europe produced around 9 million tonnes of WEEE in 2005.

Predicted to reach 12 million tonnes by 2020.

The UK produced 2 million tonnes.

A UK citizen born in 2003 will be responsible for 8 tonnes of WEEE.
Introduction
The composition of WEEE varies by product:

<table>
<thead>
<tr>
<th>Product category</th>
<th>PE</th>
<th>PP</th>
<th>PVC</th>
<th>PS</th>
<th>ABS</th>
<th>PC</th>
<th>PA</th>
<th>PET</th>
<th>Other</th>
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<tbody>
<tr>
<td>Large domestic appliances</td>
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<td>PU</td>
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<tr>
<td>Small domestic appliances</td>
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<td>Epoxy</td>
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<td>Epoxy, PU</td>
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<td>Brown goods</td>
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<td>PET</td>
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<td>Telecommunications equipment</td>
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<td>Thermosets</td>
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<tr>
<td>Electrical equipment</td>
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<td>Epoxy, PU</td>
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<td>Office equipment</td>
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<td>Cables</td>
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</table>

Typical major plastic types found in WEEE
The key plastics commonly encountered in WEEE include:

- Polystyrene and ABS
- Polycarbonate
- PC/ABS blends
- High impact polystyrene
- Polyphenylene oxide blends
- Polyethylene and Polypropylene
- Polyurethanes
- Other specialist materials
New Technologies for Recycling

- There are still technology issues limiting the amount of materials recycling e.g. plastics separation
- Much work underway to develop new approaches for materials recycling from end-of-life electronics
  - metals recovery and separation techniques
  - rapid identification of plastics
  - liquid crystal display treatment and metals separation
  - removal of brominated flame retardants from polymers
  - many others on novel materials and techniques
There are numerous issues impacting the ability to recover and recycle plastics eg:

- difficulty in separating them – need for new automated technologies
- presence of proscribed materials eg brominated flame retardants, POPs, antimony, cadmium, lead etc
- end of life in Europe, while new products are made in the Far East
- degradation of polymers with time, so need to reformulate to give virgin properties
- legislation impacts – WEEE, RoHS, EuP, ELV and REACH
Electronics Waste and Recycling

- The current situation with end-of-life electronics is not sustainable and wastes valuable resources
- More work needs to be done to encourage and develop new approaches to end of life electronics
- Europe has forced the issue through ‘Producer Responsibility’ legislation such as WEEE and EuP
- New technologies are needed and new thinking across society as a whole, eg design for disassembly, repair, reuse
Several novel and interesting plastic recycling technologies available

- Multi-wavelength spectroscopy/MVSA
- Froth Flotation
- Ionic liquids
- CreaSolve process
- Use of RFID/RFIX in electronics
One of the barriers to polymer recycling is the rapid identification of polymer types in mixed waste streams. Needs to be made possible quickly and economically. IeMRC supported work at Surrey University on the use of multi-wavelength spectroscopy coupled with *MVSA for identifying plastics in real time.

*MVSA = multi-variate statistical analysis
Multi-Wavelength Spectroscopy

- Visible spectral range (electronic transitions): information relating to colour variation
- Near-infrared (NIR) spectral range (overtones and combinations of molecular vibrations): information relating to presence of specific functional groups
- MVSA unscrambles all spectral information: regression of spectral data against known materials parameters
- Fibre-optic probes designed for sampling in the field
- Non-destructive and fast technique

*MVSA = multi-variate statistical analysis*
Multi-Wavelength Spectroscopy

 Courtesy Gary Stephens, Surrey University,
Plastics Characterisation Results

- Plastic types and grades can be identified
- Flame retardant content determined to better than 0.2%
- Property variations can be read with good accuracy
- Influence of UV exposure can be seen
- Mechanical processing effects can be identified
Froth Flotation

- Froth flotation – polymer separation process developed by Argonne National Laboratory, Illinois, USA
- Gas bubbles attached to surfaces of polymers modifying their density and enhancing the separation of less dense from more dense
- A 2 tonne per hour pilot plant capacity built with a mechanical separation facility and a six-stage wet density/froth flotation plant
Froth Flotation

• Mechanical stage separated waste into five primary components:
  - polymer fraction (45%)
  - residual metals concentrate (10%)
  - polyurethane foam portion (5% by weight)
  - an organic-rich fraction (25%)
  - metal oxides fraction (15%)

• Polymer fraction then separated further in the froth flotation system

• Enables recovery of individual plastic types or families of polymers
• Ionic Liquids/Deep Eutectic Solvents – novel group of new materials capable of selectively dissolving various plastics
• Two stage solvent process developed – initially separate a number of polymers then selectively dissolve PVC
• HiPerPol uses advanced computer model to select less toxic DE solvent
• Reduced heat input (no steam, low temperature recovery) and costs
• Cadmium and lead reduced to below 100 ppm
• Production of virgin quality polymer from recyclate

[Chemical structures of Choline Chloride and Ethylene Glycol]
• SIMS separates WEEE material into useful fractions – metals, glass, plastics (ABS, polystyrenes, polyolefins).

• Remaining has no value – composites, unusual fillers, other organics etc.

• Can not recover energy due to high PVC content.

• Two stage solvent process developed – initially separates a number of polymers followed by selectively dissolving PVC.

• Remaining material suitable for energy recovery and PVC for sale.

100 litre pilot plant built by C-tech Innovation for process trails and scale-up studies.
CreaSolv Process

- Plastics from WEEE often contains brominated flame retardants (BFRs) – banned in Europe under the RoHS Directive
- Because of the BFR issue, e-plastics has been baled and shipped to China (estimated 99% of U.S. e-plastic shipped)
- The CreaSolv process, developed by the Fraunhofer, Germany, removes brominated flame retardants from plastics
- CreaSolv uses a non-VOC solvent developed by CreaCycle GmbH
- Test show the process capable of reducing brominated FR concentration down to 0.055% ie below RoHS limits
Use of RFIX Devices - InBoard

- The electronic equipment contains an embedded semiconductor device.
- Monitors the whole product life cycle and provides recyclers with useful information, e.g., service life and history, material composition, presence of hazardous materials, types of polymers used, and disassembly information.
- Highlights issues during service that may cause problems at end of life or shorten life.
Use of RFIX Devices - InBoard

• The RFIX tags can be integrated and manufactured reliably into PCBs
• Product design does not need to be changed significantly
• Embedded RFIX withstands harsh environments
• Product information can be accessed through the product life cycle
• Decision making optimised due to accessibility of product information
Use of RFIX Devices - Intellico

- Use of RFIX during manual disassembly enables components and materials to be selectively removed prior to shredding.
- i.e. upgrades the value from the recycling operation.
- Method used by vertically integrated Japanese recyclers but NOT in the UK or Europe.
Different Approaches to WEEE

- In Europe WEEE recycling has traditionally focussed on precious metal recovery – ie preparing for smelting
- The collection processes have also tended to mix material collected under the WEEE Directives
Electronics Recycling in Japan

Matsushita’s METEC Facility - Japan
Until recently most LCDs used compact fluorescent tubes to provide the backlighting. These contained small amounts of mercury (a few mg per tube). New technologies now replacing traditional backlights presented a problem for recyclers and RoHS compliance. Circuit boards and components can also contain BFRs.
LCD Recycling Issues

LCDs Contain Hazardous Materials

COLD CATHODE FLUORESCENT LAMP IN LCD PANEL CONTAINS A SMALL AMOUNT OF MERCURY, PLEASE FOLLOW LOCAL ORDINANCES OR REGULATIONS FOR DISPOSAL.
TV Backlight Content

<table>
<thead>
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<th>Lamp number</th>
<th>15&quot;</th>
<th>17&quot;</th>
<th>19&quot;</th>
<th>20&quot;</th>
<th>26&quot;</th>
<th>32-37&quot;</th>
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</tbody>
</table>

The bar chart illustrates the number of lamps used for different TV sizes.
Display Technology is Rapidly Evolving

- Display technology has rapidly moved from CRT to Liquid Crystal
- LCD technology is also evolving eg from CFL to LED backlighting
- New types of display are emerging
- Likely to see OLED and related technologies finding increasing use
- These will offer new materials recycling opportunities and challenges
Future Display Considerations

Disposal of Televisions 2005 to 2020

• LCDs contain a wide range of materials

• A key challenge is to determine which are worth recovering

• Consider factors such as value of the material and time to access

• Example materials include various plastics, metals, glass and the liquid crystals themselves

• Key materials might be copper, gold, indium, LCDs, ABS/PC
### Material Composition of 1 tonne of LCDs

<table>
<thead>
<tr>
<th>Material/component</th>
<th>Weight/kg</th>
<th>Percent/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>830</td>
<td>83</td>
</tr>
<tr>
<td>Plastic</td>
<td>149</td>
<td>14.9</td>
</tr>
<tr>
<td>Electronic Component</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>Liquid Crystal</td>
<td>1</td>
<td>0.1</td>
</tr>
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</table>

Within these individual components are many different materials but How are they accessed?
Materials Recovery Challenges

- LCDs are complex assemblies
- It takes considerable time and effort to access component parts
- The display itself is a complex assembly
- Multiple and disparate materials
• Several polymer types found in LCDs

• The casing is the most obvious and easy to access

• The display itself probably contains the most valuable polymeric material

• But it is difficult to access and to separate the individual polymers
WRAP supported project to trial and assess some of the most promising separation techniques to emerge in recent years.

Techniques that showed promise for separating WEEE materials included:

- TITECH Near infrared (NIR) ‘Polysort’ sorter
- Visys laser sorter
- Delft University Kinetic Gravity Separator
- Holman Wilfley wet shaking table
- Allmineral ‘Allflux’ upflow classifier

Future Trends

- Electronics is typically characterised by increased performance, reduced size and lower costs

- More legislative pressure on materials use and also material scarcity issues

- Increasing levels of recovery and recycling required – WEEE Recast

- Many new technologies emerging with implications for plastics use and recovery;
  - large area electronics – advertising, lighting, clothing
  - printed electronics – only deposited where needed
  - organic materials more widely used – OLEDs, photovoltaics, batteries
Information about the IeMRC

- Visit the IeMRC website
- Contact IeMRC’s researchers
- Annual reports available; new one ready to print
- Collaborative Seminars
- Annual Conference –September in Loughborough, UK
The Materials Content of WEEE – Plastics

m.goosey@lboro.ac.uk

+44 7808 910844