Biodegradable carrier bags – Solutions through innovation

Lot 2: Detection and Separation

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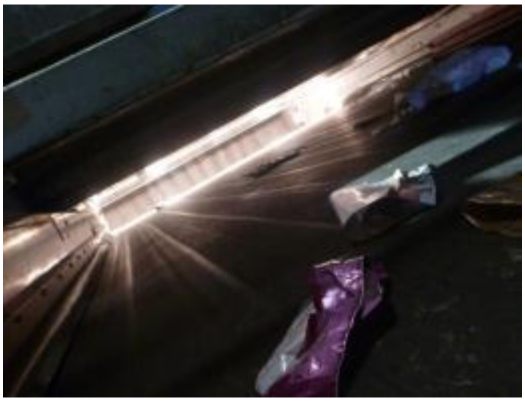

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Introduction

There are no direct measurements of the quantity of post-consumer film and flexible packaging waste generated in the UK each year, but combining the estimates from various sources indicates that the total annual arisings in the UK are in the range of 500,000 to 1.2 million tonnes of post-consumer film and flexible packaging waste. Of this, approximately 50% is polyethylene (PE) in various forms and approximately 15% is polypropylene (PP), both of which are of value to recyclers and reprocessors.

There are a number of well-developed technologies for effectively separating two dimensional (2D) and three dimensional (3D) components in the household waste stream such as ballistic separation, disk screens and air separation. Near infra-red (NIR) sensor-based sorting is used to separate the different 2D components into paper, cardboard and mixed plastic streams and can also be used to discriminate between some different plastic film types. However, some non-recyclable plastic film types, particularly the oxo-degradable and biodegradables are not readily identified using current NIR technologies. This is important as the presence of these polymers in the plastic waste stream would not currently be acceptable in feeds used by recyclers to manufacture longer life and structural products.

The UK Government is considering options for encouraging the use of biodegradable Single Use Plastic Carrier Bags (SUPCBs) in the UK. Single use carriers comprise about 6% of the UK plastic film waste stream. If they are converted from PE to polymer types which are not compatible with PE or PP then they may need to be removed from the film stream by recyclers in order to avoid them contaminating the recycled plastics that they produce. If these new polymer types or additive systems are introduced to the SUPCB waste stream it will be important to demonstrate to recyclers that they can be separated cost-effectively by automated techniques in order to avoid downgrading the recyclate from other films in the waste stream.

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Aims and objectives

One of the key aims of this project is to investigate techniques for separating the new polymer types and additives that may be used in SUPCBs in future. The purpose of this study is to:

a) Review the current market as it exists in the UK for the disposal, collection and recycling of post-consumer film waste;

b) Briefly overview the situation in other European countries, particularly with reference to collection schemes for post-consumer film waste;

c) Review the current technology for separating 2D and 3D components in the waste stream;

d) Review the current technology for separating film from other components in the 2D stream;

e) Investigate whether current technologies would be capable of separating recyclable from non-recyclable film materials; and

f) Examine any possible ‘design for recycling’ features that might assist recycling SUPCBs and other types of post-consumer film waste.

Methodology

This project has predominantly been undertaken by desk-based research covering the most recent technologies available for separating plastic film from other materials in the waste stream. It has researched new and emerging technologies that have potential to enable the detection and separation of the non-recyclable components of post-consumer household film waste.

Current technologies for separating film from other waste stream components

Overview of post-consumer waste separation processes

Recyclable waste is treated differently in different regions of the UK. In some areas recyclable waste is collected in a single comingled stream, whereas in other areas paper and card are collected separately from other dry recyclables such as plastic bottles, glass and cans. This distinction is important for the recovery of plastic film (including bags) because paper and card, like plastic film, are 'flat' 2D materials. Most waste sorting plants use a 2D/3D separation to separate the flat materials from 3D materials such as cans and bottles. If the comingled collection contains only paper or only film then the 2D/3D separation is able to isolate a single product stream. When both paper and film are present in a comingled waste stream in large quantities the 2D/3D separation will recover a mixed paper and plastic film stream. This stream must then be separated further, usually by means of NIR sensor based sorting separation technology.

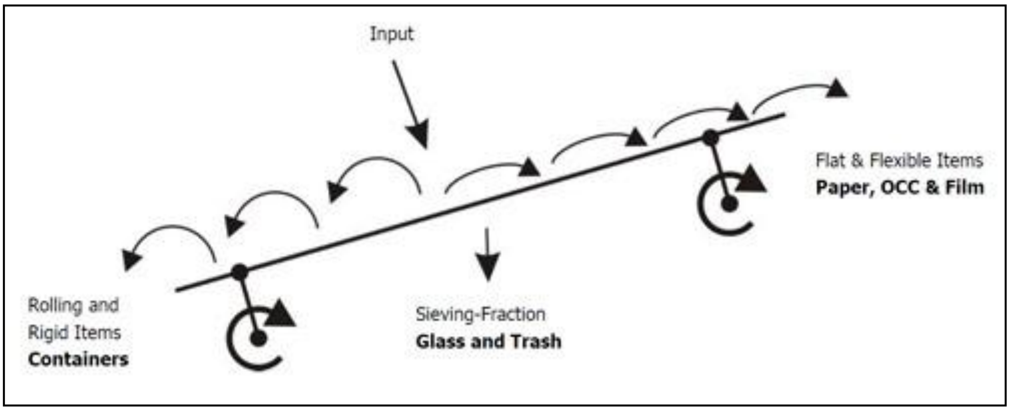
Separation of 2D and 3D components in waste stream

The following processes are commonly used to separate 2D and 3D material.

Ballistic separation

Ballistic separation works using the principle that 3D material (bottles, cans, etc.) tends to roll down slopes, whereas flat, light 2D material will not. Figure 1 shows the principle of operation of this technology.

Figure 1 Principle of operation of ballistic separators



Disk screen

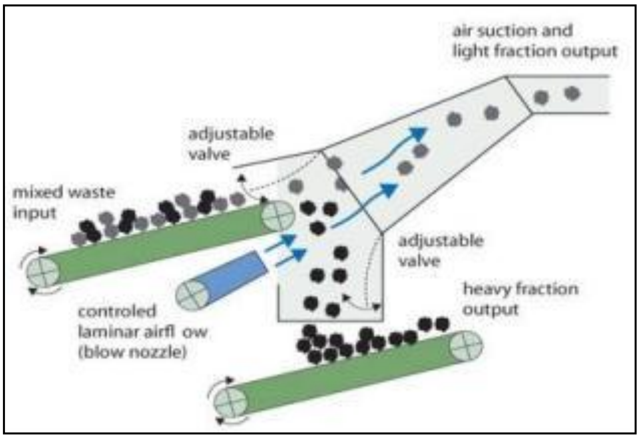
Disk screens have rows of disks rotating about a horizontal axis. The waste travels horizontally over the rotating edges of the disks. Small items simply fall in between the disks, whilst 2D materials lie across several disks and are transported across the top of the disks and out of the machine at the higher end. Figure 2 shows a disk screen.

Figure 2 A disk screen separator showing the rows of rotating disks

Air separation

In contrast to ballistic and disk screen separation, this technology separates purely on the basis of shape and density, and so relies on the assumption that 2D material is lighter and has more air resistance than 3D material. Figure 3 shows a schematic of an air separator.

Figure 3 Schematic diagram of an air separator



Separation of 2D (plastic) components

There are two approaches that are likely to be successful in separating recyclable from non-recyclable plastic films. The first is to 'tag' recyclable films so that the tag can be detected in the waste processing plant and the second is to differentiate materials by detecting differences in chemical composition between the constituent materials.

Detecting differences in chemical composition

Plastics can be identified and then sorted based on detecting differences in their chemical compositions. One such technique is already routinely used in the sorting of plastics; Near Infra-red (NIR).

NIR

This technology is established and routinely used in the UK and around the world for separation of streams of paper, cardboard and mixed plastics. NIR is also used to separate plastic materials into the following categories:

- Polyethylene terephthalate (PET) – clear and coloured;
- High Density polyethylene (HDPE) – natural and coloured;
- Polypropylene (PP);
- Polystyrene (PS); and
- Other (multi-layer laminates, foil laminates, metallised film, and other plastics).

Whilst NIR separators are highly effective for the main polymer types, the technology is unable to detect very dark and black plastics and struggles to identify items in the 'other' category including biodegradable plastics. NIR measures the strength of reflection of light from the item at five to ten discreet wavelengths in the NIR part of the spectrum. This is in contrast to a newer technique called Hyperspectral Imaging (HSI) which is starting to be adopted in the waste sector and looks at hundreds of wavelengths over the same spectral region. NIR gives a rather course spectrum of the optical reflectivity of the material, which is indicative of the chemical composition. This has proved adequate for separation of single materials or polymer types such as PE and PP however it struggles with more difficult tasks such as differentiation of biodegradable materials. Feed rates are typically 2-3 t/hr per metre width of conveyor belt. Efficiency of sorting can be up to 95% dependent on the feedstock and design of the process.

There is some evidence to support the case that if suitably optimised NIR can discriminate between some types of multi-layer film and single polymer films however, this is not yet widely adopted within the sector. Further evidence is needed to determine whether NIR can be optimised enough to distinguish between biodegradable and oxo-degradable plastics.

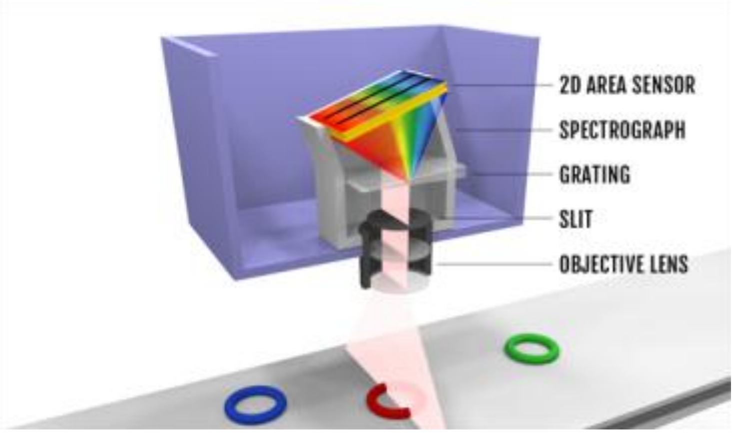
Hyperspectral Imaging (HSI)

HSI is a newer version of spectroscopic sensor based sorting that senses more detail in the spectrum of the material and so can discriminate a greater variety of materials. HSI can use the NIR wavelength range or can use a much wider wavelength range covering the ultra-violet, visible, NIR and mid infra-red parts of the spectrum. In general the wider the spectral range the greater the number of materials that can be distinguished. For most plastics the chemical structure is such that the most useful parts of the spectrum are the near and mid infra-red.

NIR systems use a single detector for each wavelength however HSI uses more modern cameras to detect the reflected light. This results in measuring hundreds of wavelengths simultaneously and also gives a higher spatial resolution across the conveyor belt. Therefore, even for HSI systems that use the same wavelength range in the near infra-red as NIRs, a better degree of discrimination between different materials is expected.

Figure 4 shows the principle of HSI. An 'image' of a line across the conveyor is formed on the sensor. Each point of the image is dispersed in wavelength in the direction perpendicular to the line across the conveyor, thus at each point across the conveyor an entire infra-red spectrum is recorded.

Figure 4 The principle of HSI



Of the materials that need to be sorted, HSI can be used to discriminate PE, PET, PP, multi-layer laminates and some biodegradable materials. Since most substances have characteristic spectra in this wavelength region, it is highly likely that polyhydroxyalkanoates (PHA) and starches will be detectable, because they are chemically very different from PE and PP. Oxo-degradable material may present a greater challenge since this material is a conventional plastic, for example PE but with a metal salt additive that causes the PE polymer chains to breakdown in the presence of oxygen. So to detect this material the HSI detector would have to detect the small amount (around 2%) of additive against the background of PE. Again further work is required to determine whether HSI can distinguish biodegradable and oxo-degradable materials. As the technology is more accurate than NIR it is anticipated that HSI would currently offer the best opportunity to achieve separation of multiple different polymer types within a waste stream.

Laser Induced Breakdown Spectroscopy (LIBS)

LIBS involves shining a high intensity pulse of laser light on to the sample such that a tiny amount of the material is vaporised from the surface. This vaporised material then emits a spectrum of discrete wavelengths of light which depends on the elements within the sample. A computer is used to compare the spectrum with standard libraries. The result is an analysis of the quantity of each element in the material. LIBS is a very powerful and sensitive technique that will almost certainly be able to identify all the materials of interest.

At present LIBS is principally a laboratory technique however a few groups are applying it to waste sorting. There is a start-up company in Europe (Secopta) commercialising LIBS for sorting, however their present system can only analyse material in a single line in the centre of the conveyor belt, so further development work will be needed to achieve commercial sorting processes but this is not unreasonable to expect.

It is likely that in the short to medium term this technology will be developed sufficiently for use in waste sorting applications.

Terahertz

Terahertz is a part of the spectrum in between microwaves and infra-red. This technique is receiving a lot of attention since it has the ability to penetrate many materials giving images somewhat similar to x-rays, but without the safety issues associated with x-rays.

A group at the Fraunhofer Institute for Intelligent Analysis and Information Systems, Sankt Augustin, Germany is working on this technology for waste sorting applications. They have demonstrated that this technology can be used to identify PE and PP even when they are coloured black with a carbon pigment. With NIR wavelengths the black pigment strongly absorbs and so it is not possible to use NIR to discriminate plastics when coloured black using carbon. Terahertz frequencies are unaffected by the carbon pigment and so can successfully be used to discriminate material containing carbon pigment.

Terahertz is a very new technology, even within the academic world; the light sources and detectors are experimental and not yet sufficiently robust for industrial applications. It is expected that this technology will take at least ten years before it is sufficiently mature to be used in the relatively hostile environment of a waste processing plant.

Tagging

Tags could be used to mark items as recyclable thus aiding separation in the waste processing plant. Any tagging system would have to satisfy a number of criteria:

- Low cost to apply and detect;
- Non-hazardous to human health or the environment;
- Must be easily detectable on the waste processing line with good accuracy;
- Must not carry over through the recycling process;
- Must not interfere with commercial branding; and
- Must not degrade the performance of the item.

Suitable tagging methods could include:

1. Coloured ‘logos’

It would be technically possible to add ‘logos’ in a specific colour to flexible packaging and then use vision systems to detect this particular colour and thus identify the material as recyclable. There are drawbacks with this approach as it’s likely the coloured logo shall either occupy a significant portion of the item or have to be reproduced in several places across the item. This might pose a significant issue for brand owners. Furthermore the required logo may use similar colours to that of other packaging in the waste stream and so cause the vision system to falsely identify the item as recyclable.

2. Optical shape codes

This technique is similar to coloured logos but instead of performing the recognition on colour, a pattern is used. It is likely to be necessary to have the shape code printed in several locations on the item to give a reasonable chance of detection even in the presence of contamination, folds and creases.

As with coloured logos, the technology to do this exists, however reader machines suitable for the waste processing plant would need to be designed, tested and constructed.

3. Tagging molecules within the material

A variety of potential tag molecules exist that could be incorporated within the material. Potential candidates include molecules that fluoresce when illuminated with ultra-violet light (UV). This approach has the advantage being invisible to the human eye so unlike the first two approaches will not have a detrimental impact on commercial branding.

At present very little work on these types of tag molecules has been undertaken and detailed experimental work will be required to assess the available tag molecules. A significant advantage of this technique is that the ability to detect the tag in the waste processing plant will be unaffected by compaction and deformation of the packaging items as they go through the use, waste collection and sorting phases and should be able to handle at least some degree of surface contamination.

Although the detection of fluorescence in waste processing plants will require development of new machines, the technology to do this exists today.

In summary although coloured logos and shape codes are simple and low cost to implement, it is felt that these are unlikely to be suitable solutions due to the likely resistance from brand owners and retailers and reduced effectiveness caused by the compaction and deformation of packaging items as they go through the waste collection and sorting system.

Tag molecules do appear to have some very useful characteristics and it is recommended that further work is undertaken to identify whether the criteria listed above are achievable.

Conclusions

Compared with other consumer waste products, the recycling of post-consumer film waste in the UK is in its infancy. Collections of household waste film packaging for recycling are just starting to be developed and rolled out across the UK. There is currently limited capacity to separate and process post-consumer film waste as a specific stream.

Recent trials have also shown that good quality, high value polymer end products can be made from the current recovered post-consumer film stream and it is likely that other relatively high-value products such as fuel oil will also be viable end-products from recovered lower grade post-consumer film. This is why it is important to test and prove new separation techniques for biodegradable and oxo-degradable SUPCBs in the event that these are to be introduced to the film waste stream as a result of legislative changes.

Technical advances in the last two to three years have shown that there are opportunities to increase the commercial viability and therefore attractiveness of recycling post-consumer film waste. Tuned and optimised NIR detection technology has been shown to successfully separate PE film and PP film from comingled household waste. Whilst sorting PE and PP is achievable, sorting biodegradable from non-biodegradable material is more difficult. There is some evidence from discussions with NIR manufacturers that NIRs can, if suitably optimised, discriminate between some types of multi-layer film and single polymer films; however this is not yet widely adopted within the sector.

Hyperspectral imaging systems are just entering the market and have the potential for even greater sensitivity and accuracy. They may be able to detect and eject some or all of the film types that are currently viewed as undesirable by film recyclers. It offers the potential to detect biodegradable materials, for example discrimination of PLA has been demonstrated. However, the commercial efficacy of identifying biodegradable and oxo-biodegradable plastics has yet to be fully evidenced. Oxo-degradable material especially may present a greater challenge as this material contains only a small amount of additive against the background of conventional PE.