Sensor based sorting: A key technology for sustainable waste management

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Abstract

Waste is a heterogeneous mixture of materials often containing reusable or recyclable materials. In accordance with the hierarchy of the EU requirements “Prevention - Preparing for reuse – Recycling - Other Recovery – Disposal of Waste”, waste processing and recycling additionally fulfills the duty to protect the environment and to preserve primary resources. In order to meet the demands of increasing recycling rates and the quality of recycled waste materials sensor based sorting is playing an important and increasing role in waste processing techniques.

Keywords

Sensor, sorting, recycling, waste

1 Introduction and basics

Physical sorting represents an important step within the unit operations of waste treatment including crushing, screening and separating. The separation technology can be sub-classified in direct and indirect segregation procedures. Direct separation or conventional separation is utilizing interactions between the material properties of single particles and the force fields dependent on the used equipment. This becomes apparent regarding e.g. separation in magnetic fields which allows a selective segregation of ferrous items due to their difference in magnetic susceptibility. However, sensor based sorting is among the indirect separation methods as the working principle initially stipulates a specification of material attributes with detectors like color, electrical conductibility, density and spectral reflection, etc. The actual separation occurs subsequently by digital software based interpretation of the detector signals so that positively recognized particles separately can be blown out of the flight trajectory by compressed air from nozzles (PRETZ, 2005).

Sensor based sorting in waste treatment has evolved substantially since the early 1980s. This represents a technique with non-contact detection which has revolutionized the design of treatment methods, especially in the field of solid waste processing systems. The first phase applications of sensor based sorting devices (chute type sorters) used visible light in order to detect ceramics, stones and porcelain from glass waste. The second phase applications of sensor based sorting devices (belt type sorters) used near infrared detection techniques (NIR) in order to separate recyclable materials like

beverage cartons from collected mixtures of light packaging waste since 1990s (PRETZ AND KILLMANN, 2007). Thus, this method allowed replacing hand sorting by much more powerful machine systems. There were great improvements in technology of sensor based sorting in the last two decades. More than 2000 NIR sorters are already implemented in the recycling industry worldwide (ROBBEN AND WOTRUBA, 2010). Other systems for example color sorting devices as well as machines equipped with induction and x-ray detectors have been used in many fields of waste processing for more than 10 years.

Today, newly developed systems often are operated with a combination of two or more sensors. Thus, machines with a multiple sensor system can guarantee much better separation results especially for sorting of complexly composed waste mixtures in comparison with single sensor devices. In addition, these sensor systems will find new applications for the treatment of various waste mixtures.

2 Principles and typical applications of sensor based sorting

2.1 Principles of sensor based sorting

In general, the most sensor based sorting systems (compare Figure 1 and 2) consist of a material feeder (1) (very often a vibrating conveyor) and a transport unit (1) (sliding chute and/or fast moving belt conveyor) for dissemination and singling of the material flow, a detector system (2) which is arranged below or above the material flow to identify unique features of different materials, an electronic classification unit (3) and a discharge device (4) to separate the identified particles from the material flow. Thus, these two sensor sorters (belt and chute sorters) represent the basic types of construction which are most commonly employed (KILLMANN AND PRETZ, 2006).

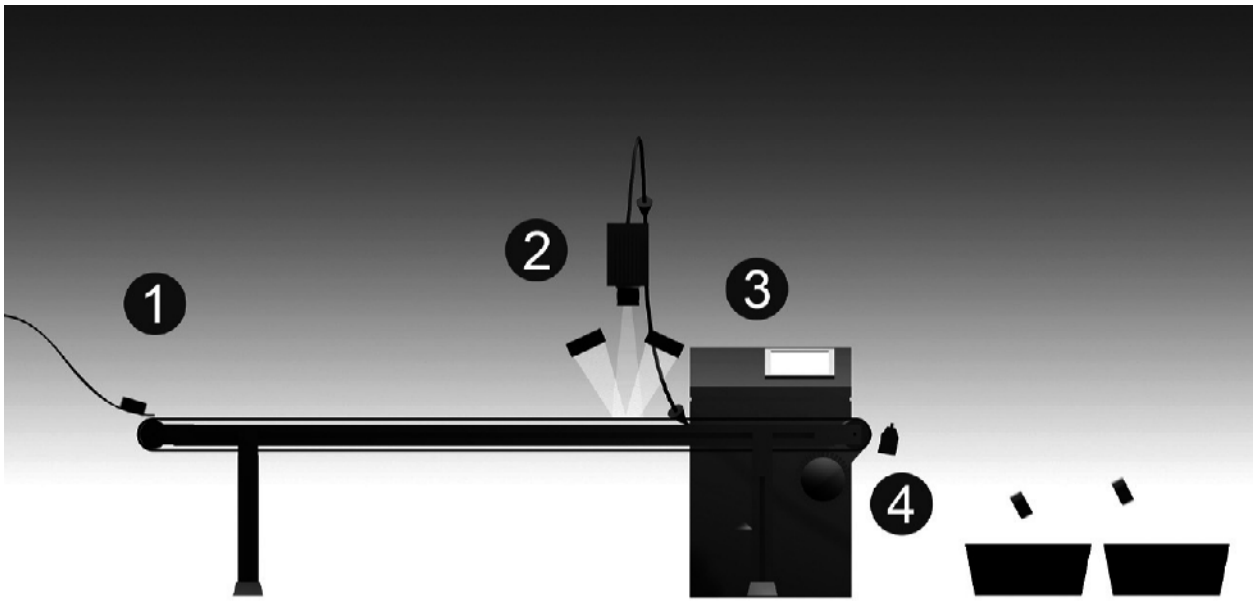

Figure 1 Schematic view of belt sorter (PRETZ AND JULIUS, 2008)

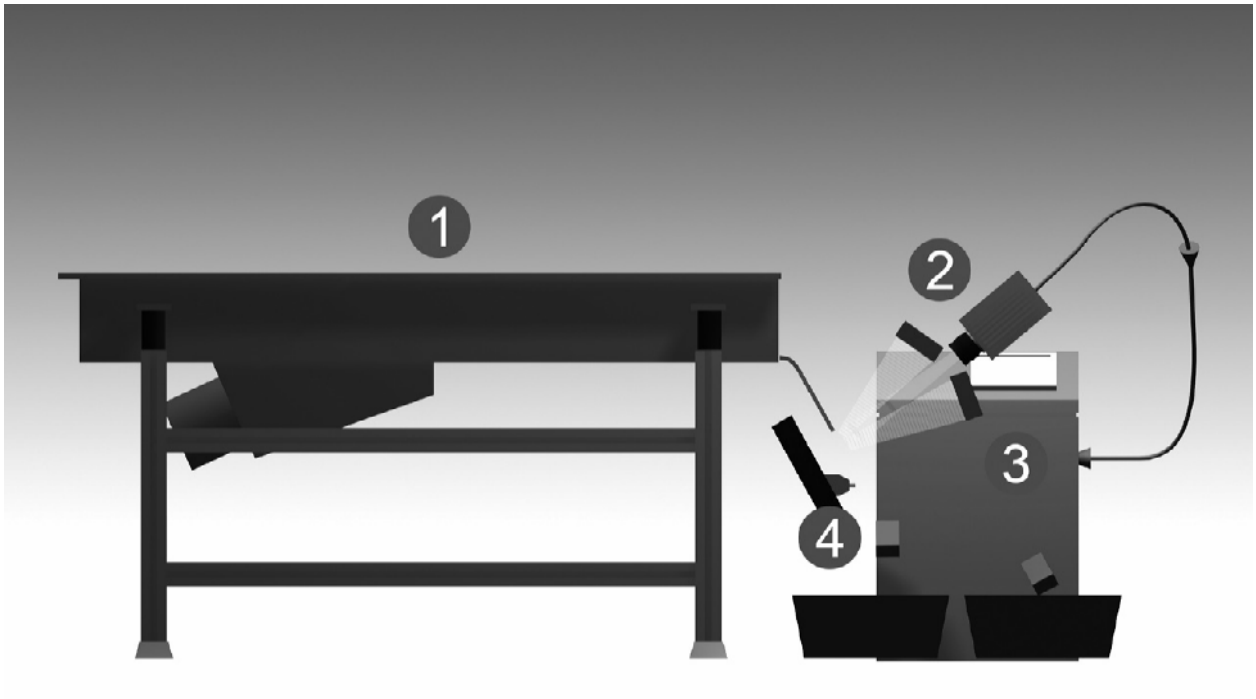

Figure 2 Schematic view of chute sorter (PRETZ AND JULIUS, 2008)

2.2 Typical applications

2.2.1 Commonly used wavelengths and sensors

Figure 3 shows the most common wavelengths of electromagnetic radiation between gamma rays and acoustic noise which are used in sensor based sorting systems for detection. Frequently employed ranges are the visible light, near infrared and x-ray spectrum. Typical sensors and applications are listed in Table 1 (HABICH, 2010) (KILLMANN AND PRETZ, 2006) (MAKOWE, 2010) (PRETZ AND JULIUS, 2008) (PRETZ AND WOTRUBA, 2008).

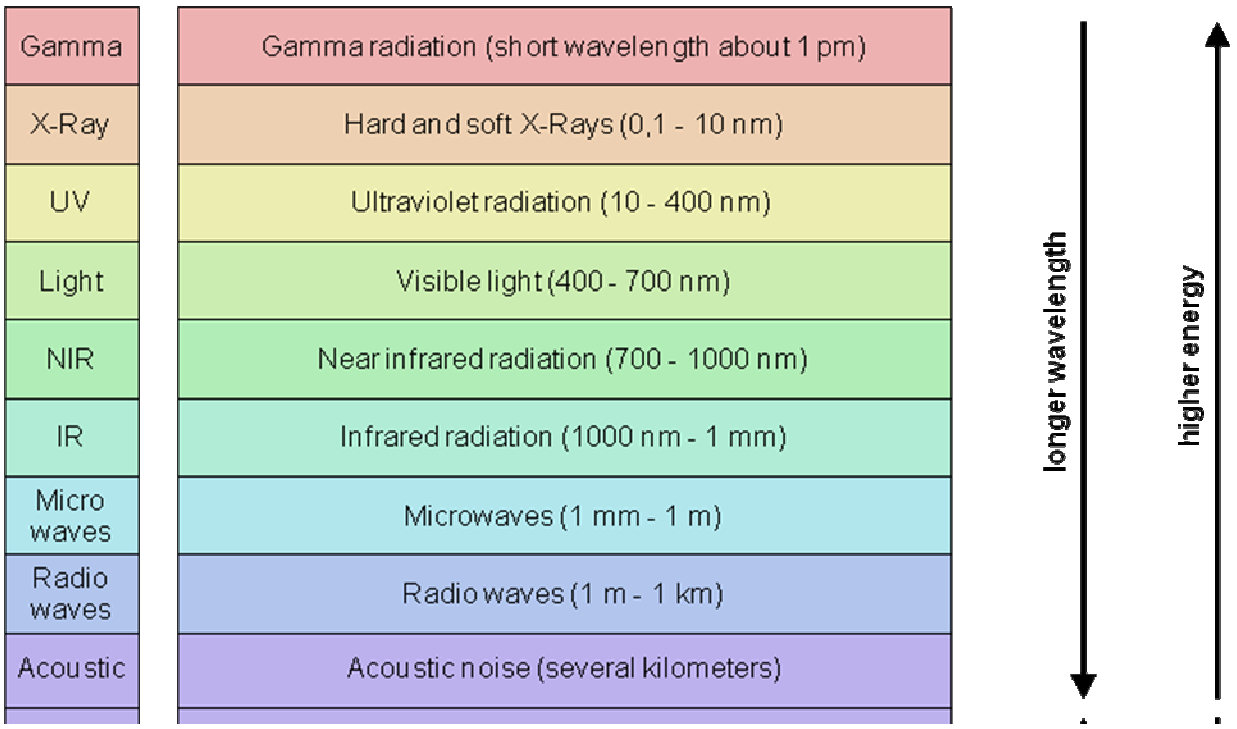

Figure 3 Commonly used wavelengths for detection used in sensor based sorting systems (PRETZ AND JULIUS, 2008)

Table 1 Typical applications of sensor based sorting

Sensors	Separation criterion	Examples for applications
X-ray detectors	Density	Stones, plastics and rubber from wood, copper, stainless steel and copper wires from shredded products, extraction of Zn, Cu alloyed Al from metal mixtures, printed circuit boards extraction from WEEE, extraction of glass ceramics (heat-resistant glass) and leaded glass
Color cameras, VIS (Visible light) spectrometer	Color, brightness	Glass, plastics, PET flakes/resins, copper and brass from NF Metals, circuit boards from electronic scrap, paper sorting
Color cameras	Transparency, luster	Separate magazines from waste paper, separate ceramic/stones/porcelain and heat-resistant glass, determination of lead content in glass recycling
NIR spectrometer	Molecular composition at the surface of material	Bulky waste and wood from other waste, mixed plastics, Paper, wood and textiles from waste mixtures to substitute fuel production, PVC from RDF, paper, cardboards and packaging, detection of flame-retardant additives in polymers
Inductive detectors	electrical conductivity	Wire recovery, metals from incineration slag and shredder residue, stainless steel from metal mixtures, metals from RDF, electronic scrap
Laser (LIBS)	chemical elements	Online metal analysis and sorting of wrought and cast aluminum scrap

2.2.2 Color sorting

Applications of color sorting usually are used for the waste glass separation into different colors and contaminants such as ceramics, stones and porcelain. Another application is plastic recycling like PET flakes as recycled PET is used for many applications with high demands on product quality. The employment of CCD color line scan cameras as sensors makes it possible to identify false colored particles with sizes of approx. 2 mm. The contents of impurities below 50 ppm are possible.

2.2.3 NIR systems

Sorting systems with near infrared spectrometers which are arranged over a conveyor belt with a velocity of approx. 3 m/s are state of the art. These devices are successfully applied for sorting of mixed plastics (PVC, PE, PP, PS, PA and many more.), wood and paper recycling. The recovery rate of single plastic types from the mixtures amounts to about 80 to 90 %. The available product purity reaches 90 to 97 wt-percent. New developments for the detection of halogenated flame retardants in polymers with NIR spectral imaging showed positive results. However, it is still impossible to detect black or very dark colored particles with the NIR technology as the amount of reflected light is too low (PRETZ AND JULIUS, 2008).

2.2.4 Inductive recognition with so called metal sensors

In the field of metal sorting conventional devices like magnetic separators for ferrous metals as well as eddy current separators for non ferrous metals commonly are employed. However, in order to recover also stainless steel and other metals which can not be segregated with conventional methods sensor based sorting with inductive detectors successfully is used for these purposes. Other applications for this technology are working with additional sensors like NIR detectors and line scan cameras with the aim of separating of insulated wires and e.g. copper and brass respectively from diverse mixtures. Currently, inductive sorters are able to recognize particles as small as 0.5 mm.

2.2.5 Multi sensors

In general and as mentioned above, the separating results can be improved by using multi sensor systems which contains two or more sensors in order to determine several material properties at the same time. For instance, color sorting is more effective if the position and shape of the feed materials can be determined more precisely. Moreover, these detector systems allow opening up new applications for the separation of waste mixtures which could not be processed before with sufficient success. Table 2 gives an overview about multi sensor combinations and typical applications (BALTHASAR AND REHRMANN, 2010) (VAN DE WINKEL, 2010) (VAN LOOY, 2010).

Table 2 Typical sensor combinations and applications

Sensor combinations	**Separation of**
NIR + Color Camera	Transparent and opaque, color and black plastics flake sorting
NIR + Induction	Copper wires and printed circuit boards
NIR + Induction + Color Camera	PET Bottles and metals removal
Color Camera + Induction	Waste glass and metals removal
Multi NIR	Different plastics

2.2.6 Online material flow analysis

Sensor based recognition systems also can be used for an online-analysis of different waste mixtures which are characterized by their heterogeneous composition with varying ingredients. Conventional offline measurement with very small samples in laboratories is featuring the disadvantage that important parameters e.g. concerning the quality demands of final products can not deliver prompt results. Thus, sensor systems can be used to perform an online analysis of waste parameters like calorific value, water content or material composition. For example, LIBS (laser-induced breakdown spectroscopy) technology allows the determination of the elemental chemical composition of metal products (MAKOWE, 2010) and NIR- detection is suitable for the determination of the calorific values and flame-retardant additives in polymers (LEITNER ET AL., 2010).

3 Summary

Sensor based sorting systems have applications in waste treatment since approx. 30 years. The continuing development of new sensor systems keeps opening up new fields of application. Sensor based sorting is as key technology for sustainable waste management more and more necessary.

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