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Plastic classification with infrared radiation

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1 Abstract

Most of the things around us contain plastic in their composition, which makes plastic one of the most widespread materials on earth, and as a result of its short life, this makes the recycling process necessary and important.

The recycling process requires a highly accurate sorting process, and it is not logical that the separation process is done manually, which led to the development of automatic methods of separation.

This project focuses on the development of an automated system that utilizes near-infrared reflectance spectroscopy to identify and separate different types of plastic. The system employs the principles of near-infrared radiation to analyze the reflective properties of plastic samples.using a conveyer belt, the plastic piece is placed on it and separated based on a reading that is taken and sorted into containers using an air pump.

2 Introduction

2.1 Recycling Concept

Recycling can be defined as the operation of collecting, sorting, processing, and converting waste materials into new products or raw materials that can be used again. The purpose of recycling is to reduce waste and conserve resources by diverting materials from landfills and incinerators and turning them into useful products. Recycling can involve a variety of materials, including paper, plastic, glass, metal, and electronics, and can take place at both the individual and industrial level. By recycling, we can reduce the amount of waste that ends up in landfills, conserve natural resources, save energy, and reduce pollution.

2.2 Importance of Recycling

Recycling is an important part of sustainable waste management and can have a number of environmental, economic, and social benefits. Here are some additional points about recycling:

2.2.1 Environmental benefits

Recycling helps to reduce the amount of waste that ends up in landfills, conserves natural resources, reduces greenhouse gas emissions, saves energy, and reduces pollution.

2.2.2 Economic benefits

Recycling can create jobs, reduce the costs of waste disposal, and conserve natural resources, which can reduce the costs of raw materials for manufacturers.

2.2.3 Social benefits

Recycling can help to promote a sense of environmental responsibility and can provide opportunities for community involvement and education.

2.3 Objectives

in this project we are going to use NIR spectroscopy to recognize the Plastics' types, then classify it using Automated way.

3 Project Background

Plastic is a synthetic material made from polymers, which are long chains of molecules that are chemically bonded together. Plastics are typically created from fossil fuels, such as petroleum and natural gas, through a chemical process called polymerization. There are many different types of plastics, with a wide range of properties and uses. Some common types of plastics include:

3.1 Types of Plastic

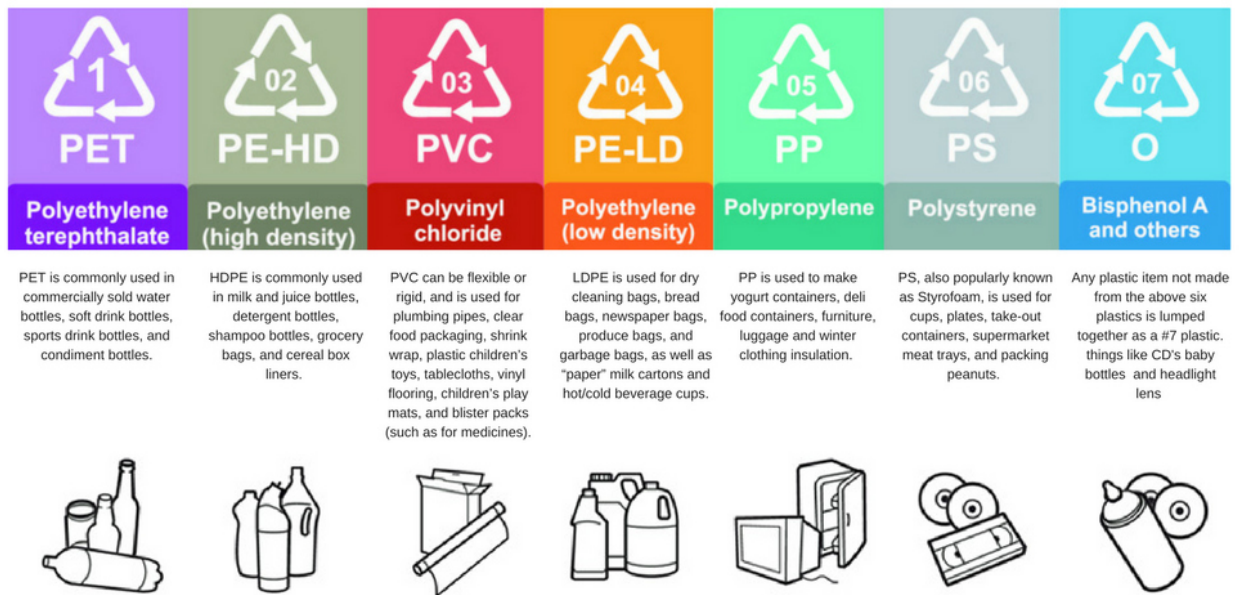


Figure 1: Types of plastic and products that can be made from it after recycling

3.2 Recycled Plastic

The recyclability of plastics is influenced by the arrangement of their molecules. Certain polymers are prone to failure and degradation when exposed to mechanical or thermal pressure, which hampers their recyclability.

	what is it used for?	next life	ease of recycling
Polyethylene Terephthalate (PET) 	soft drink bottles, food packaging such as punnets	used to make more PET products	Easy
Polyethylene Terephthalate (PET) 	milk cartons, cleaning products, yoghurt pots, soap dispensers	garden furniture, pipes and more milk cartons	Easy
Polyvinyl Chloride (PVC) 	pipe fittings, window fittings, thermal insulation, car parts	used to make more PVC products	Difficult
Low Density Polyethylene (LDPE) 	food bags, shopping bags, magazine wrapping	bin liners, plastic furniture and floor tiles	Manageable
Polypropylene (PP) 	margarine tubs, microwave meal trays, fibres and filaments for carpet, wall coverings, vehicle upholstery	clothing fibres, food containers, speed humps	Easy
Polystyrene (PS) 	some yoghurt pots, takeaway boxes, plastic cutlery, protective packaging, insulation	as more packaging	Difficult
Other 	this includes other forms of plastic including composites, such as salad bags and crisp packets	goes to landfill	Very Difficult

 Recyclable
  Recyclable at specialist points
  Not easily recyclable

Figure.2: The types of plastics that can be recycled

3.3 Ways for Recycling Plastic

Typically, the segregation and classification of different types of plastics for recycling purposes rely on distinguishing their distinct chemical, optical, electrical, or physical characteristics. Various techniques are employed for the identification and separation of unused plastics, ranging from manual sorting by humans to automated technologies. These methods include:

3.3.1 Air sorting

In this particular process, the commingled material in flake form is introduced into an upward stream of air, resulting in the separation of lighter particles from the heavier ones. The sorting of the material is accomplished by taking advantage of the differences in specific gravity, or density, of the components.

3.3.2 Electrostatic sorting technique

Another approach to separation involves utilizing electrostatic charging of diverse plastic materials. By applying electrostatic charges, the plastics can be separated based on their distinct electrostatic properties. This method takes advantage of the variations in electrostatic charges among different plastics to achieve effective separation.

3.3.3 NIR spectrum

This technique entails exposing plastics to near-infrared radiation. When the infrared interacts with the plastic material, the unique infrared absorption band of each resin can be measured. These measured values can then be compared to known polymer values in order to identify the specific type of the plastic.

3.3.4 Mechanical sorting

Mechanical sorting is an effective method for separating different types of plastic based on their physical properties.

3.3.5 Sorting by melting

Sorting plastic by melting is a technique known as "thermal separation" or "thermal degradation." It involves subjecting mixed plastic materials to high temperatures, causing them to melt and undergo various chemical and physical transformations.

3.4 Why we choose NIR spectrum

The near-infrared (NIR) spectra of commonly used plastics exhibit clear differences, making NIR spectroscopy an ideal method for plastic classification. This sorting technique offers several advantages, including fast, dependable, and precise identification of plastics. Additionally, it is robust enough to be employed in industrial settings, ensuring its suitability for use in demanding environments.

3.5 spectrum

Spectroscopy is the study of the absorption and emission of light and other radiation by matter. It involves the splitting of light (or more precisely, electromagnetic radiation) into its constituent wavelengths (a spectrum), it used to detect, determine, or quantify the molecular or structural composition of a sample.

3.5.1 Infrared spectrum

Infrared spectroscopy specifically focuses on the infrared region of the electromagnetic spectrum. It is a highly prevalent and extensively utilized spectroscopic technique that proves valuable in the identification and structural analysis of various substances. Infrared spectroscopy enables the characterization and investigation of molecular vibrations, providing insights into the chemical composition and structure of the analyzed substances.

3.5.2 Infrared radiation (IR)

Infrared radiation is a form of electromagnetic radiation with longer wavelengths than visible light, and shorter than radio waves, the wavelength for infrared goes from 0.75 μm to 1000 μm , it's invisible radiation but it can be sensed as heat.

the wavelength for the radiation is separated into 3 regions: • Near: 0.75 – 2.6 μm • Middle: 2.6 – 26 μm • Far: 26 – 1000 μm

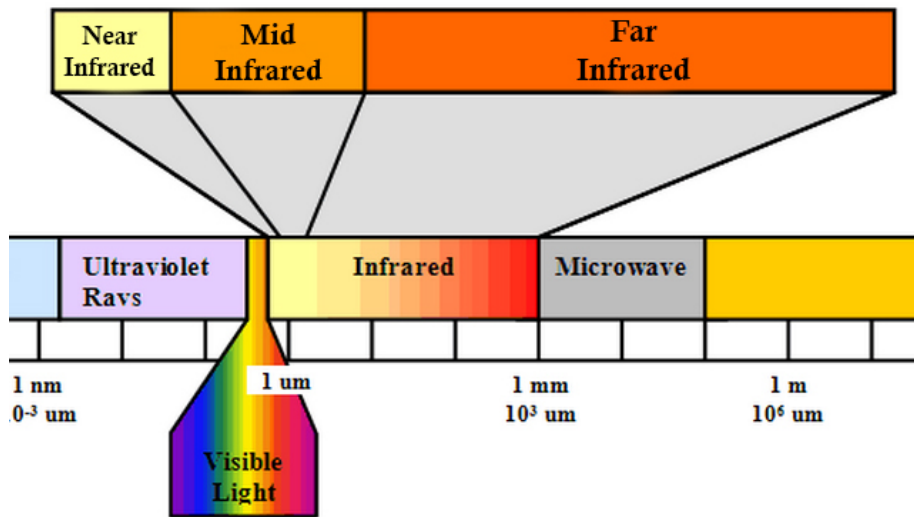


Figure 2: NIR spectroscopy

3.5.3 NIR spectrum effects on materials

When the radiation falls on a surface, its interaction with it depends on the properties of both the material and the specific wavelength of infrared radiation.

The color of the material affects the radiation in different ways, for example, the black material absorbed most of the radiation, so we didn't use black samples in our process.

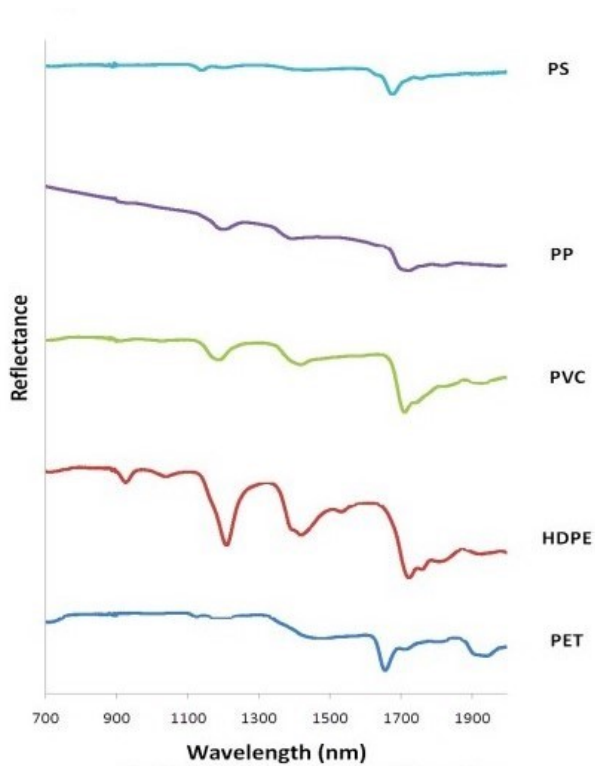


Figure 3:the reflectance for each type of plastic with its wavelength

4 Methodology

4.1 Project items

4.1.1 Conveyor Belt

The belt that carries the plastic samples through testing process, it consist from one or two pulleys powered by a DC motor

4.1.2 Controller

In our project we use Arduino Mega as a controller, we used diffrent ports from it like digital input/output pin, Analog pins, it gave us a fully integrated system.

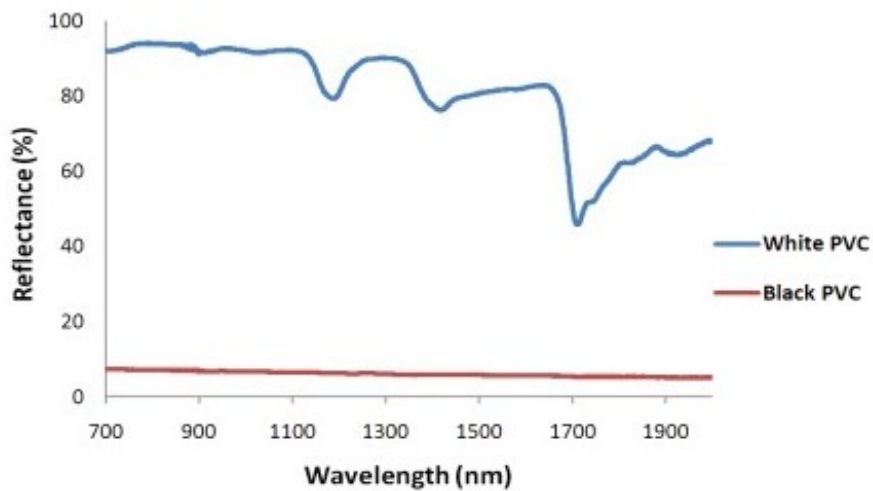


Figure 4: Effects of radiation on PVC samples with different colors





Figure 5: conveyer belt

24-volt power supply is an electrical device or system that provides a constant voltage output of 24 volts. It is commonly used in various applications where a low-voltage power source is required. in our case, we use it to power the whole system, for components with 24volt, 5volt,9volt, 12volt, the items with voltage less than 24 volts, needs a converter that converts the 24volts to the required voltage.



Figure 6: arduino mega



Figure 5: power supply 24 volt

4.1.3 electronic air valve

An electronic air valve, is an electronically controlled air valve or solenoid valve work on 24 volt, a specific type of valve that is operated electronically to control the flow of compressed air or gases. We use it to control the compressed air from a Compressor, after the testing process, the air valves work depending on the type of plastic, and push it to its determined container.

note: the figure below shows an approximate idea of our valve and not exactly like what we used.



Figure 6: electronic valve

4.1.4 DC motor

A DC motor, is an electrical machine that converts direct current electrical power into mechanical power. we use 9 volt DC motor.



Figure 6: DC motor

4.1.5 shaft coupling

The device being referred to is a coupling. A coupling is a mechanical component that connects two shafts, allowing them to rotate together and transmit motion and power. It is designed to remain engaged under normal operating conditions, ensuring a continuous transfer of power between the connected parts. In some cases, couplings also serve as a safety mechanism, preventing excessive loads from being applied to the connected components and providing protection against overloads. By securely joining the shafts, couplings enable efficient power transmission and contribute to the overall performance and reliability of machinery and systems.



Figure 6: shaft coupling

4.1.6 IR Emiting diods

The basic component in this project, a devices that emit infrared light when an electrical current passes through them. They are a specific type of LED (light-emitting diode) that emits light in the infrared spectrum, which is not visible to the human eye.

Infrared light is a form of electromagnetic radiation with wavelengths longer than those of visible light. IR LEDs typically emit light in the near-infrared range, with wavelengths ranging from around 700 nanometers (nm) to 1 millimeter (mm). the wave length for the near infra-red used (NIR) is nearly 940 nm



Figure 6: ir leds

4.1.7 IR receiver diodes

An IR receiver, also known as an infrared receiver or IR sensor, is an electronic device that detects and receives infrared signals. It is used in conjunction with IR transmitters.

IR receivers typically consist of a photodiode or phototransistor that is sensitive to infrared light. When an infrared signal is directed at the receiver, the photodiode or phototransistor detects the changes in the intensity of the infrared light and converts it into an electrical signal.



Figure 6: ir reciver

4.1.8 IR sensoer

used to detect the position of the plastic samples on the belt. IR sensors mainly consist of an Infrared(IR) LED and a Photodiode.



Figure 6: ir sensor

4.1.9

section LDR module An LDR module, also known as a Light Dependent Resistor module, is an electronic component that consists of a Light Dependent Resistor (LDR),in our project we use it as a detector for laser light.

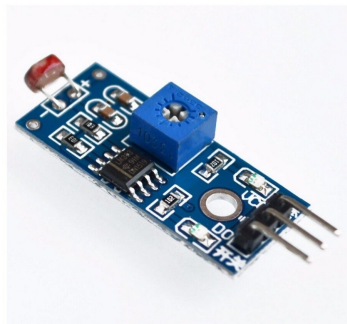


Figure 6: ldr module

4.1.10 relay module

A relay is an electromechanical switch that is controlled by an electrical signal. It consists of a coil and one or more sets of contacts. When a current flows through the coil, it generates a magnetic field that actuates the contacts, either opening or closing the electrical circuit.



Figure 6: relay module

4.1.11 laser diode

A laser diode is a type of semiconductor device that produces highly intense and coherent light. The light waves are synchronized and aligned, resulting in a concentrated and well-defined beam of light. The laser diode achieves this coherence through a process called stimulated emission, where the emission of photons is triggered by the interaction of excited electrons and photons within the semiconductor material. The coherent and high-intensity light emitted by laser diodes finds applications in various fields such as telecommunications, optical storage, laser printing, laser pointers, and medical and scientific instrumentation.



Figure 6: laser diode

4.2 procedure

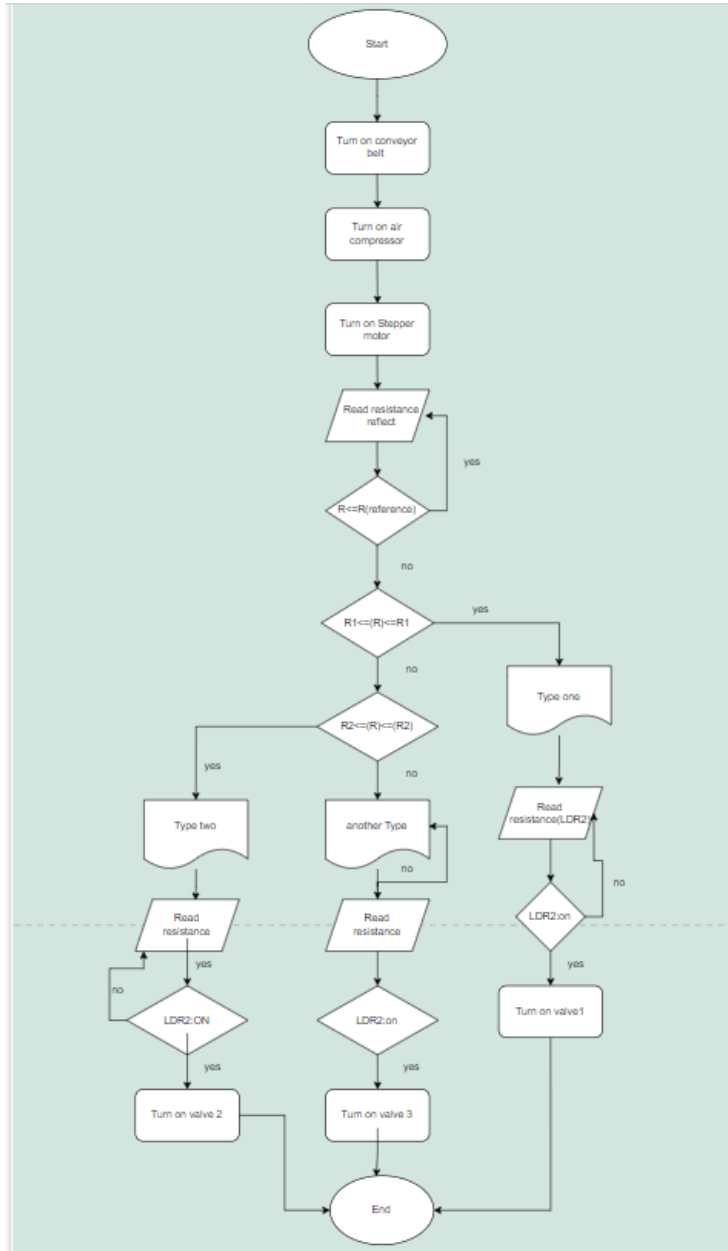


Figure 6: the process

1-When the plastic samples enter the system, they are directed towards the area where a stepper motor is located. The stepper motor strategically scatters

the samples on the conveyor belt, ensuring that they are spread out for easier classification.

2-Once the belt starts moving, the plastic pieces are transported to the plastic identification process.

3-To identify the plastic flakes, an infrared (IR) emitter and detector are positioned above the conveyor belt. 4-Prior to the arrival of the plastic flakes, the detector measures the energy reflected by the conveyor belt, indicating the absence of any plastic.

5-As a plastic piece passes through the IR radiation, it absorbs a portion of the radiation while reflecting the rest. By analyzing the amount of reflected radiation captured by sensors, the system identifies the type of plastic based on the unique characteristics of each material.

6-The composition of each plastic type determines the extent of radiation absorption and reflection, which aids in accurate identification. As the sensor detects the reflected IR radiation, it triggers changes in voltage, current, and resistance, providing valuable data to the controller. Using this data and its knowledge of different plastic types, the controller determines the classification of each plastic piece.

7-while the belt move, the sample reaches the designated container. To ensure proper placement, a laser beam and a light-dependent resistor (LDR) are employed. When the plastic piece interrupts the laser beam reaching the LDR. Two essential conditions must be met: a. The plastic piece is identified as a specific type (e.g., Type X). b. The laser beam is obstructed by the sample, triggering the change in resistance.

8-Once both conditions are satisfied, the controller signals an electric valve to open, releasing a burst of high-pressure air. This pressurized air exerts a power on the sample , propelling it into its designated container.

By following this operational process, the system ensures efficient sorting of plastic flakes based on their types using NIR spectroscopy, sensor technology, and automated mechanisms.

5 Results

In this section, we will analyze and interpret the results obtained for the various types of plastics, totaling 17 samples. Each sample underwent testing from four different sides to determine the approximate amount of infrared (IR) radiation reflected by the sample. This allowed us to obtain a average values for the sample resistance in Kohm.

The recorded values of the resistance change in the IR receiver for every type of plastic are presented in a table. This table provide us the range of resistance change observed for each type of plastic.

5.1 Table of results

#	pvc +pp	HDPE	PET
1	10.9	7.9	5.8
2	13.3	7.89	5
3	10.4	6.6	4.8
4	10.58	6.7	3.7
5	11.8	6.82	2.2
6	10.08	8.4	3.01
7	12.7	7.89	4.3
8	11.2	7.91	5.11
9	10.8	8.7	1.13
10	15.4	8.5	4.89
11	19.8	8.3	7.1
12	15.8	7.3	3.4
13	10.66	9.5	2.5
14	20.1	9.6	1.89
15	11.7	7.3	3.4
16	17.5	11.5	10.1
17	9.11	5.5	4.5

Figure 5: Results

Type 1 / pvc+pp samples show the change in the resistance of the IR receiver within the range of 9-16 kilo ohm. This indicates that the majority of the samples had a similar level of resistance change in response to the reflected IR radiation.

Type 2 / HDPE samples show the change in the resistance of the IR receiver within the range of 6-12 kilo ohm. This indicates that the majority of the samples had a similar level of resistance change in response to the reflected IR radiation.

Type 3 / PET samples show the change in the resistance of the IR receiver within the range of 0-6 kilo ohm. This indicates that the majority of the samples had a similar level of resistance change in response to the reflected IR radiation.

6 difficulties and constraints

1- Infrared radiation is highly sensitive and responsive to various materials and conditions.

2- Availability of Reference Spectra: NIR spectroscopic analysis relies on the comparison of measured spectra to a database of reference spectra for accurate identification. The availability and completeness of reference spectra for all types of plastics can pose a challenge, especially for newer or less common plastic materials.

3-Contamination: Plastics often come in contact with other materials or substances during their lifecycle, leading to contamination. Contaminants such as dyes, additives, coatings, or dirt can affect the accuracy of NIR spectroscopic measurements and potentially hinder proper plastic classification.

4-Sensitivity to Environmental Conditions: NIR spectroscopy can be sensitive to environmental factors, such as temperature, humidity, or ambient light. Fluctuations in these conditions during measurements can introduce noise or variability in the spectral data, impacting the reliability of plastic classification results.

Addressing these challenges requires advancements in technology, database expansion, and refinement of spectral analysis algorithms to enhance the accuracy and reliability of NIR spectroscopy for plastic recycling.

7 Conclusion

The classification of plastics can be effectively achieved by utilizing measurements of NIR reflectance spectroscopy. By employing automated sorting systems based on NIR spectroscopy, plastic recycling can become economically viable. This technology has the potential to transform waste into a renewable resource, effectively diverting a significant amount of material from the waste stream. By enabling efficient plastic recycling, NIR spectroscopy contributes to environmental sustainability, making the Earth a greener and more eco-friendly place.

8 Recommendation

1-Enhance sorting accuracy:

Improve the precision of plastic sorting by refining the algorithms used for spectral analysis, leading to more accurate classification based on NIR spectroscopy data. Expand the reference spectra database to encompass a wider range of plastic types and variations, thereby increasing the accuracy of classification results. Employ advanced techniques such as machine learning or artificial intelligence to enhance accuracy through the use of larger datasets and sophisticated pattern recognition algorithms.

2-Accelerate sorting speed:

Optimize the hardware configuration and integration of the NIR spectroscopy system to enable swift and efficient data acquisition. Utilize parallel processing or advanced computational methods to expedite the analysis of spectral data, resulting in faster sorting times. Streamline the sorting system's workflow and automate processes to minimize downtime and maximize overall throughput.

3-Optimize system design:

Conduct systematic evaluations and optimizations of the system design, taking into account factors such as light source intensity, detector sensitivity, optical path arrangement, and sample presentation techniques. Conduct rigorous testing and calibration to ensure that all system components are functioning optimally, delivering accurate and dependable measurements. Implement feedback mechanisms or real-time monitoring systems to promptly identify and rectify any deviations or errors that may occur during the sorting process.

9 References

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