# Sorting methods for used CGM Applicators for Sustainable Waste Management

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I. **The growing use of continuous blood glucose monitors generates significant waste. As the applicators are not recycled and are directly disposed, this project addresses the need for a fully automated sorting solution to accurately separate materials for recycling., we wanted to explore better ways to separate different types of plastics without relying on the usual float-sink method. Float-sink is common, but it is commonly applied to separate only plastics of two types and it's a wet process as well, which might be a concern in industrial settings. So in this paper, we looked into a few other ways to sort plastics either before or after shredding. We focused on three methods: using computer vision (CV), using near-infrared (NIR) sensors, and triboelectric separation. These methods give us alternative ways to sort common plastics like polypropylene (PP), polycarbonate (PC), polybutylene terephthalate (PBT), and polyacetal (POM). We discuss how they will be used in practical recycling systems.**

## II. Introduction

When we are dealing with shredded plastic waste, detecting the plastic type can be challenging, we can use float-sink separation, but it's not always the cleanest method as it is a wet process. Water needs to be handled, dried, and reused, and concentration of the solution should be maintained. So we explored various other dryer options. This paper goes through a few alternative methods that can be used instead of float-sink: one where you dismantle the product and use computer vision or NIR sensors to identify the plastics, and another where you sort shredded plastics using electric charges.

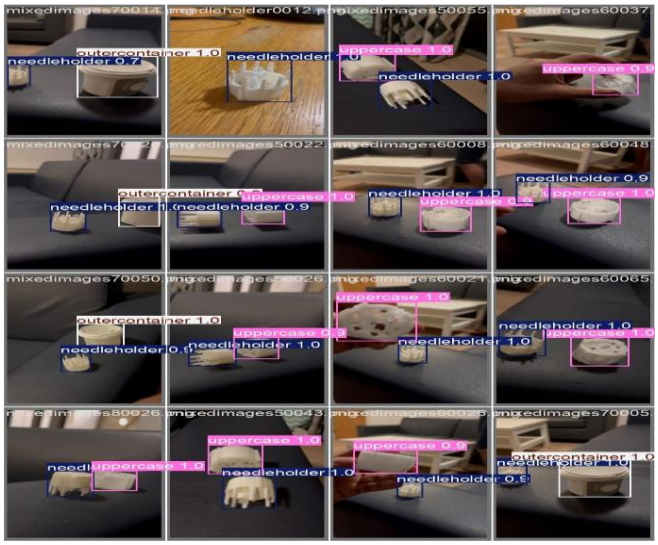
## III. Analysis

Dismantling CGM applicators before shredding can make it easier to get clean plastic. When the parts still have their shape, you can use cameras or sensors to identify the part. But if it's already shredded, identifying the plastic becomes challenging, methods like triboelectric separation help. All of these work equally better at different stages.

## IV. Methodology

### A. Computer Vision

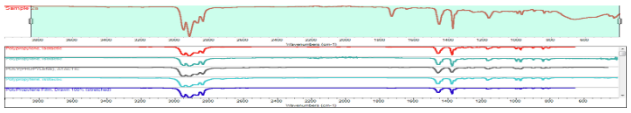
In this setup, we dismantled the product first so that each plastic part could be seen clearly. An Object detection model trained on custom dataset which was collected specifically on the individual parts of the CGM applicator like the outer casing, needle holder, uppercasing, and springs. Once the model detects and identifies the part using shape and texture, actuators can then push that part into the correct bin. This method works better when the parts are clean and visually distinct.



### B. NIR Spectroscopy

Same idea as vision system, but instead of using a camera, this one uses NIR light. Each plastic reflects the light differently, thus the system can identify the type of plastic. Then a robotic arm, Piston or air jet moves it to the correct bin. This method is fast and reliable, but it doesn't work great on black or dirty plastics.

TABLE I



| | Match | Title | Range | Folder | Filename | Index |
|---|---|---|---|---|---|---|
| 1 | 93.20 | Polypropylene, isotactic | 3842.0-642.0 | HR Comprehensive Forensic FT-IR Collection | c:\my documents\omnic\libs\sea600.lbd | 2818 |
| 2 | 90.08 | Polypropylene, isotactic | 3842.0-400.0 | HR Specta Polymers and Plasticizers by ATR | c:\my documents\omnic\libs\sea464.lbd | 67 |
| 3 | 88.93 | POLY(PROPYLENE), ATACTIC | 3843.0-447.0 | Hummel Polymer Sample Library | c:\my documents\omnic\libs\sea006d.lbd | 41 |
| 4 | 88.91 | Polypropylene, isotactic | 3842.0-400.0 | HR Hummel Polymer and Additives | c:\my documents\omnic\libs\sea406.lbd | 942 |
| 5 | 88.74 | PolyPropylene Film, Drawn 100% (stretched) | 3842.0-642.0 | HR Comprehensive Forensic FT-IR Collection | c:\my documents\omnic\libs\sea600.lbd | 2810 |

### C. *Triboelectric Separation (Shredded)*

This method works after shredding. When plastic bits rub against each other, they pick up a charge positive or negative with different intensities. Then, they pass through an electric field. Depending on the charge, they get pulled in different directions and sorted. This doesn't need any water or drying, but you need to control dust and moisture to keep it accurate.

TAB LE II

| Plastic | Charge Tendency | Relative Behaviour |
|---|---|---|
| PP (Polypropylene) | Strongly positive | Tends to gain electrons; easily becomes positively charged when rubbed against other plastics. |
| PC (Polycarbonate) | Slightly negative | Becomes negatively charged, but not extremely. |
| POM (Polyacetal) | Strongly negative | Tends to lose electrons and develop a strong negative charge. |
| PBT (Polybutylene Terephthalate) | Moderately negative | Sits between PC and POM in charge capacity negative, but less than POM. |

### D. *Comparison*

TAB LE III

| Method | Stage | Plastic Form | Pros | Cons |
|---|---|---|---|---|
| CV-Based Sorting | Pre-shredding | Whole parts | Works on shape/colour, flexible | Struggles with dirty or worn parts |
| NIR Spectroscopy | Pre-shredding | Whole parts | Very accurate and quick | Can't handle dark or mixed plastics |
| Triboelectric Separation | Post-shredding | Shredded | No water needed, compact setup | Needs dry material, sensitive to dust |

### E. *Discussion:*

Each method presents unique benefits and challenges, making them suitable for different recycling scenarios. Pre-shredding identification techniques like computer vision or NIR give you an efficient separation. They're fast and accurate but only work if the parts are in decent condition. Triboelectric separation is more useful when things are already shredded and mixed. It doesn't need any liquids and can be built into a compact system, but it needs good control over flake size, moisture, and air quality. Choosing the right method depends on what kind of plastic waste you are dealing with and whether you can break it down before shredding.

## V. Conclusions

A three stage float sink separation process has been shown to effectively sort four different types of plastics. However, while this method can be efficient, it remains a wet process that typically involves solutions such as sugar or salt water. When appropriate safety protocols and maintenance procedures are in place, the process can be managed reliably. Nevertheless, it is not the only viable approach. For applications involving complex plastic waste or where there is a preference for a dry and cleaner recycling workflow, the alternative methods discussed computer vision, near-infrared spectroscopy, and triboelectric separation offer promising solutions. These techniques can be implemented independently or in combination, depending on system requirements and constraints. When properly integrated, they have the potential to significantly enhance sorting efficiency and support the development of more scalable and intelligent plastic recycling systems.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## References


[1] Pongstabodee, S., Kunachitpimol, N. and Damronglerd, S., 2008. Separation of mixed post-consumer plastic waste using selective flotation. Separation and Purification Technology, 62(3), pp.455–462.

[2] Schmidt, R., Christiansen, C. and Lovrinčić, R., n.d. Portable NIR Identification System for Plastic Waste Sorting. Waste Technology Review Journal. [online] Available at: https://www.wtrj.org/articles/portable-nir-identification [Accessed 25 Jul. 2025].

[3] Sifnaios, I., Kavvadias, K., Papazoglou, M. and Polyzos, D., 2024. Deep learning based hyperspectral imaging for polymer identification in recycling systems. Sensors and Actuators B: Chemical, 422, pp.1–10.

[4] Smith, D.T., Nagel, K. and Rajamani, R.K., 2019. Eddy current separation of non ferrous metals using rotating drums. Waste Management & Research, 37(1), pp.55 65.

[5] Zhang, Y., Forssberg, E. and Arvidson, B., 1999. A review of current progress in eddy current separation. Resources, Conservation and Recycling, 23(2), pp.109–129.

[6] Jimoh, K. et al. (2021). Intelligent Model for Manual Sorting of Plastic Wastes. Sustainability.

[7] Springer, M. et al. (2019). Sensor-Based Sorting for the Recycling Industry. Waste Management Journal.

[8] Luo, X. et al. (2020). Recycling of Electronic Waste with Advanced Techniques. Journal of Cleaner Production.

[9] Walker, D. C. et al. (2024). Quantification of CGM and Insulin Pump Waste. Journal of Diabetes Science and Technology.

[10] Heinemann, L., & Klonoff, D. C. (2020). Diabetes Technology