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PLAST2bCLEANED

Advanced sorting classification models based on Raman spectroscopy and chemometrics to improve WEEE plastics recycling

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Going Green CARE INNOVATION
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This Project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement N. 821087

SUMMARY

- Introduction to the PLAST2bCLEANED project
- Waste of Electric and Electronic Equipment (WEEE) plastics recycling
- Advanced sorting process - Raman spectroscopy and chemometrics

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Objectives of the project

PLAST2bCLEANED project´s aim is to develop a human and environmentally safe recycling process for WEEE plastics in a technically feasible and economically viable manner.

OBJECTIVES FOR SORTING
1) ↑ Recycling rates
2) Identify polymers in any colour (blacks)
3) Enhance plastics circularity

1 Development of a mechanical presorting technology

2 Closing 3 loops using dissolution under superheated conditions by separation of:
(1) the polymer
(2) the bromine
(3) the antimony trioxide

3 Process integration and scale-up

4 Performance testing of process and products

5 System optimizing for sustainability and economic viability

https://plast2bcleaned.eu/

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Consortium

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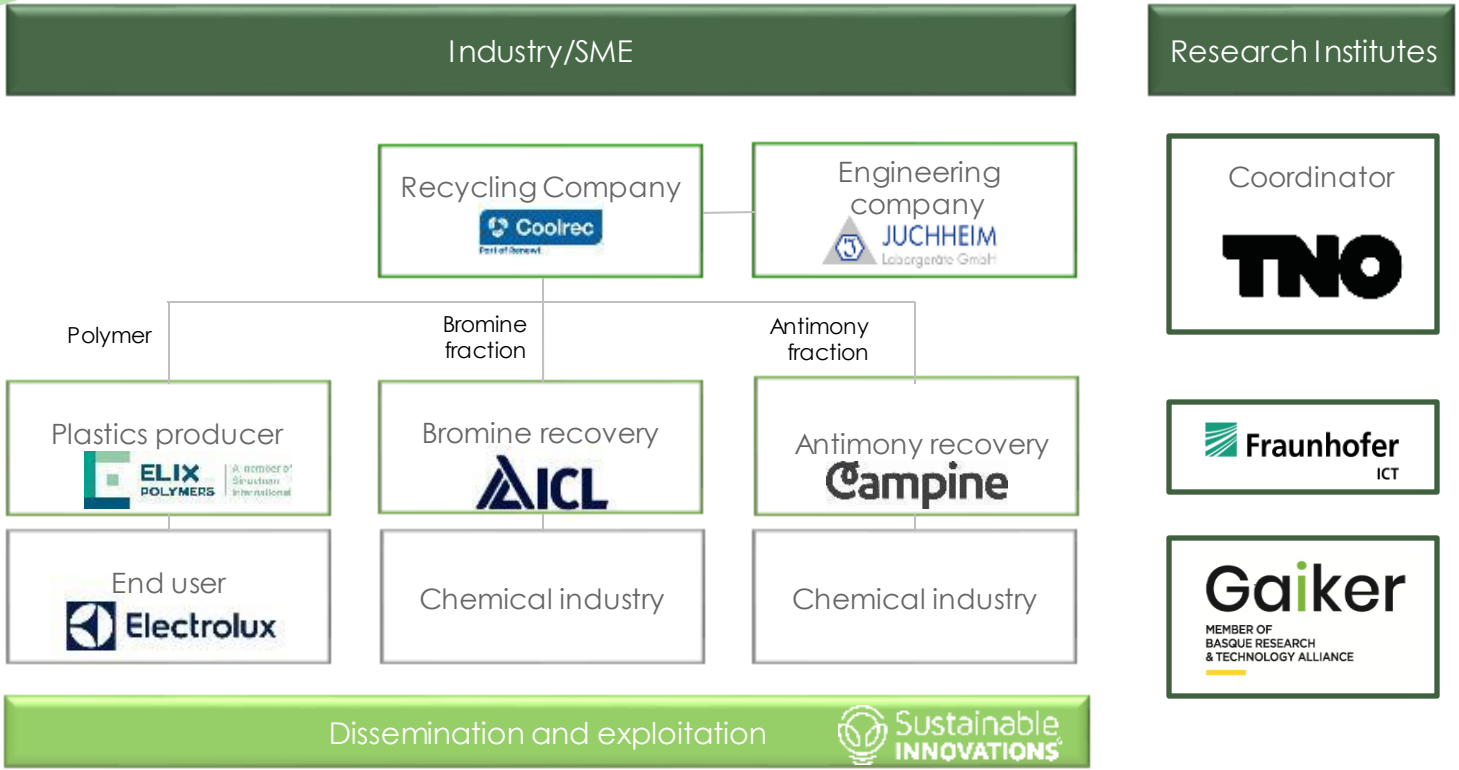

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WEEE plastics recycling

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WEEE plastics treatment → Mechanical separation

Industrial technologies

- Spectroscopy (NIR)
- Density separation
- Electrostatic separation

Opportunities/Challenges → A large part of these plastics are not recovered now

- Incorrect identification with usual spectroscopic techniques
- Due to the high content of additives like pigments (carbon black), stabilizers, plasticizers or brominated flame retardants (BFR)
- Complex composition of the mix – engineering plastics, PCB's, cables, metals (…)
- Regulatory compliance

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Advanced sorting of WEEE plastics

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- **Key technologies**: Traditional sorting technologies + **RAMAN spectroscopy**
- **Target polymers: HIPS & ABS**
- **Innovation: Sensing coloured & dark samples**
- **Considerations for developing the classification models:**

Technical requirements of the WEEE plastics recyclers

Quality requirements of the end users of recycled plastics

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Advanced sorting of WEEE plastics

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WEEE FRACTION

SINKING FRACTION

Heavy plastics
(BFR-rich, black polymers)

TARGET POLYMERS FOR SORTING
PS:10%-20%
ABS:10%-20%

OTHER POLYMERS:
PC/ABS, PC, PP, PMMA, POM, PVC

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Advanced sorting for WEEE plastics

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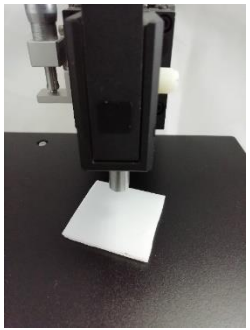
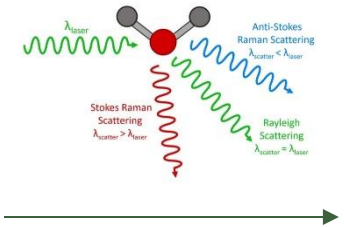
SORTING TECHNOLOGY: RAMAN SPECTROSCOPY

- Analytical technique based on light scattering that uses a laser as a source of high intense monochromatic light
- Laser wavelength (λ): UV – NIR range (532 nm / 785 nm / 1064 nm)

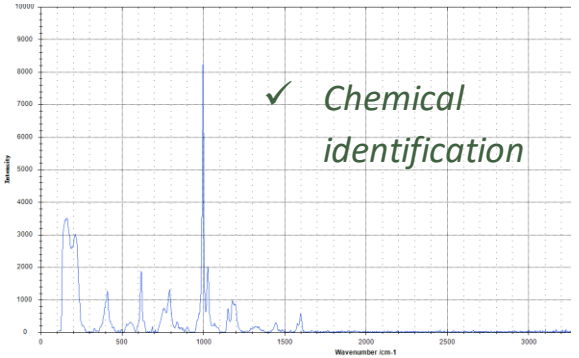


Sample irradiated with the laser beam



SPECTROMETER

Raman spectrum



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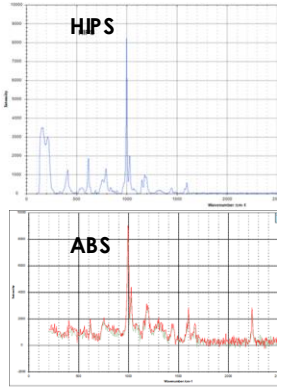
DEVELOPMENT OF CLASSIFICATION MODELS FOR WEEE PLASTICS

APPROACH 1. RAMAN SPECTRUM ANALYSIS

WEEE PLASTICS → **RAMAN SPECTROSCOPY** Settings: λ, P(mW), t(s) → **SPECTRUM OPTIMISATION** (Peak intensity, Baseline correction…) → **POLYMER IDENTIFICATION** (Spectral library)

2 spectrometers Optosky
Lasers: 785 nm & 1064 nm

- Maximise Raman signal
- Reduce fluorescence



Settings:
- Laser power (P=0-500 mW)
- Integration time (t=0.1s - 60s)
- Focus distance (4 – 6 mm)

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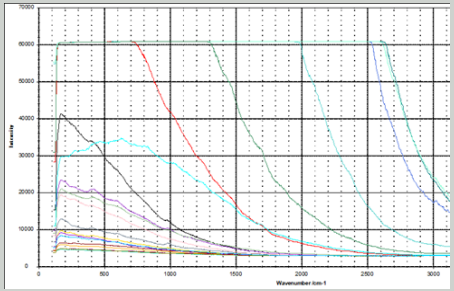
APPROACH 1. RAMAN SPECTRUM ANALYSIS

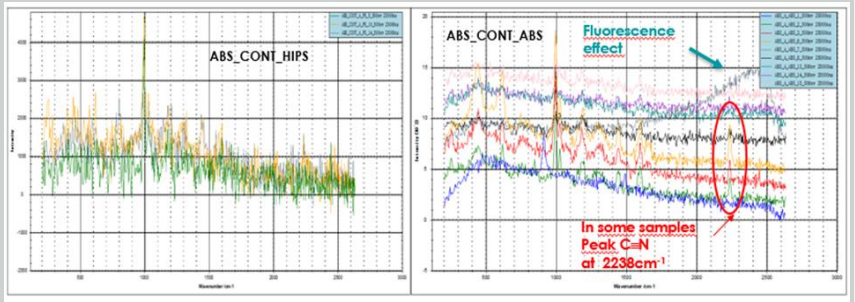
Laser 785 nm	✓ Laser 1064 nm

HIPS (BLACK) P=150-350mW, t= 0.1-1s



- Background/fluorescence was observed in many WEEE heavy plastics (<1000cm^{-1})
- Difficult to discriminate ABS vs. HIPS
- Detector saturated in most black samples (*Overheating*)

PS & ABS P=500mW, t= 25s



- Longer measuring time possible
- Less fluorescence < 1000 cm-1
- Raman spectrum of better quality for some WEEE plastics (vs. 785 nm)
- Characteristic peaks in some ABS samples

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APPROACH 2. RAMAN SPECTRUM DATA ANALYSIS - CHEMOMETRICS

- Chemometrics applies **advanced data analysis techniques (*Mathematical models*)** to extract information of a chemical system.

- In spectroscopy is used to:
  - ✓ Remove unwanted signal (background/fluorescence)
  - ✓ Identify patterns in data to classify samples based on features not necessarily known.

- Multivariate Analysis (MVA). 3 methods tested (LDA, SVM and SIMCA)

- Tool: Unscrambler ™ 11 software Aspen Unscrambler™ Unscrambler by Camo Analytics

- Raman spectral data of WEEE samples: *Laser 1064nm, t=1s*

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MAIN ACHIEVEMENTS PERIOD 2

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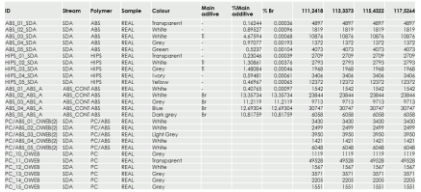
❑ CLASSIFICATION MODELS OF WEEE SAMPLES WITH CHEMOMETRICS

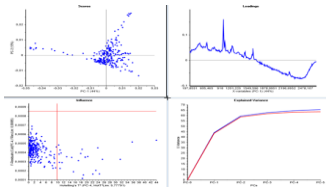
1. Data set construction → **2. Pre-processing spectral data** → **3. Model training** → **4. Samples classification**



Raman spectral data

Representative of the sinking fraction

Principal Component Analysis (PCA)



- Calibration set
- Validation set

Classified_	ABS	PS	PC	OTHERS	Class
	1	2	3	4	5
ABS_14_S...	1	-6,6239	-13,4894	-4,5384	10,8619	OTHERS
ABS_19_S...	2	-4,3512	-6,3522	-59,0806	-11,8166	ABS
ABS_21_S...	3	-2,5938	-12,8677	6,1266	16,1848	OTHERS
ABS_22_S...	4	-6,9500	-13,7236	-12,9631	5,2556	OTHERS
ABS_23_S...	5	-0,6534	-2,7000	-47,8688	-8,1340	ABS
ABS_24_S...	6	-3,6498	-2,2660	-78,6048	-13,9286	PS
HIPS_19_S...	7	-17,3578	-21,6848	-82,1972	-21,8226	ABS
HIPS_20_S...	8	-9,1997	-20,7193	5,1185	10,2097	OTHERS
HIPS_21_S...	9	-20,0091	-24,7636	-137,6181	-48,9709	ABS
HIPS_23_S...	10	-8,4675	-12,4048	-42,6319	-5,0556	OTHERS
HIPS_24_S...	11	-10,7513	-11,7820	-99,6704	-26,8473	ABS
HIPS_25_S...	12	-7,0086	-16,7438	5,6002	14,4159	OTHERS
HIPS_27_S...	13	-13,6159	-26,4162	-3,6291	4,2502	OTHERS
ABS_15_O...	14	-12,0165	-22,6453	-19,0023	-2,8106	OTHERS
ABS_16_O...	15	-9,1852	-24,2042	10,6811	15,2410	OTHERS
ABS_17_O...	16	-17,2872	-24,4474	-52,9848	-12,0180	OTHERS
ABS_18_O...	17	1,7259	-7,0418	14,8127	16,2429	OTHERS
ABS_19_O...	18	-11,6842	-21,1503	-9,7192	5,5623	OTHERS
ABS_20_O...	19	3,5050	-2,3585	3,0657	9,0394	OTHERS
PS_06_OW...	20	-3,2536	-12,4194	8,7394	12,8413	OTHERS
PS_07_OW...	21	-13,5839	-22,0888	-12,6690	7,4936	OTHERS
PS_08_OW...	22	-21,6800	-32,6875	-70,7117	-26,4568	ABS
HIPS_15_F...	23	-10,5575	-8,0026	-206,1355	-68,5160	PS
HIPS_16_F...	24	-55,5747	-33,6696	-1056,2210	-385,7740	PS
HIPS_17_F...	25	-16,3430	-21,0689	-83,6233	-23,9036	ABS
HIPS_18_F...	26	-14,9770	-13,3222	-225,6815	-78,2906	PS
HIPS_19_F...	27	-8,9608	-8,9709	-138,6550	-40,8955	PS
HIPS_20_F...	28	-22,4018	-19,0658	-254,8545	-85,9653	PS

Classification results with Unscrambler™ 11

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❑ CLASSIFICATION MODELS OF WEEE SAMPLES WITH CHEMOMETRICS

INDIVIDUAL MODELS	TARGET POLYMER	
2 CATEGORIES	PS vs. OTHERS	ABS vs. OTHERS
% CLASS	73	85
%PURITY	64	60

MODEL	1-step sorting
4 CATEGORIES	(1) PS, (2) ABS, (3) PC+PC/ABS, (4) OTHERS
% CLASS. (Overall)	~ 60%
%PURITY (PS & ABS)	~ 80%

➢ **Working on improving the classification models (Raman spectral data lab-scale)**

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Improved sorting of HIPS and ABS

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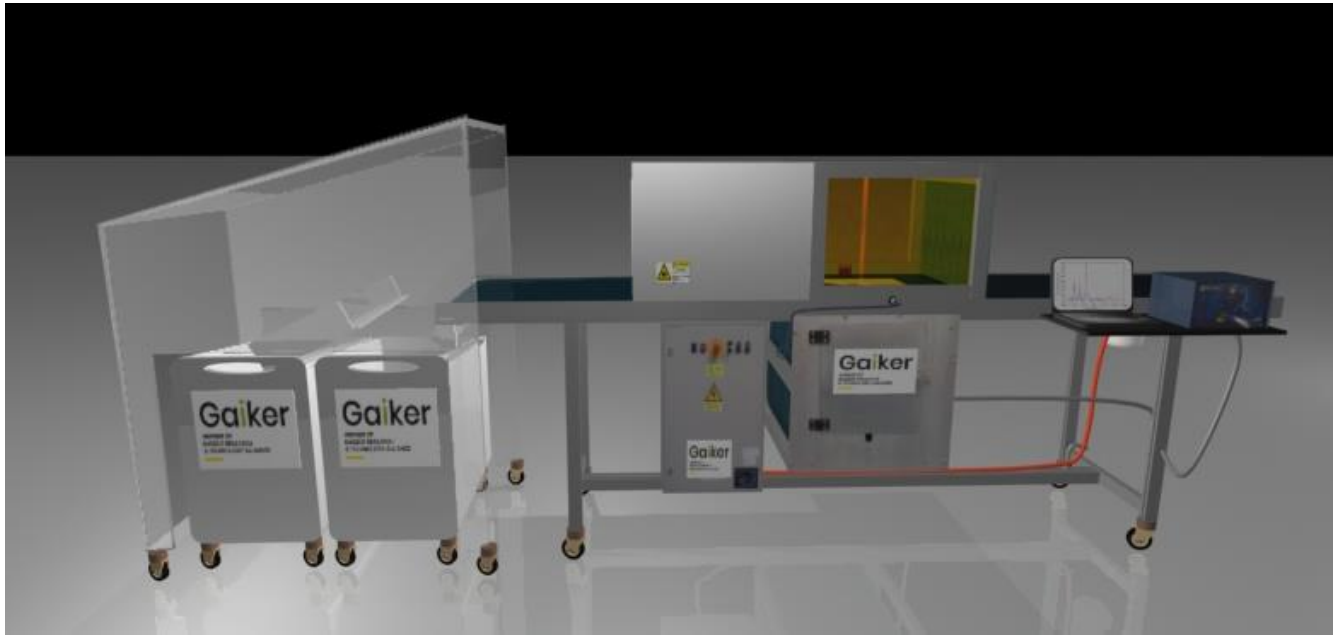
DESIGN, DEVELOPMENT AND TESTING OF A RAMAN SORTING PROTOTYPE



Testing results for the classification model at pilot scale by September 2023

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THANK YOU FOR YOUR ATTENTION

Contact us for further information:

- **Raman spectroscopy –Classification models for WEEE plastics**

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- **WEEE plastics recycling:**

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