Deliverable report

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DOCUMENT HISTORY AND CONTRIBUTION OF THE PARTNERS

VERSION	REVISER	CONTENT
V0	Miguel Sedano, Xabier Aparicio (MAI)	First draft
V1	Irma Mikonsaari, Carolyn Fisher (ICT)	Review
V2	Miguel Sedano (MAI)	Revision
V3	Irma Mikonsaari (ICT)	Submission

Table 1. Version management

PARTNER	SHORT NAME	ROLE IN THE WP	CONTRIBUTION TO THE DELIVERABLE
MAIER	MAI	WP Leader Leader of task 4.3 & 4.4	Author of the deliverable 4.5
ITRB Group	ITB	Reviewer	
Fraunhofer ICT	ICT	Reviewer	

Table 2. Partners' contribution to the deliverable

LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
ABS	Acrylonitrile butadiene styrene
DOE	Design of Experiment

Table 3. List of abbreviations

1 INTRODUCTION AND OBJECTIVES

The EU-funded project CREAToR focusses on process development and demonstration (to TRL 5) to remove hazardous, already banned bromine-containing flame-retardants from waste streams using continuous purification technologies (supercritical CO_2 and cost-effective solvent-based processes using natural deep eutectic solvents (NADES)) in twin-screw extruders. CREAToR covers the whole value chain, starting from collecting thermoplastic waste streams from construction and demolition waste (C&DW) and from waste electrical and electronic equipment (WEEE). Recyclers and sorters of both industries are part of the CREAToR consortium. The project is implementing ways to collect secondary raw materials, identify the presence of hazardous flame retardants, remove these contaminants and finally reuse the materials. As case studies the materials will be reused as valuable secondary raw materials for new building and construction (B&C) insulation panels (creating a circular economy), for automotive interior application, and for producing 3D printed parts for aerospace applications. The end user partners for each sector are also part of the CREAToR consortium. To further increase the economic feasibility of the approach, an optimised logistic concept and a harmonised material quality classification scheme is being developed and applied.

The use of sustainable materials is one of the current demands from automotive OEMs, so MAI's customers are looking for new grades and formulations based on recycled materials. These recycled materials need to have the same performance (the technical and aesthetical properties of recycled materials rarely meet the requirements defined by OEMs for added-value parts) and the same cost as the virgin materials.

In the deliverable "D4.6 2D demonstrator showing CREAToR's potential for automotive application", the application of recycled ABS for an automotive interior component is validated. The document provides a detailed report on the validation and verification of the quality of the 2D demonstration parts.

2 2D DEMONSTRATOR FOR AUTOMOTIVE APPLICATION

2.1 MANUFACTURING: RECYCLED ABS FOR INTERIOR VEHICLE PARTS BY INJECTION MOULDING

2.1.1 DESCRIPTION OF THE COMPONENT

Based on the materials and formulations developed in the project, MAIER has produced demonstrator parts for an automotive interior application.

MAIER has carried out these tasks on 2D geometries. As these demonstrators do not have a complex geometry, MAIER can determine the optimal processing conditions of the formulation independent of the final geometry.

The study has met the objective of carrying out different injection moulding trials, where processability, a process window and the mechanical performance of the different materials developed have been determined.

MAIER has painted these 2D demonstrators in order to check and analyse the behaviour of the new formulations not only during the injection moulding process but also during the coating process. During this 2D demonstrator phase, material production is carried out to perform a screening of different formulations. The most promising and best-balanced compounds will be selected to be up-scaled to a real component prototype with 3D geometry in the project.

Furthermore, the components will be later used for technical demonstration of the results in various dissemination events.

2.1.2 DESCRIPTION OF THE INJECTION MOULDING PROCESS

The general dimensions of the 2D prototype injection mould (Figure 1I) used for the CREAToR project at MAIER are:

Horizontal dimension	398 mm
Vertical dimension	350 mm
Height	330 mm
Clamping force of the injection moulding machine	800 kN

The prototype mould for the production of the 2D demonstrator parts is injected in an injection moulding machine Demag 80. Both the mould and the injection machine are set-up to produce parts under fully automated conditions, according to the industrial standards of productivity and quality. The following pictures (Figure 1, Figure 2, Figure 3 and Figure 4) show a general view of the prototype mould and the injection machine during the production of CREAToR 2D samples.

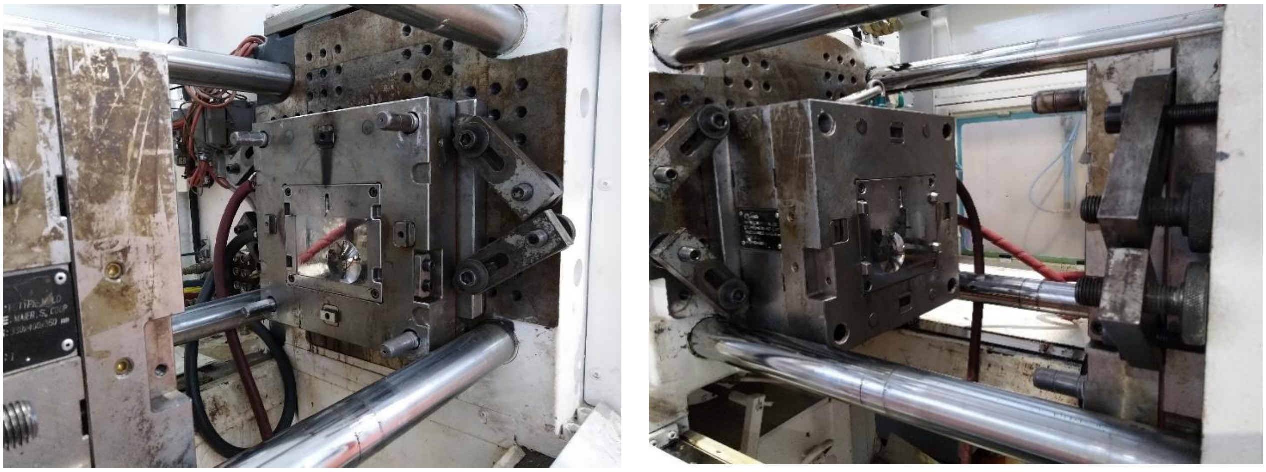

Figure 1: Prototype 2D injection mould. Fixed half (left) and moving half (right)

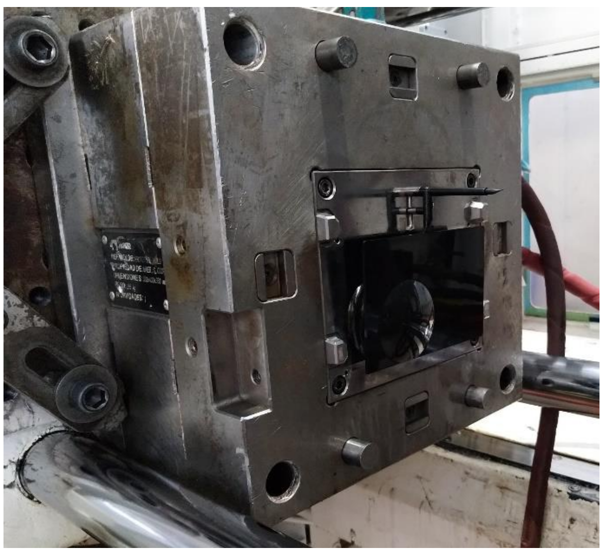

Figure 2: 2D injected demonstrator part on the mould

Figure 3: Injection moulding machine

Figure 4: Injected sample parts

With the different compounds received from the Transfercenter für Kunststofftechnik (TCK), MAIER has performed a complete DOE of the injection moulding of a 2D demonstrator. The parameters that were modified for the trials are presented in the Table 1:

Table 1: Injection moulding DOE matrix

EXP	MOULD TEMP (°C)	MELT TEMP (°C)	FILLING TIME (s)
1	40	210	1,5
2	40	250	1,5
3	40	210	3
4	40	250	3
5	80	210	1,5
6	80	250	1,5
7	80	210	3
8	80	250	3

The final injection moulding parameters fixed for the processing of these 2D demonstrators, defined after DOE trials with every compound are (Table 2):

Table 2: Final injection moulding parameters

PART CODE	MATERIAL	PARAMETER
Drying	Time (h)	2
	Temperature (°C)	80
	Set (°C)	80
	Injection speed (cm^3/s)	17,2
	Injection pressure (Max) (bar)	780

Injection	Injection filling time (s)	3
	Holding pressure (bar)	578
	Holding pressure Time (s)	8
	Cooling time (s)	30
Melt Temperature	Nozzle (°C)	250

Every compound has its own injection parameters. The previous table shows a balance between all of them.

In total, MAIER has carried out more than 88 2D demonstrator injection trials. To perform all of these trials, a set of specific inserts for the injection of CREAToR materials was manufactured to ensure the processability of the new formulations and to verify that the grades do not damage or degrade the mold.

In terms of processability at the injection machine, all the compounds show a similar performance.

2.1.3 INJECTION MOULDED SAMPLE PARTS

Two different recycled polymer materials are used in the developed compounds:

- White recycled ABS from fridges (501)
- Black recycled ABS from domestic applications (502)

The virgin ABS to develop those compounds has been delivered by MAIER to TCK.

These are the compounds that MAIER tested when implementing the complete DOE previously explained (Table 3):

Table 3: Summary of the injection moulded compounds

COMPOUNDS FOR THE INJECTION MOULDING STUDY

SAMPLE	%	MATERIAL 1	%	MATERIAL 2
300	100	VIRGIN ABS (500)		
301	0	VIRGIN ABS (500)	100	RECYCLED ABS (501)
302	93	VIRGIN ABS (500)	7	RECYCLED ABS (501)
303	75	VIRGIN ABS (500)	25	RECYCLED ABS (501)

304	50	VIRGIN ABS (500)	50	RECYCLED ABS (501)
314	25	VIRGIN ABS (500)	75	RECYCLED ABS (501)
308	0	VIRGIN ABS (500)	100	RECYCLED ABS (502)
310	93	VIRGIN ABS (500)	7	RECYCLED ABS (502)
312	75	VIRGIN ABS (500)	25	RECYCLED ABS (502)
313	50	VIRGIN ABS (500)	50	RECYCLED ABS (502)
315	25	VIRGIN ABS (500)	75	RECYCLED ABS (502)

Aesthetically the injected parts show differences in colour due to the different content of recyclate material. The following figures Figure 5 and Figure 6 show the samples manufactured.

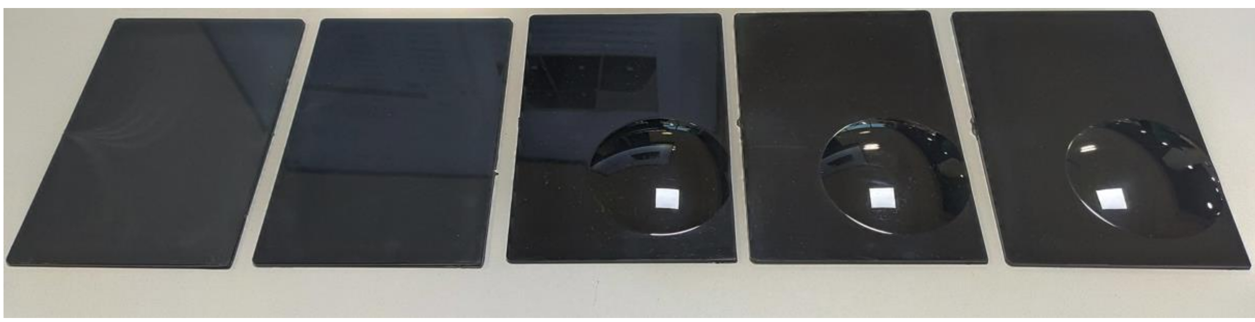

Figure 5: From left to right 308, 315, 310, 312, 313

Figure 6: From left to right 301, 314, 302, 303, 304

2.1.4 CHARACTERISATION OF THE 2D INJECTION MOULDED DEMONSTRATORS

Concerning the results of the lab tests defined for the injection moulded parts, all the results are acceptable with the exception of the climate cycles test.

All the demonstrators show deformation in this test, but this can be due to the simplified geometry. The components do not include any ribs or geometrical reinforcements that provide stiffness to a part and which would result in a more stable structure. This point will be investigated in the future with the 3D demonstrator (Table 4)

Table 4: Summary table for injection tests with results

N°	DESCRIPTION	REQUIREMENT	301	302	303	304	308	310	312	313	314	315
1	GENERAL AESTHETIC	No evidence of bubbles, streaks or injection flux	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
2	TEMPERATURE RESISTANCE: 22 HOURS @ 85 °C	No relevant deformations or aesthetical changes	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
3	COLD RESISTANCE: 7 DAYS @ -30 °C	No relevant deformations or aesthetical changes	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
4	CLIMATE CYCLES: 7 X (16 H @ 40 °C + 95 % HR AND 3 H @ -20°C + 5 H @ 85 °C)	The part must not lose any of its aesthetic properties. No relevant deformations should appear	NOK	NOK	NOK	NOK	NOK	NOK	NOK	NOK	NOK	NOK
5	IMPACT RESISTANCE 800 g/50 cm/23 °C	Part must remain unbroken	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
6	IMPACT RESISTANCE 400 g/50 cm/-30 °C	Part must remain unbroken	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

2.1.5 PAINTED SAMPLES

The scope of the project did not include painted parts. Neverthless, taking into account the positive results achieved with injection moulded parts, all 2D demonstrators were manually painted and characterised.

The chosen painted finish is a silver paint. The following images show the painting process.

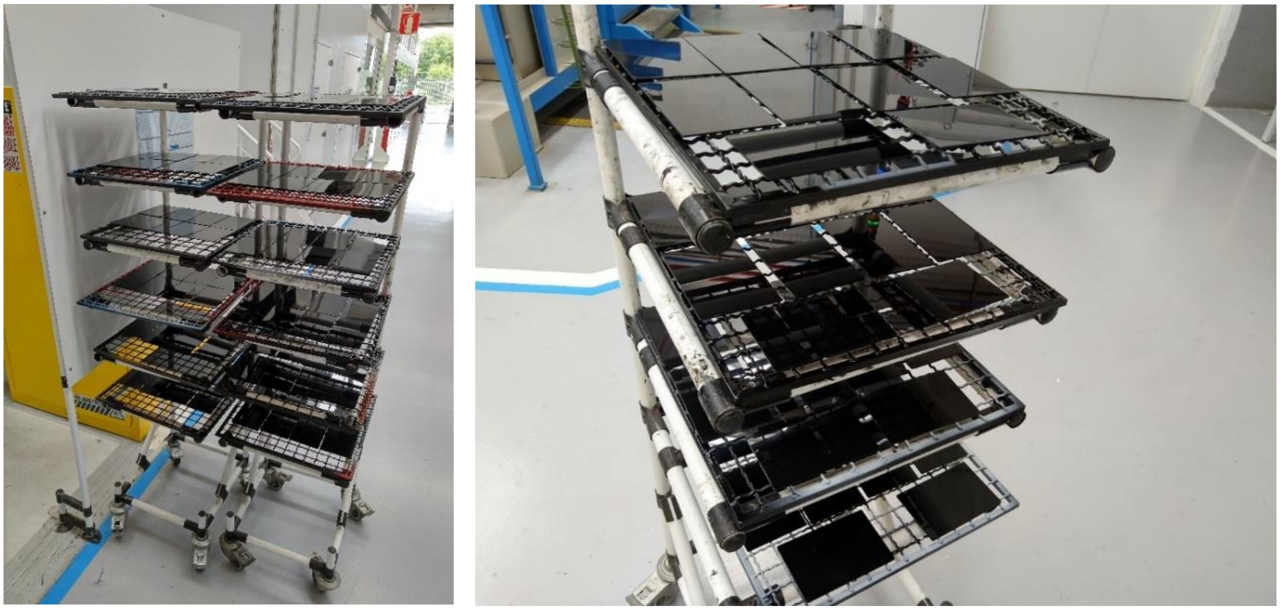

Figure 7: 308 injected samples over horizontal painting jigs before painting

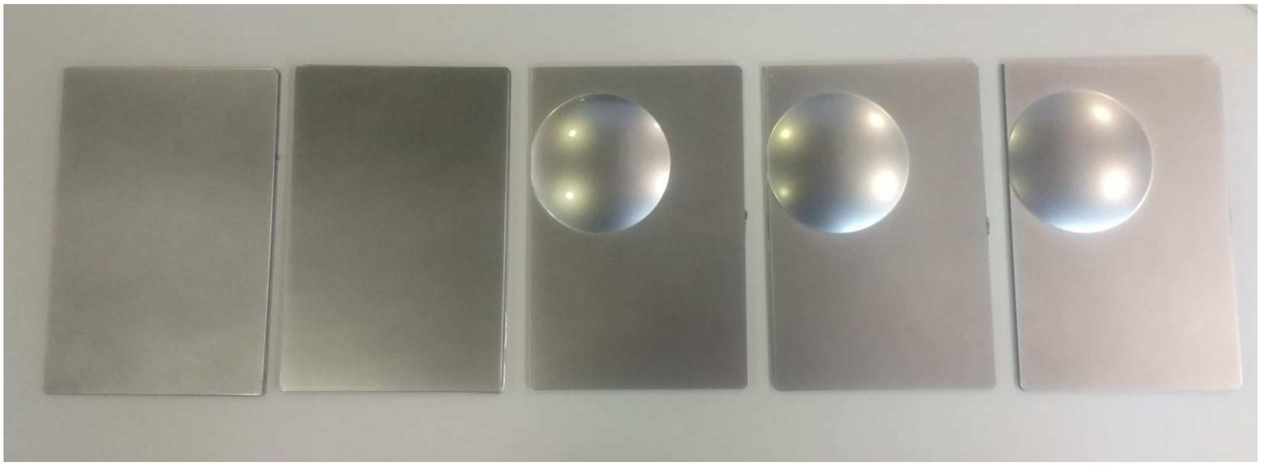

Figure 8: From left to right 308, 315, 310, 312, 313 painted demonstrators

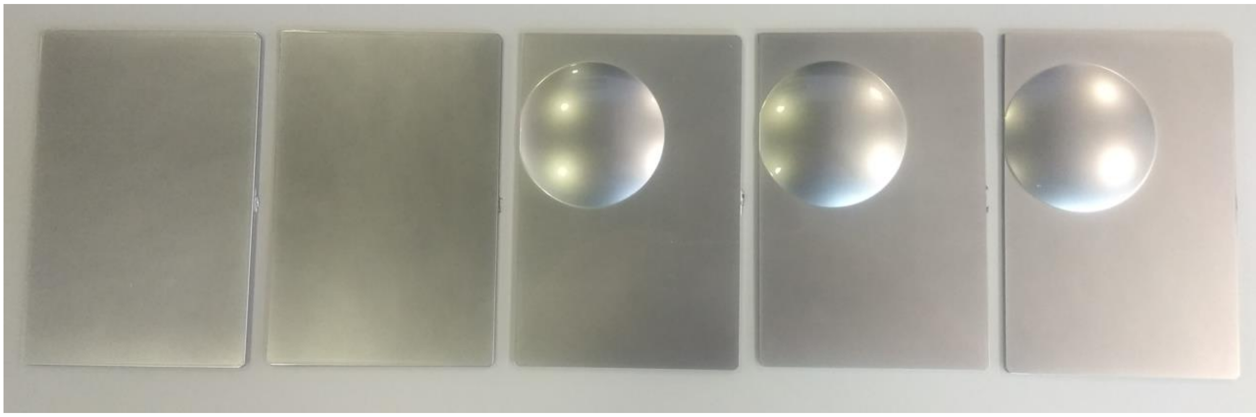

Figure 9: From left to right 301, 314, 302, 303, 304 painted demonstrators

2.1.6 CHARACTERISATION OF THE 2D PAINTED DEMONSTRATORS

The following Table 5 shows the validation of the samples in terms of their aesthetics, adherence and resistance to handcream and suncream.

Table 5: Summary table for painted tests with results

N°	DESCRIPTION	REQUIREMENT	301	302	303	304	308	310	312	313	314	315
1	GENERAL AESTHETIC	No evidence of bubbles, streaks or injection flux	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
2	INITIAL ADHERENCE	No paint lift	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
3	HANDCREAM RESISTANCE: 24 h @ 80 °C + TEAR-OFF @ 10 N	No paint tear-off	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
4	SUNCREAM RESISTANCE: 24 h AT 80 °C + TEAR-OFF @ 10 N	No paint tear-off	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Table 5. Summary table for painted tests with results

Although characterisation of the painted parts is not included in the scope of the project, all painted 2D demonstrators were subjected to initial paiting tests.

Figure 10: Left: Handcream and suncream tested demonstrator; right initial adherence tested demonstrator.

Table 6 summarises the colorimetrical results of the samples.

Table 6: Summary table for colorimetry analysis of compounds containing 100% recycled material

SAMPLE	L	A	B	BRIGHTNESS
301	69,5	-0,69	0,04	107,7
308	70,2	-0,76	0,02	106,4

The L*a*b* color space was designed based on an opponent color theory that states that two colors cannot be red and green at the same time, or yellow and blue at the same time. Therefore, L* indicates the Luminosity, and a* and b* are the chromatic coordinates.

L* = Luminosity

a* = Red / green coordinates (+a indicates red, -a indicates green)

b* = Yellow / blue coordinates (+b indicates yellow, -b indicates blue)

According to these results, we can conclude that the recycled substrates used in the CREAToR project don't affect to the color and brightness of the silver painted surface.

3 CONCLUSION

The objective of this project is to validate a material that contains 7 % of recycled material for automotive high-added value interior components.

The following results were obtained after the injection moulding process:

- Regarding the injection moulding process, processability of all the compounds is comparable with the virgin material: the injection moulding parameters established for these compounds are comparable to those of virgin ABS, and the small adjustments required are within the normal range of an industrial process.
- Tests performed over the injected parts show good results. The 2D samples only present a deformation after the climate cycle test, due to the simplified geometry (the lack of ribs and geometrical reinforcements that provide stiffness to a part)
- The aesthetic of all the different samples can be evaluated as OK

The following results were obtained after painting:

- The initial tests performed over the painted parts shows good results.
- The recycled substrates used in the CREAToR project do not significantly affect the colour and brightness of the painted surface.
- The aesthetic of all the different samples can be evaluated as OK

After completing the work on the 2D demonstrators, and taking into account the results obtained, the most ambitious goal that will have the biggest impact is to validate a formulation based on 100 % recycled material. A decision was taken to use the compounds containing 100 % recycled material for the 3D demonstrator upscaling.