PolyCE

Post-Consumer High-tech Recycled Polymers for a Circular Economy

Project Duration: 01/06/2017 - 31/05/2021

Deliverable No.: 7.3

Deliverable Title: PCR Plastics module for LED lighting

Version Number: v1

Due Date for Deliverable: 28/02/2021

Actual Submission date: 28/02/2021

Lead Beneficiary: ONA

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Deliverable Type: DEM

R = Document, report
DEM = Demonstrator, pilot, prototype, plan designs
DEC = Websites, patent filing, press & media actions, videos, etc.

Dissemination Level: PU

PU = Public
CO = Confidential, only for members of the consortium, including the Commission Services

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Disclaimer

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730308

Summary

Ona is a design agency with a strong link to architecture, design, art and culture. They create lighting designs and custom lamps for their clients. In addition to the design and quality of their products, Ona is specialized in developing and manufacturing those ideas, concepts and lighting products that their clients dream about, matching their architecture and interior design projects.

Ona set out to develop a specially designed high-end LED lighting fixture using PCR and PIR plastic materials without compromising on the high quality standards where the company is known for. After the first design concept was presented their was a need to go back to the drawing board and start again from a black page as the first design showed several difficulties which would be hard to overcome. A second design was thought out based on the idea to use one part multiple times to create a fixture. The concept of modularity was introduced and a design based on a tulip was developed consisting of three elements.

1) Structure/frame: made of aluminium
2) Electrical components
3) Modular plastic part

The development was carried out by the Ona design team while the technical aspects of the material, mechanical characteristics and the polymer selection were selected in consultation of different members of the PolyCE consortium. One of the most critical features of the so-called boomerang parts is the connecting feature. Here Pezy group and Ghent university aided in the design to ensure full functionality and producibility.

The mould production was subcontracted to a supplier. This mould design was developed as a cooperation between the supplier and Ona. Later the design was checked by different members of the consortium and suggestions were shared. Unfortunately the supplier with which Ona developed the mould was not capable to produce the required quality needed. Ona was forced to change supplier, which caused a delay and was a huge challenge for a micro SME like Ona. Collaboration with another supplier led to changes in the mould and successful moulding trials and production.

Task description

ONA, a leading company in the development and design of lighting, will develop a housing for LED lighting taking into account the Design from Recycling strategy developed in WP4 to facilitate the use of the PCR plastics compounded within WP5 in lighting components. Special attention will be put on Design for Disassembly and Design for Recycling to assure that the different lighting components can be separated from each other when the product reaches its end-of life, thus allowing to close the loop for all PCR polymers in a sustainable manner. The specific lighting product will be chosen at the start of the project, based on current contracts of the company ONA, so that the demonstrator is a commercial product that will effectively make it to the consumer market. Develop a lighting demonstrator (lamp), based on the recycling guidelines and the selection of polymer materials developed in the PolyCE project.

Goals

Create a modern and aesthetically pleasing lighting product with the following characteristics:

- Plastic with the highest percentage of recycled plastic possible without compromising on aesthetics.
- All the elements that make up the luminaire should be able to be separated/disassembled easily to facilitate recycling, once end of life of the product is reached
- Overcome the barrier of the look, feel and opinion of recycled materials and try to achieve a product with a finish that is as close to that of noble materials (colour, texture, transparency, brightness, etc)
- Achieve a profitable and desirable design which can be produced with injection moulding.
- The cost of the mould had to be in line with the expected production run

Approach

Within the PolyCE project Ona set the goal to develop a high-end design fixture for LED-lighting, implementing Post Consumer Recycled (PCR) or Post Industrial Recycled (PIR) plastics in multiple future high-end lighting components. The appearance needs to comply with Ona's design principle of creating products with a 'noble appearance'. Currently, Ona uses materials like metals, exotic woods and ceramics to represent a noble and durable character. Switching to recycled plastics formed the major challenge as plastics are commonly perceived as 'cheap and low end' in their markets. Tackling this challenge with Ona's limited experience in using plastic in production called for an integral yet step by step approach to define solutions. A usual step to take in implementing r-plastics in products is to start with the so called, low hanging fruit; parts or product housings which do not have very challenging requirements. The parts for Ona's products however required high gloss transparency and translucency.
A full product design and development process was undertaken by Ona. Conceptual designs were reviewed by Pezy and Ghent University and concepts were adjusted were needed. Close attention was put in the recyclability of the concept. Modularity was a key feature to achieve a long life-time and easy disassembly when recycled. A second big challenge was finding materials with the required quality. In order to achieve the quality needed to achieve a noble look (translucency and transparency) close collaboration with the materials supplier (Sitraplas) was required. Being flexible in the source of the recycled material and the experience of the material supplier were key for obtaining the materials needed to produce a successful demonstrator.

Results:

Design concepts

The first concepts with a "reading lamp" typology presented by Ona can be seen on Figure 1. The reading light concept presented many challenges for production with (recycled) plastics. The long straight beams and and rather tall/elongated concept clearly indicate the need for metals en stone (concrete). The design, if even feasible, would require specialty production techniques and reinforced polymer grades to realise. The specific challenges being:

- Long, narrow beams
  - Plastics are prone to creep
- A havy base is required to prevent the light from tipping over
  - Plastics are to light weight, heavy materials like concrete would be more suitable
- The light covers are presented as straith cilinders which are hard to produce with plastics
  - A draft angle would be required to produce the parts via injection moulding.
- Multiple different toolings and production techniques needed to produce parts.
  - Production likely not economical for a first concept.

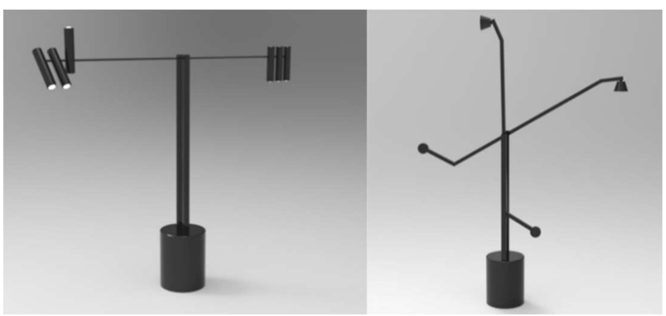

Figure 1: First design concept, a reading light typology

After thorough brainstorms and discussion it was decided to step away from the first concept and start from a blank page. The new core idea was to design a lighting concept were multiple configurations would be possible and in which the polymers that were being developed in the Polyce project are accentuated. This time the design concept was performed from the premise of obtaining a modular element that would provide us with a range of product types (table lamp, pendant, etc) and shapes, while taking into account the specific hurdles of desinging a plastic product and the design guidelines for recycling (mono material, easily separeted). The second concept can be seen on Figure 2.

Figure 2: Second design concept, modular typology

This concept is comprised of an arrangement of multiple times the same part (further called the boomerang). After concultation with Pezy and Ghent University the concept was tweeked and could be worked out in more detail. The experts within the consortium were asked what could be the appropriate plastic type taking into account the following constrains:

- Variety of colour
- Transparency
- "glass-like" appearence
- Recycled

Once the boomerang piece was fully defined, different configurations were developed taking into account all the options that this piece could enable. The developed configurations can be seen in Figure 3. Also colour options were taken into account during the concept stage.

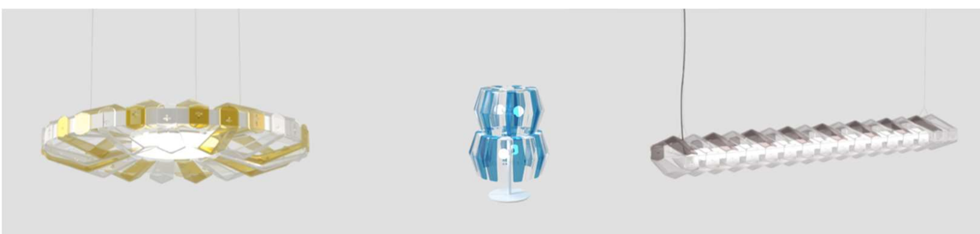

Figure 3: Light fixture configurations

Material

The light fixture is designed to be used indoors and even (sheltered) outdoor area's which do not expose it to extreme environments. The material used must also transfer and/or diffuse light well, resist possible falls (impact) from reasonable mounting heights (3 meters) and be able to be easily assembled and disassembled without breaking, in case the user decides to change the configuration or colours. The major concern is to be able to obtain a wide and vivid variety of colours, taking into account that the plastic used consisted of the highest amount of recycled content possibly.
The pieces are design for polycarbonate (PC) with high attention to the finish, transparency, brightness and colour. On top of this the material needs to be resistant to ultraviolet light so that it does not lose aesthetic

properties over time (brightness and colour). Therefore, Sitraplas developed a PC that fulfils the previously discussed requirements.

The connection feature between the structure and the boomerang pieces was designed as the development of the part progressed. The clipping system was optimized to reduce the tooling costs without affecting its functionality. See Figure 4 & Figure 5.

Figure 4: Clipping system evolution from left to right; the first rough placement, Second concept did not fulfil requirements and the final clipping design.

Figure 5: final clipping design detail

Colour options/limitations and transparency

In the concept stage, the goal was set to use plastics sourced from post-consumer waste. However, during the development stage it became clear that high quality transparent PCR materials are nearly non-existent. Therefore, plastics from both post-industrial and post-consumer sources (outside of WEEE streams) have been used. The required noble appearance could eventually be achieved by sourcing only the best recycled materials available from packaging and other waste sources. Whilst PCR materials are preferred, PIR materials should still be considered before virgin.

The quality and variety of colours is very important for this demonstrator especially as it focusses on the decoration/design market. A good colour range makes it easier for the consumer to decide where the product would fit in the interior. Giving the option the play with colours is an added luxury which few fixtures offer, adding to the desireability. Next to this an variaty of colours also makes the fixture suited for a wide assorment of interiors.

For this reason, a colour palette was proposed to Sitraplas based on real glass samples. By providing the fysical samples we could clearly explain the desired effect (transparency, colour intensity, etc) that was intended. The colour samples sent can be seen on Figure 6.

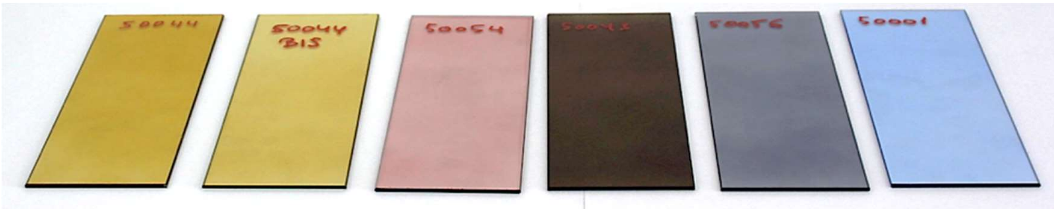

Figure 6: Glass colour samples

Sitraplas produced the following coloured materials based on both PCR and PIR non-WEEE sources:

- SITRALON (PC) EP11762-CO Light blue
- SITRALON (PC) EP11762-CO Dark blue
- SITRALON (PC) EP11762-CO Brown
- SITRALON (PC) EP11762-CO Yellow

The produced materials are shown on Figure 7, the technical datasheet of the base material can be found in the appendix, the colour differences do not effect the properties.

Figure 7: developed PC colours from Sitraplas

Modularity

It is commonplace in WEEE recycling that the products are shredded before separating the various materials via an assortment of separation techniques. The ability for a product to be broken up into the different mono-material components by means of shredding often determines the recyclability of the product. As recyclability is a core idea of the product, special attention was put in following the guidelines when developing a product for easy recycling:

- The used materials are recyclable and targeted by WEEE recyclers
- Enabling easy manual or mechanical separation
- Avoid glued joints or other permanent fixings
- The electrical components are quickly and easily disassembled from the structure (aluminium parts) and without having to use special tools.

These requirements can easily be implemented when looking at modular design. Modularity in the product design not only allows for versatility in a variety of end-products but also has the advantage that broken parts can easily be replaced or separated in the different components. This first of all, prevents the renewal of entire product enabled Ona to extend the overall product life-time and secondly allowing easier recycling.

Quality of the mould and experience of the moulder

The mould was developed by a supplier that was subcontracted by Ona. The design was closely discussed between Ona and the supplier and shortly reviewed by members of the consortium. Once the machining had been finished the mould the first injection moulding trials were set-up. It was possible to fill the entire part, but an issue with jetting became visible as can been seen on Figure 8.

Figure 8: Results first injection moulding trials

After discussion with the experts within the consortium, different conclusions were made. Finally it was decided to search for a new injector that would be able to achieve an better result. This caused a great challenge and delay in the planned schedule for the task. Knowledge of plastics moulding appeared to be crucial in the development process. One easily tends to blame the material (not performing as desired) when issues in production occur. And even more so when using recycled materials. However, knowing how to deal with materials in moulding and the willingness to execute tests can lead to surprising and satisfying results. The experience of the person handling the material is key for success.

Reaching out to another supplier, having more experience with PC, immediately showed improvements. The first injection moulding trial without adapting the mould showed to be promising. As can be seen on Figure 9 the jetting issue is much less.

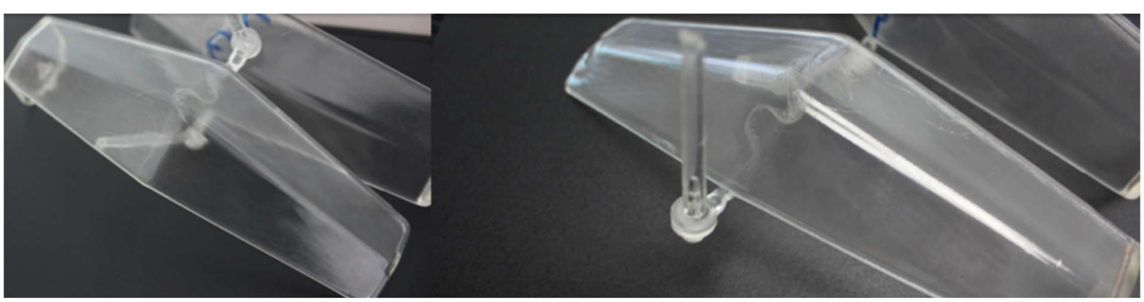

Figure 9: Results first injection moulding trial with second supplier

In discussion with the new supplier it was decided to change the point of input. The new inlet gate (see Figure 10) is machined at posistion B where it previously was at point A.

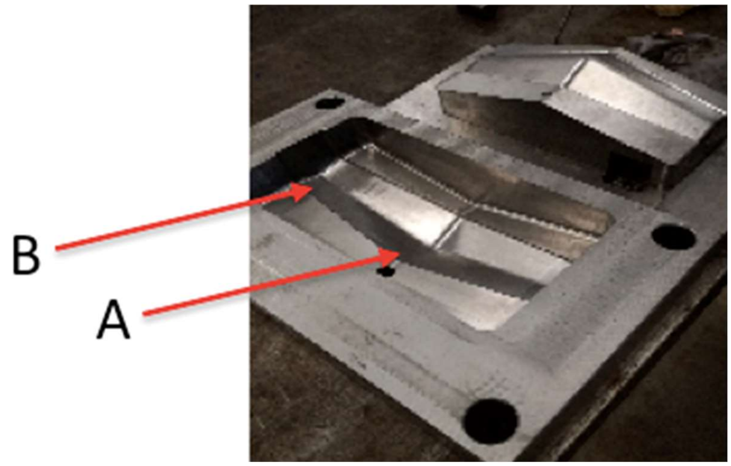

Figure 10: Inlet gate change

After gate modifications were performed and injection trials were successfully performed, the mould was polished to obtain the desired finish. After polishing some small defect became visible at the inlet gate, as seen on Figure 11. This required another change of the inlet gate. This time not on the position but on the shape of the inlet.

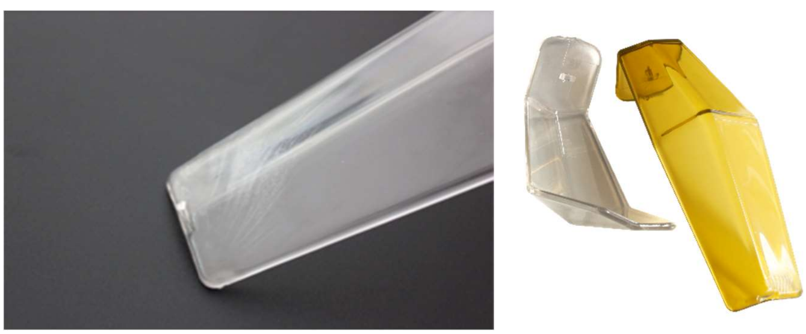

Figure 11: Trials after mould polishing, Streak marks at inlet

After the shape of the gate inlet was modified, injection moulding trials did not show the streak marks anymore. As can be seen on Figure 12 were sample one represents the mouldings before gate modification and sample two after. At the time of writing production of the parts in the various colours is ongoing.

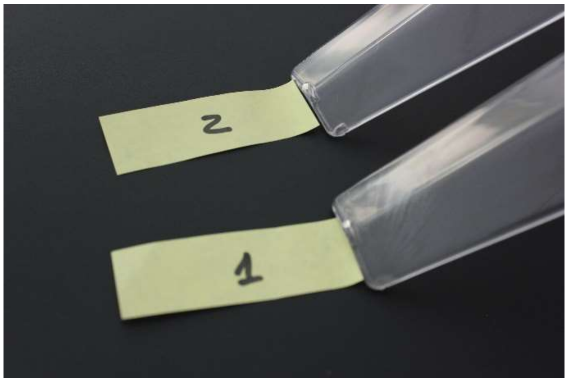

Figure 12: Sample before and after gate modification

In conclusion it can be said that initially the moulding trials, although virgin PC was used, did not result in producing successful parts. However, partnering up with an experienced moulder made the difference in moulding parts successfully.

Electronics

The type of electrical components used have been chosen according to the model and its functions. The table lamp has standard market bulbs, allowing users to change said element easily and quickly at any time. Meanwhile the hanging models have LED strips, which guarantee a good performance and durability.

Design for recycling

The set-up of our demonstrator is made up of three elements: electrical components (cables, lamp holders, plugs, …), structure/frame (aluminium) and lampshades/boomerang (plastic).

- The electrical materials used can be easily removed manually or by shredding and treated accordingly.
- The structure/frame is made of aluminum, which is a material with high recycling rates. The frame is even made from recycled aluminium.
- The PC developed by Sitraplas is a commonly recycled polymer type, all the pieces are also easily removed from the rest of the product thus reducing the changes of contamination.

One of the biggest hurdles when developing a product with Design for Recycling in mind is making sure all parts are easily separatable at its end-of-life without compromising on its life-time or durability.
For example, in our case, the lampshades and the structure can be separated manually thanks to the clipping that was explained in the previous section, making the separation of material as easy as possible without compromising on the functionality or durability.

Conclusion

By working with a step-by-step approach, under expertise consultation and making concrete choices on the material early on in the development process is was possible to design a new high-end lighting fixture that can compete with fixtures made from more “noble” materials.

We have been able to verify that it is possible to obtain a product with similar quality and characteristics (colour, transparency, etc.) to more conventionally used materials with recycled polymers. The added advantage is that the shape of the product allows for more freedom than with conventional materials, opening new and unexplored design possibilities.

The biggest problem has been to find a supplier that had the experience and the adequate machinery needed to produce the product with the choses material (PC) and with the required quality standards that have been set for this demonstrator. It is important to take into account the fact that the production quantities needed for these design elements are quite small, where usually most suppliers work with higher production runs. Economically these low production runs do not appeal to most suppliers. Often these small production batches are produced in between larger runs which makes it cumbersome to optimize production. The cost of the mould is another factor that must be taken into account. High-end design products are usually produced in small quantities especially compared to products that are commonly made with injection moulding so, the cost of the mould must be shared over much less parts which drives up the price. Hybrid moulding could offer a solution although high surface quality is still difficult to achieve.

However, in this case, the use of a modular design that covers different types of lamps, (table lamp, pendant lamp) with different possible shapes (circular, elongated, rectangular, ...), requires the production of larger quantities of the same part. This can also increase sales as the design is customizable depending on the wishes of the clients and the available space. This means that the cost of the mould can be justified.

In general the four key learnings concluded from this successful demonstrator are listed below.

1. **Transparent colour limitations**
   Obtaining colour freedom and transparency in recycled polymers is one of the big challenges of recyclers today. This means that finding high quality coloured and/or transparent grades for similar projects is challenging but not inevitable.
2. **PIR over virgin**
   When PCR plastics do not meet requirements, it is worth exploring PIR grades. A higher purity and colour freedom can be obtained from these sources. Compared to virgin, PIR plastics is still the better option.
3. **Processing experience**
   Moulding experience and the will to perform moulding tests are key to succeed. Involving the experience and knowledge of the moulder can make the difference in achieving the results you are looking for in your material.
4. **Modularity in design**
   Modularity is a great way to design a versatile product and offers the advantage to replace broken parts easily without replacing (and wasting) the entire product. Modularity also has the potential to better support recycling processes as parts usually break apart during shredding.

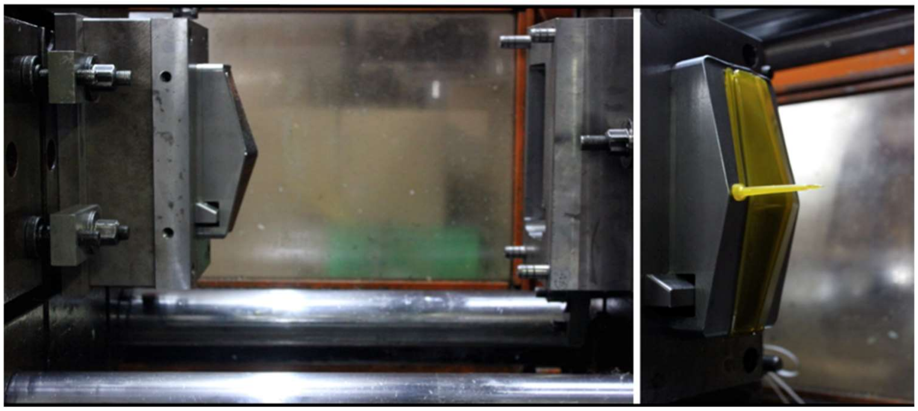

Figure 13: moulding of boomerang pieces

PRELIMINARY DATASHEET

PolyCE PCR-UV standard

Print date 11.02.2021

Product description Polycarbonate / Amorphous Thermoplastic / UV stabilized

Properties	Standard	Test condition	Unit	Value
Rheological Properties				
Melt Volume - Flow Rate (MVR)	ISO 1133	300°C / 1,2kg	$cm^3/(10min)$	20
Mechanical Properties				
Tensile Modulus	ISO 527 -1, -2	1 mm/min	MPa	2.400
Stress at yield	ISO 527 -1, -2	50 mm/min	MPa	50
Charpy impact strength	ISO 179 - 1eU	23 °C	kJ/m^2	N
Charpy notched impact strength	ISO 179 - 1eA	23 °C	kJ/m^2	8
Strain at yield	ISO 527 -1, -2	5 mm/min	%	5,5
Thermal Properties				
Vicat softening point	ISO 306	50°C/h; 50N	°C	140
Other Characteristics				
Density	ISO 1183	23°C	g/cm^3	1,2

Conditioning	Drying temperature	100-110 °C
	Drying time	2-4 h
	Max. moisture content	< 0,02 %
Processing	Melt temperature	280-300 °C
	Mold temperature	80-120 °C
Storage	dry, dust-free, protected from light not above 30 °C	

Remark