PolyCE

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

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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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Gunther Höggler	MGG polymers

Disclaimer

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Summary

The Imagination Factory (IF) originally planned to develop a modular smartphone demonstrator with Circular Devices. However, during the PolyCE project Circular Devices left the consortium and instead IF was tasked with developing a consumer electronics product with one of their SME partners. This partner is called FundWaste which is a "wealth to waste" company helping people increase levels of recycling. Part of their ecosystem is an IoT sensor that helps companies maintain the quality of their recycling and avoid contamination of their waste streams. The IoT sensor requires a plastic housing so IF applied the design for/from recycling guidelines developed in the PolyCE project and selected a material from MGG polymers. Injection mouldings of the design were produced by Pezy and passed the requirements for performance. This included carrying out drop tests since the product is intended to be used in some unforgiving environments. The surface finish of the final mouldings, although not developed to a very high specification, demonstrated that PCR materials are perfectly acceptable to the intended market.

The development of the electronics that was carried out instead of the modular smartphone attempted to maintain a degree of modularity. This was only achieved at the level of the core IoT component which can be swapped between Cellular and Wi-Fi versions.

During the design of the demonstrator two main deviations from the guidelines were found to be necessary which produces useful learning and a challenge for further research and development.

Firstly, there is a plastic lens that covers an Infra-Red LED used to illuminate the scene in the dark which could not be sourced in a PCR material. Due to it being a dissimilar material to the housing the intention was to secure it in place with a press fit. However, after testing with the moulding it was found that this would be better secured with clip features. Currently, these lenses would be ultrasonically welded or glued in place which is not acceptable for recycling.

Secondly, the product would ideally have a seal to prevent water ingress. Since a suitable material was not found for this and FundWaste confirmed that this initial batch of devices will be used under cover there was no seal incorporated into the design. However, FundWaste intend to fit the sensors inside commercial bins in some cases where a seal will be essential.

Task description

In this task The Imagination Factory developed an IoT sensor for an SME called FundWaste. The plastic housing of the sensor was designed and moulded using materials developed by one of the PolyCE consortium partners. The moulded housing was tested for performance in real world conditions to confirm that the information on the data sheet conforms in practise.

Goals

Using Post-Consumer Recycled (PCR) plastics, design a consumer electronic product for an SME. The resulting product should:

- Be electronically and mechanically feasible.
- Offer a profitable business case for the SME.
- Provide an element of modularity for future upgrade to the electronics.
- Easy to use and attractive to end users.

Approach

A full product design and development process was undertaken to create these housings from conceptual design, visual brand positioning, and through to design for production. The Design for Recycling guidelines were used and implemented into the design of the parts. New PCR plastics were also used to produce parts and issues were identified, highlighted, and where possible rectified along the way.

The delivery of the prototypes demonstrates what TRL level can be achieved with the PCR plastics. Problems or limitations in using this approach have been documented and will give direction for further investigation.

At the start of the development process, several aspects concerning the requirements of this product in combination with Design for/from Recycling were indicated that needed to be investigated:

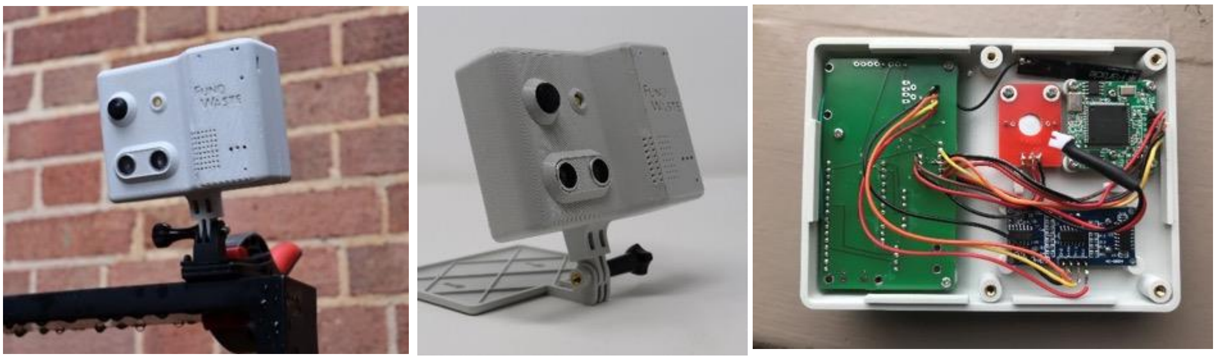
- Properties of recycled PC-ABS
    - Colour options and limitations
    - Functional performance in the intended environment
    - Mouldability
- Design for shredding
    - Parts should not be held with tapes, glues or other adhesives
    - Wall thicknesses must be above a minimum threshold
    - Combination with specialist materials such as lenses
- Logo on product

Properties of recycled PC-ABS:

The FundWaste sensor is designed for prolonged use in outdoors, industrial environments with minimal maintenance. It is important that the casing is rugged and resistant to drops from reasonable height and impact with hard flooring such as concrete or metal bins.

Both PCR plastic offerings within the consortium were considered. PC-ABS is more commonly selected for electronics and telecommunication applications as it offers the superior strength and heat resistance of PC and the flexibility of ABS. Virgin PC-ABS materials are also desirable for its large range of colours and the ease of processing due to low overall shrinkage and high dimensional accuracy.

The EvoSource PC-ABS 5368 polymer from MGG was selected for the development of the Fundwaste casework as it contained a much higher percentage of recycled content and the data sheet suggested good comparable performance in terms of impact strength etc. as with virgin material.



Starting point: 3D printed minimum viable demonstrator (MVD) produced by Imagination Factory.

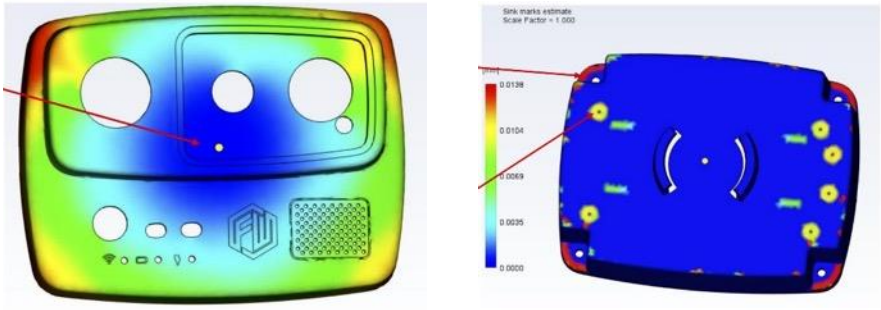
Designing a product for the circular economy required thought about both manufacture from recycled materials and design for efficient recycling at the end of the product's life.

In terms of the Fundwaste sensor, there was essentially a blank canvas from which to work. An MVD had been produced using break-out electronic components and 3D printed housings. The next stage in the design development was to reduce the overall footprint of the electronics and visually progress the design to better appeal to consumers.

Design development of a rugged aesthetic, suitable electronic layout, and features for mouldability.

There were key concerns over how the PCR material would perform compared to virgin materials in terms of mouldability. It was not known how these materials would perform in terms of shrinkage and warpage during cooling or how the flow of material may differ from simulations using data from virgin material.

Consortium partner Pezy were consulted to perform mould flow analysis on the parts and design changes were implemented to reduce the risk of sink marks and increase the wall thickness to allow easier flow of material in the mould.



Mould flow analysis results showing areas of sink risk.

It was recommended, based on the simulations, that the wall thickness of both parts was increased from 2mm to 2.5mm and material thinned out around the base of screw pillars to reduce the risk of sink.

Colour options/limitations

Whilst it is desirable, from an environmental point of view, to use materials with the highest PCR content and good mechanical properties, it would be the SME partner’s preference that the product housings would be white and silver.

RAL colour options expected from MGG datasheet as found online.

The data sheet for the EvoSource PC-ABS 5366 material that was used states that only a range of dark grey or black options are commercially available at a cost slightly less or comparable to virgin material. The only feasible option was to offer an alternative colour scheme for the product using the darker colours. The Slate Grey (RAL 7015) was specified for the front housing and the Jet Black (RAL 9005) for the back housing and button. This was a good compromise to use the available colours and maintain the visual contrast at the split line and with all the other components.

SME partner preferred colour scheme, slate grey and black concept and final demonstrator.

Upon receipt of the materials from MGG however, it was noticed that the grey colour was much lighter than was anticipated and therefore deemed not appropriate for use in the demonstrators. The product delivered to the client is therefore black all over. Naturally, this is a compromise compared to the options provided by virgin material but, at this stage, is one deemed worth it for the overall benefits of using PCR materials.

Design for Shredding

One of the most common techniques used in WEEE recycling is shredding, this breaks up the product into smaller pieces and separates the different material components. Using glues or mixed materials in the assembly of a product can make this harder to achieve. During the shredding, the product will not easily fall apart into individual material components. This makes it harder to recycle and, in the worst case, it can end up being incinerated. It is therefore imperative that Design for Shredding guidelines are followed so the product can be effectively recycled at the end of its life. Some design points considered in this demonstrator regarding Design for Shredding are listed below:

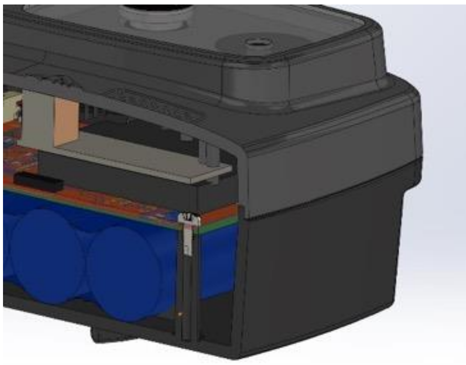
- No glue or tapes. Only screws or clips.
- No mixed materials moulded together or materials permanently enclosed.
- Avoid small wall sections which become dust and can be lost in extraction.

Other similar products on the market achieve waterproof housings by ultrasonically welding the caseworks together. This has been avoided to aid the retrieval of technical components such as the battery. Instead, thread forming screws were used for the assembly of the two halves of the casework and the PCB boards. This is important as the battery is likely to explode if put through the shredding process. Thread forming screws also negate the need for metal threaded inserts which are moulded into the plastic.

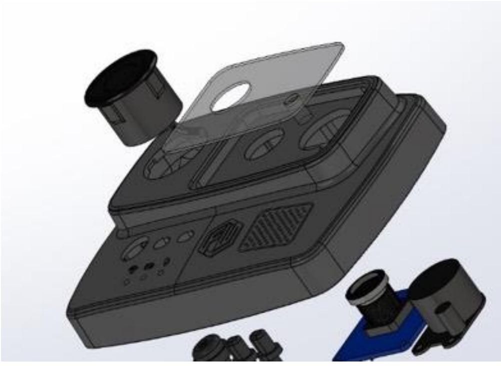
Thread forming screws in assembly of demonstrator.

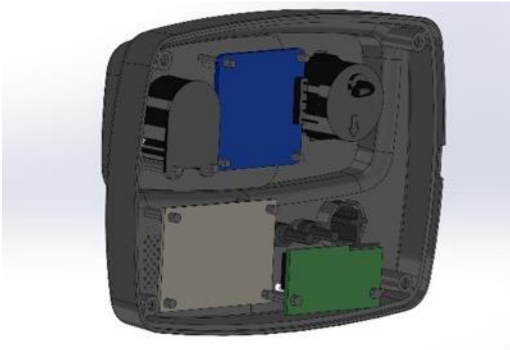
Ideally, the Fundwaste sensor is intended to be water resistant to IP54. It was discussed with consortium partners as to the ability to produce a PCR version of elastomeric polymers to form a gasket seal. This is not yet possible with current recycling technology. Therefore, to use gasket seals would introduce more technical components that would need to be recovered prior to recycling. It was decided, for the purpose of this demonstrator, to instead maximise the water resistance by simpler means such as torturous paths, and lips and grooves etc.



Cross section showing lip and groove and screw boss detail.

One technical component which could not be avoided was the infrared transparent window on the front of the product. This was hoped to be laser cut from a flat sheet of PC, however, upon investigating material choice this product was not available as a PC so PMMA has been used in the demonstrator instead. This window is push fitted into the front housing of the product. Whilst this increases the likelihood of the window being knocked out of place, it is an important feature of the design for shredding guidelines that these different materials are not permanently fixed with glues. Other PCB boards which had mounting holes too small to accept screws are also push fitted on to bosses in the housing. A further development of the design could add clip features to the IR lens to hold it in place securely in case the product is dropped.





Push fit technical components for avoidance of permanent fixtures.

Building on previous knowledge

At the beginning of the PolyCE project there was some concern over whether the black PC-ABS from MGG might interfere with the RF signal required for the sensor to connect and send data over the internet. However, work that Pezy carried out had proved this was not an issue by the time IF began its design work. More information can be found in D7.4.

Branding with logo

It is commonplace to add a logo to a product to promote the manufacturer of a product. Adding a logo can be done in numerous ways but not all are appropriate for efficient recycling as it can alter the density of a part making the identification process more difficult. For this application two choices were possible for a logo on the housing, in-mould embossing/debossing or a pad printed logo.

Pad printing offers the most freedom in terms of colour and small details, but it does also introduce a small amount of lacquer added to the PC-ABS housing. As it is a small logo in this case, the amount added is much lower than the 1% threshold described in the guidelines. Therefore, this would not necessarily disrupt the recycling process.

Embossed or debossed details in the mould tool is the best option from a recycling point of view. The colour and amount of small detail is limited to the colour and mould flow characteristics of the material but this method avoids any additional processing and cost of adding the logo as it is included in the price of producing the tooling.

At this scale both options would comply to the design for recycling guidelines. The choice could be made on an aesthetical basis and price, although avoiding the use of any lacquer where possible will keep the material purer and easier to identify and therefore is most in line with the goals of the PolyCE project.

SME partner preferred concept for blue, metallic logo Vs. Debossed in-mould logo produced for demonstrator.

Results

Electronics

Electronics were developed within this project to fit within the new housing design and to enable the use of the Particle B523 IoT core. All PCBs were designed to be attached to pillars in the housing with thread-forming screws. The LiPo battery was positioned so that it is held in place by the main PCB and some ribs on the rear moulding. This should facilitate removal prior to shredding as per the guidelines.

Moulding Quality and Surface Finish

Tooling was created by consortium partners at Pezy to produce a batch of prototype parts for assembly and testing.

The moulds for the bottom housing and the button produced good results; similar to expectations from the mould flow analysis.

First off tool mouldings of the on/off button and housing bottom.

The housing top, however, produced some different results to those expected. The material failed to fill the tool correctly around the cluster of small holes for the gas sensor. Where the mould flow simulation shows no issues with the layout and size of holes, the partially filled tool shows that the material gets held up here and therefore does not fill.

Mould flow analysis Vs. first off tool results for top housing part

At the time it was not known if this issue with the front housing was due to marginal differences between the PCR material and virgin material in terms of mouldability. To rectify the problems the number of holes had to be reduced to allow better flow of the molten plastic. It is believed that this has not affected the functionality of the gas sensor. Prior to modifying the tool Pezy ran a virgin PC-ABS through it and discovered that in fact the same issue was observed. This is a further encouragement that the PCR moulded in a very similar way to virgin material and in fact the issue was due to limitations within the Moldflow simulation software. It also highlighted that even amongst those of us who are keen to use PCR materials when something unexpected happens we tend to blame the material first. Much work will be necessary to change this attitude amongst manufacturers and designers.

Drop Tests

To evaluate the mechanical performance of the casework parts, drop tests were conducted on four casework assemblies; three caseworks without any electronics and one fully assembled electronic assembly.

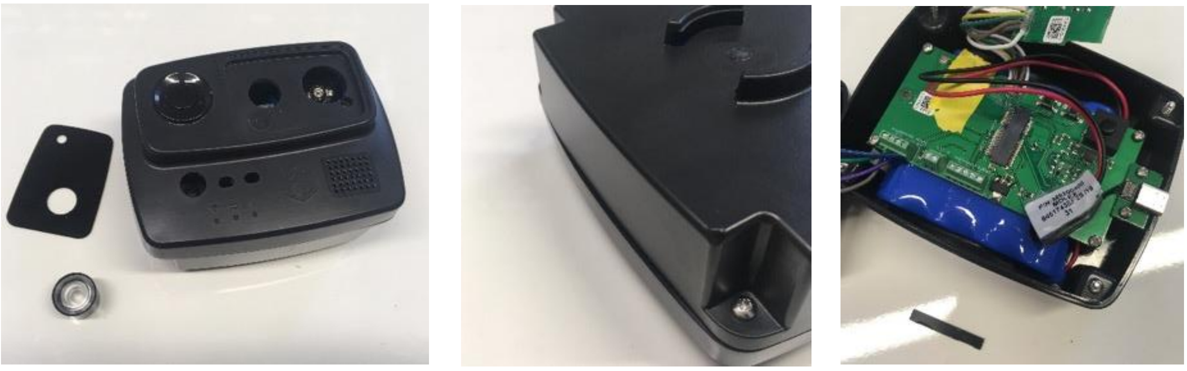
Each assembly was dropped on to a platform consisting of 3mm stainless steel sheet bonded to 25mm plyboard. The caseworks were dropped incrementally from a height of 750mm, 1000mm and 1500mm above the platform. Each assembly was dropped twice from each height before moving on.

Overall, the housings performed well in all tests. The empty caseworks displayed only minor visual scuffs and dents. At the 1500mm height, it was noticed that the split line began to warp and shift causing a small overhang. This does not significantly affect the integrity of the housing but was an unexpected outcome. Without a similar housing made from virgin PC-ABS, it is hard to tell whether this is because of differences in the PCR material properties or a result of the housing design.

Small visual dents and shift in split line. No breakages.

The full electronic assembly also performed reasonably well. On the very first drop at 750mm, the infrared window and the lens on the infrared sensor immediately fell out. This is most likely because of the lack of glue or fixings holding these parts in place. Snap fits or clips should be considered in future to hold these parts in more rigidly without the need for permanent fixings.

The inertial shock of the battery caused some of the internal ribs which were designed to hold it in place to break. The added weight of the battery and other components also meant the shift in the split line was much more pronounced in these tests. In all cases however, releasing the screws rectified the issue demonstrating elastic rather than permanent deformation. Further investigation would be needed to identify why this warping of the split line occurs.

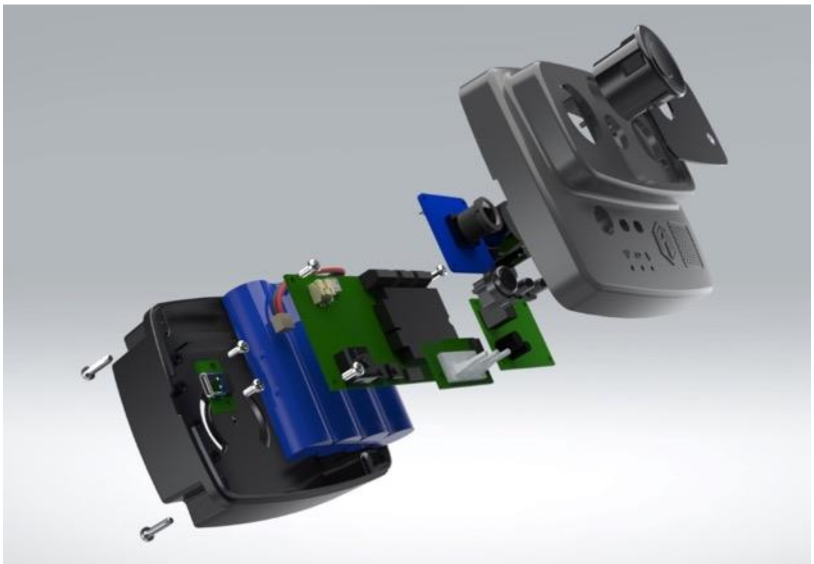


Dislodged lens and window. Shift in split line and broken internal rib features.

No other major faults, cracks or breakages were observed in any of the tests showing that the housing performed well in impact testing and displaying no discernible difference between the PCR material and virgin PC-ABS.

Design for recycling

The Design for Recycling guidelines had to be used correctly from the conceptual stage of the design. Since elastomers are not currently recycled, a decision had to be made how best to protect the function of the electronics in harsh, outdoors environments. Lips and grooves, and torturous paths have been implemented to try to stop water ingress in the product. However, this is a compromise compared to using different design features such as gasket seals, ultrasonically welding parts together, or the use of adhesive gore-tex patches which would comprehensively seal the housing and protect the electronics. This compromise has been made to fulfil all the technical requirements necessary for the Design for Recycling guidelines.



Exploded view of housings internal components.

Design for disassembly has also been considered for the retrieval of technical components prior to shredding. The use of thread forming screws has removed the need for additional metal inserts and means that the battery can be easily removed with basic tools. The use of glues, tapes and potting resins has also been avoided so that there are no mixed material components or any components which are permanently fixed or encased together.

Design from recycling

All parts other than the infrared transparent lens are made from Post Consumer Recycled PC-ABS material. This has meant a limited choice of colour and branding options for the SME partner and limited the ability to seal the product to an appropriate IP rating for the outdoors environment. Within the scope of the project, this is acceptable for initial trials and functional testing of the electronics but may cause problems in the future development of a certifiable consumer product.

Drop tests and visual inspection have shown that the mechanical and aesthetic properties of the PCR material are indistinguishable from virgin PC-ABS.

Conclusion

By making a good choice of material early in the development process, it was possible to design a product which meets the technical requirements for designing from recycled sources and designing for ease of recycling at the end of life.

Designing for Recycling limited the options in terms of waterproofing the design due to the inability to recycle elastomeric materials currently. The performance of the assembly in the drop tests was also slightly affected, although the issue of the infrared lenses falling out may be resolved with snap fits or knock down fittings.

Designing from recycled materials had little impact on the overall shape, size, and function of the design. The freedom in using colour and large printed logos with PCR materials is limiting but in this instance was of little consequence to the SME partner.

Mould tools produced and used by Pezy for production of prototype batch of parts.

First fully assembled demonstrator.