Medical/Lab Equipment

Glass2Mass team 2

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ABSTRACT

In the medical environment there exists a big amount of non-recyclable waste due to the single use devices made out of plastic that are currently being used for treatments. With Glass2Mass technology, this equipment can be manufactured in glass, meaning it will benefit from the properties of glass. These properties include the recyclability, optical properties, and the fact that it can be sterilized and therefore reused unlimited times. Our solution also envisions the possibility of creating custom-made laboratory equipment, catered to researchers that are in need of special equipment for specific experiments and lines of investigation.

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1. Introduction and team presentation

Out team from ESADE, UPC, and IED is composed by Gorka Pradas, Marc Grau, Marc Clascà, Laura Del Rio, Luca Rosati, Rodrigo Triana, Irene Fuentes, Wei Sun, and Arslan Nafikov. Together, we've been on an exciting adventure exploring Glassomer; 3D printing material for the glass of the future.

Our team has diverse talents and backgrounds: engineering, design, business… That's why we've been able to explore Glassomer from all angles and uncover its mind-blowing potential in various industries.

During the process, we have been divided into 2 groups, so we could work on different ideas as solutions for the technology application. We have been working into several potential solutions such as optics, filters, automotive, healthcare and other environments. For this aim, we have been working for several months by doing interviews, gathering information, meeting the responsibles of both the company and the teachers, and also having the opportunity to visit different workplaces in order to get inspired and find more ways to work altogether.

And finally, we've come up with these final ideas that will leverage Glassomer's unique properties. In this report you will find how we managed to reach the final conclusions, where you will be able to discover our proposals as applications for this technology.

2. Technology overview

a. Brief presentation of Glassomer

Glassomer is a patented process of manufacturing glass objects. It consists of mixing glass powder and liquid or solid binder to obtain a malleable mass. This mixture can be 3D printed, casted or also used in injection molding. Once the object has the desired shape, the binder is eliminated with a thermal step to obtain pure silica glass. The company behind this step forward is Glassomer, GmbH., who provide both the technology solution and ready-to-use on demand glass products.

Conventional methods of glass manufacturing (molds or by blowing) allow only the creation of easy shapes. With this technology, complex shapes can be created in all sizes (from nano to macro) and in different colors.

We were introduced to the technology by Bastian Rapp, CTO of the company, in a first virtual meeting in March 2023.

b. Technology detailed description

The Glassomer process allows both 3D-printing-like and injection molding fabrication processes for glass. The base nanocomposite of Glassomer can be liquid, for 3D printing, or solid, for injection molding. Glass powder and organic binder matrix are combined in a first step to obtain the nanocomposite. The second step is shaping, done by 3D printing, molding on a regular polymer injection molding machine at 130°C, or via stereolithography. Finally, the third process removes the binder from the object with an oven process at 600°C - in a first pass - and sinters the parts with a 1300°C process to obtain high-purity, highly transparent fused silica parts - in a second pass.

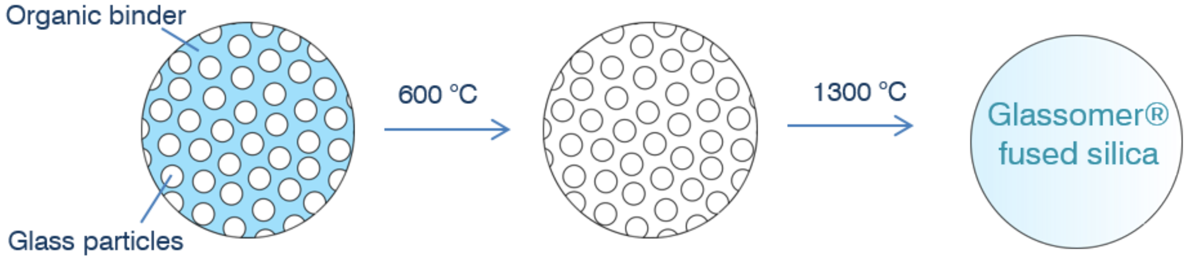

Figure: *Representation of the process of obtaining the fused silica glass, corresponding to the third step. Source:* [1]

The technology also allows a novel “3D-printing-compatible approach to manufacturing high-quality fused silica glass components using stereolithography, microlithography and microstereolithography[2]”. This process allows going beyond current size and resolution limits in glass structuring, and provides final glass products with full optical clarity and reflectivity

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[1] https://3dprint.com/261177/interview-with-glassomers-dorothea-helmer-3d-printing-fused-silica-glass-on-desktop-sla-machines/

[2] Kotz, F., Arnold, K., Bauer, W. *et al.* Three-dimensional printing of transparent fused silica glass. *Nature* **544**, 337–339 (2017). https://doi.org/10.1038/nature22061

suitable for optical applications. Silica nanoparticles are distributed in a monomer matrix, which consists mainly of the *hydroxyethylmethacrylate* (HEMA) monomer. Then this nanocomposite can be shaped with stereolithography. Finally, the process described below is applied to end up with the final glass product.

c. Main advantages and initial applications

With a first analysis of the technology, we rapidly identified the key technical aspects that add value of this glass production method over the regular glass used today:

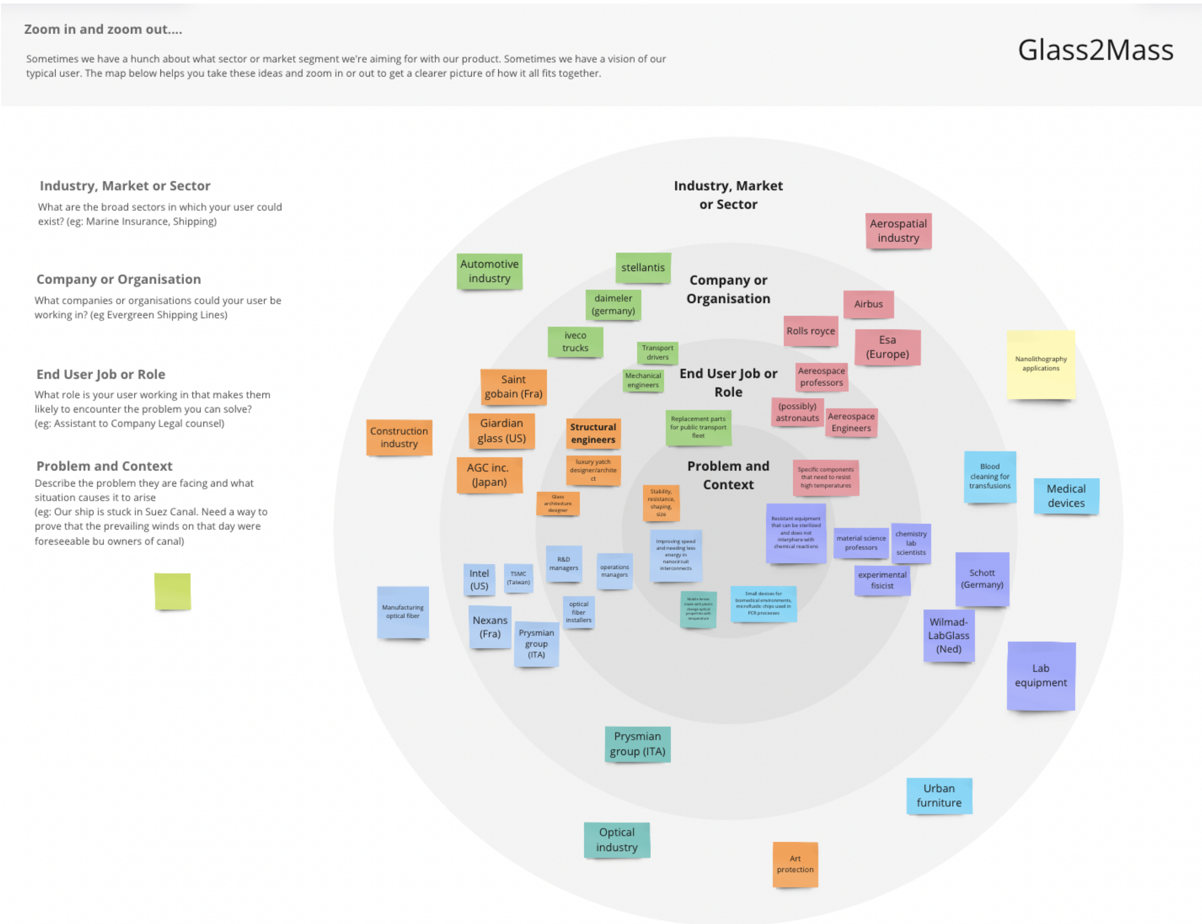
- Pure fused silica glass (silicon dioxide, quartz), and aluminum oxide, borosilicon, sodalite
- Full optical properties
- Chemically inert and resistant
- Thermally resistant
- Complex and small shapes and structures

With our initial meeting with Bastian, we discussed applications that the company was already exploring, but that we think helped give a first approach to what Glass2Mass was capable of. These applications cover optics and photonics, with precision lenses and fiber connectors; medical technology and lab-on-chip devices; or automotive industry, with the devices needed for environment sensing.

3. Exploration of application fields

a. Initial proposed fields of application

We thoroughly researched and analyzed various scenarios, considering different contexts and applications where our Glass2Mass technology could have the most significant impact. Through an extensive brainstorming session utilizing Miro, we explored potential fields of application and identified the most promising avenues to pursue.



Sometimes we have an intuition about the industry or market niche that our product is targeting. We occasionally envision our typical user. The map helped us clarify our ideas. It doesn't show the filter industry because the idea has been developed later. Here we'd like to discuss the 6 fields that seemed to be promising but were not deepened, since we decided to focus our attention on other sectors with a higher social impact.

1. **Aerospace Industry:** Glass2Mass's excellent thermal and chemical stability, as well as its transparency, make it a potential asset in the aerospace sector. Due to these characteristics, it can be used for a variety of structures and components in aircraft applications, including windows, optical systems, and sensor housings. Glass2Mass's capacity to produce intricate structures using 3D printing and precision molding would make it possible to create components for aviation and spacecraft that are light, tough, and high-performance.

2. **Automotive Industry:** Precision glass 3D printing or molding will enable the fabrication of intricate vehicle components with enhanced thermal and chemical resistance. Additionally, windows, lighting fixtures, and sensor housings could all benefit from the transparency of glass, which has both aesthetic appeal and practical advantages.

3. **Construction Industry:** Glass2Mass offers the potential for creating complex structures in glass, which could be advantageous in the construction industry. The ability to 3D print or mold glass with precision opens up new possibilities for architectural designs and construction elements. Glass structures can provide transparency, allowing natural light to penetrate while maintaining high thermal and chemical stability. This could lead to innovative applications such as glass facades, structural components, and specialized glass elements for buildings.

4. **Medical Devices:** The use of advanced glass materials in medical devices offers several advantages due to their high transparency, chemical neutrality, and biocompatibility. Glass components, such as lenses, tubes, and containers, can be manufactured with precision and tailored to specific medical device requirements. The properties of glass, including transparency and durability, contribute to improved functionality and performance in medical applications. Moreover, the recyclability and long lifespan of glass align with sustainability goals in the medical industry.

5. **Manufacturing Optical Fiber:** Glass2Mass could be utilized in the manufacturing of optical fibers, which are essential components in communication networks. The ability to produce glass with precise specifications, such as low impurities and tailored refractive indices, is crucial for optical fiber performance. Glass2Mass's process offers the potential to produce high-quality glass with desired properties, leading to enhanced transmission characteristics and improved signal quality in optical fiber communication systems.

6. **Art Protection:** transparent and chemically stable glass materials offer ideal solutions for display cases and protective enclosures. By providing optimal visibility, durability, and protection against harmful factors such as UV radiation and environmental elements, advanced glass materials ensure the long-term preservation of valuable art pieces.

b. Information gathering

Once we had our scope defined it was time to gather information and ask professionals about the different topics. In order to do this we created a spreadsheet where we were going to write all the contacts which came to our minds. Then, we filled all the information needed about these contacts and divided who will be contacting them. Therefore, we could be working in parallel and be able to cover all our contacts.

We recollected up to 40 contacts from different areas and in the following lines we are going to present the interactions which added some value to our research.

Medical Devices

Interview with Roger Puey - Laboratory Technician at Centre de Recerca Biomèdica CELLEX

The main purpose of the interview was to ask him which equipment made of plastic he uses everyday and he throws away after each use. With this, we could know some of the more technical equipment that is used. He gave us ideas about fluid reservoirs and multichannel pipettes that could be made out of glass.

Optical Fiber

We studied the application of Glass2mass in the semiconductor industry, as fiber optic inside computers. For this topic, we did some desk research to understand the possibilities of creating the needed structures in glass that can act as a fiber optic channel in processors and boards to increase data transmission bandwidths and shorten latencies. The main bottleneck in computer performance is retrieving data from the main memories to the computing units, and with optoelectronic connections this could be tackled.

We considered using Glass2Mass for developing co-packaged chips, as doing the package structure with glass allows interfacing both fiber optic and electrical lanes, and adds light transmission into an integrated circuit. In addition to this, optical lanes could be used in conventional chips for on-chip optics between cores, or for on-board optic to interconnect processors with peripherals and main memory.

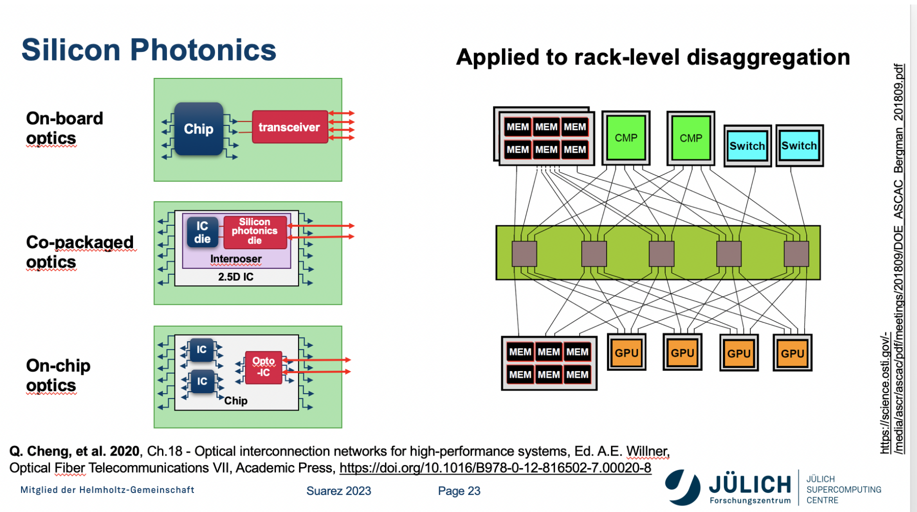


Figure: *Slide from ISC23 closing keynote, "HPC Achievement and Impact – Past and Future" from Estela Suarez. It presents the application of Silicon photonics as a near future trend in HPC systems.*

Although technically promising, this application needs further research in the filed of nanocircuit design and electronics, and thought that was out of the scope of our project.

Renewable energy

Interview with Francesc Guinjoan Guispert - Teacher and researcher at UPC

The goal of this interaction was asking for applications of glass in solar panels. We had a conversation with him about it and we can conclude some things about it. Lents are useful

for focusing the light and obtaining more irradiance in a point (this is a technology which is being phased out). Also, he gave information of elastics solar panels, which are now made of plastic, he said that they may be made of glass. He also added that we could find applications in micro optics.
From this conversation we couldn't conclude many things as it wasn't long enough and the topics were spoken very briefly. But, at the end, he gave us the contact of Santiago Silvestre which could give us more information related to this topic.

Interview with Santiago Silverstre Berges - Teacher and researcher at UPC
The goal of this interview was to find applications in solar cells technology. He suggested using Glassomer for low power cells that may have difficult shapes (i.e. circular) to replace the EVA plastic that turns yellow and reduces the efficiency of the solar cell. Moreover, he introduced the idea of creating a fresnel lens with this glass in order to improve the irradiance. However, improving the irradiance improves the heat that the solar cell receives so ventilation circuits are needed.

Interview with Onyx Solar - Photovoltaic glass panels manufacturer company
The goal of this interview was to gather more information about glass photovoltaic panels because we had some previous research on it and we find it would be interesting and a possible application. We didn't have an answer from them so this interaction didn't progress.

Academic
Interview with Jaume Castellà Maymó - Researcher and managing director of Optics at UPC
The goal of this conversation was asking about optical properties of glass. After exchanging some mails, from this interaction we can extract information about optic applications. They can be divided into two types, the ones which require image formation and the ones which don't. The first ones have more restrictions about quality, roughness and homogeneity of the component. Some of the fields which are applied are metrology, medical imaging and ophthalmology. The second ones have less restrictions and some fields will be lighting and detection of recounting, gasses,...
We concluded that we needed to research the quality of 3D printing for checking if lenses with image formation were viable (he gave us the name of a company which is starting to work with it, Luxecel). For the other, it is an available solution.

Interview with Carlos Enrique García Guerra - Researcher and managing director of Optics at UPC
The goal of this conversation was asking about optical properties of glass. This interaction didn't work out as we didn't receive an answer from him.

Aerospatial
The ability of producing complex, small glass parts on-demand raised our interest in the aerospatial applications. Pieces that could be produced on demand, with thermal resistance could be useful for situations in need of replacements for aircrafts, gadgets, or satellites. We had a conversation with people working in the industry.

Conversation with Joaquim Ferrer - Satellite Functional Test Engineer at OHB System

The company where Joaquim works, OHB System, is in charge of building and testing satellites for the ESA. The main use of glass in their company is optic lenses for the satellites. These satellites gather data about the Earth's atmosphere, terrain, and water through spectrophotometry and therefore need lenses that have full optic properties and that are resistant to temperature and thermal shock. Also, the main requirement in terms of resistance is being resistant to high vibrations. Although they buy the glass parts to external providers, their information was useful to determine the convenience of a solution into the aerospatial industry.

In our conversation with Quim we understood that satellites undergo a very deep and exhaustive fabrication and testing process, that spans along as much as 5 to 10 years for newly designed satellites, or down to 1 year for replicating models that are already in production. During this period custom optical pieces are ordered, installed and tested in different phases, so on-demand fast replacement of these pieces does not match with the fabrication process. A lot of stakeholders interact with the fabrication of a satellite and they are made usually for one or two purposes. The European Union launches only 5 satellites in one year, therefore we see that our rapid, on demand way to fabricate glass parts cannot find an application, in the current context, for the aerospatial industry.

Construction sector:

Interview with Sandra del Río - Architect and PhD student

In conclusion, this technology could be applied to build different shapes of windows. No other applications were found on a small scale.

Lab Equipment:

Interview with Gema Lopez - MNT-UPC department

She corroborated that, for example, in the clean room many applications could be found. She gave us a specific application where they needed to substitute teflon for quartz. Here we can see an image of the object that could be perfectly done with Glassomer.

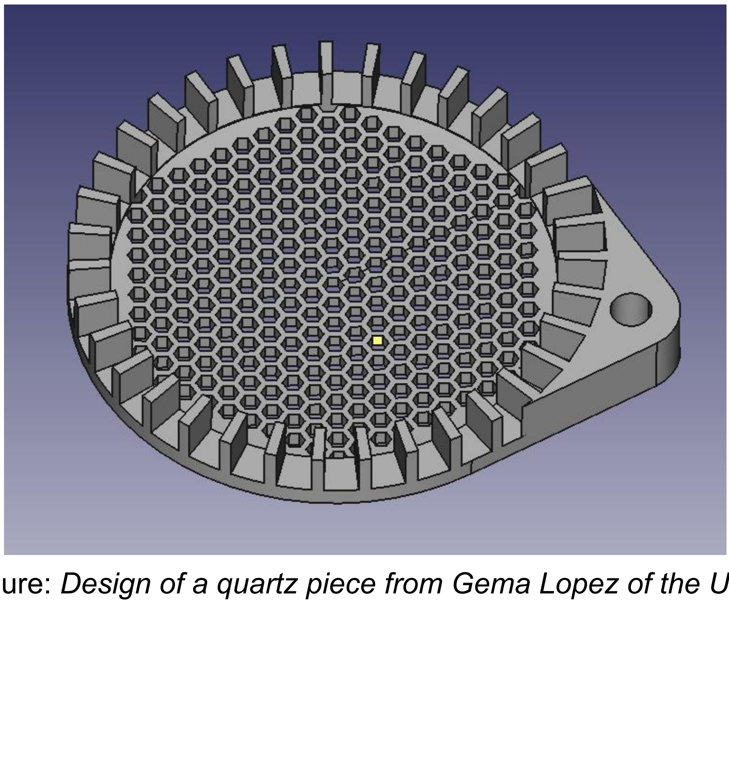


Figure: *Design of a quartz piece from Gema Lopez of the UPC*

c. Discussion on why we chose lab equipment, medical devices and filters, and which were finally “dead-ends”

After having considered many applications in the different fields that have been mentioned, we ended up choosing these three particular options for different reasons. One of the main reasons that we had to consider was the social impact that these applications had, this is why it was hard to decide on the applications we wanted to explore more.

In the case of lab equipment, the social impact it has is reduced, due to the fact that the lab equipment that will be made using this technology will be very specific, and for special experiments and research. But, it is true that this technology would bring a lot of opportunities to researchers, mainly by obtaining the equipment in a faster, completely customizable and cheaper way.

The second reason that we took into consideration is the environmental impact. This is why we focused on replacing plastic products already from the market to glass products. Glass can be completely sterilized and reused, as well as recycled, for this reason, plastic products in different industries could be replaced by glass products.

This is the case for medical devices. We chose this field because many of the products that are made in plastic and are single use equipment, could be sterilized and reused. We need to mention, though, that this has been a difficult field to study, mainly because the shapes that are used in the equipment are fairly easy to make with injection molding, and finding a piece that could be made with this technology required a lot of effort. We thought about replacing Eppendorfs, which are usually made with plastic, but we discovered that these pieces are made in a large scale way, and this technology would not be suitable for that.

The third application that we chose was filters. The filters already in the market are made of plastic and cardboard, which poses the problem that they get easily obstructed, need to be constantly replaced and can’t be recycled. Here we find one of the main issues we can solve with glass filters: the environmental impact of all the processes that need filtering, being water or air, where lots of filters have to be thrown away, with a very small portion being recycled. Making these filters in glass allows them to be cleaned with both inverse flow and more aggressive methods, makes them fully recyclable and can be reused. Applying this in critical contexts also can impact public health and microplastics pollution, with an added environmental impact, as we will describe in the following section.

The dead-ends that we found were basically products that had very large pieces, because, even though a lot of applications are envisioned with this technology, it is true that it is thought for more detailed applications, and not very large in size ones, that is why we discarded the aerospatial field. Also, as it has been mentioned, we discarded applications where we could see these pieces made with traditional techniques, because even though the making would probably be faster, the impact that it would have would be minimal compared to other applications.

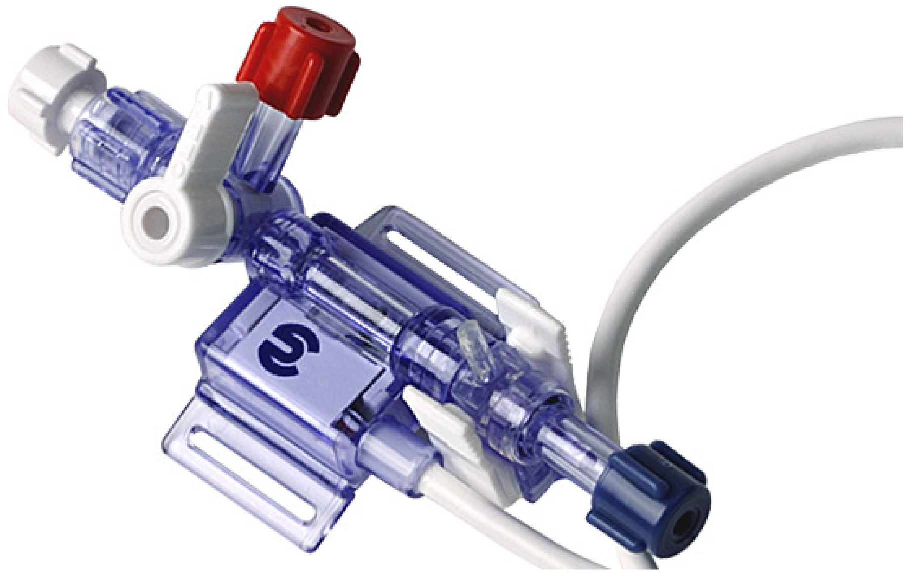
4. Final solution and application

a. Description of the problem we are solving

By making lab and medical equipment in glass we aim to solve several problems. In the case of customized lab equipment, nowadays we face the fact that these pieces are made with traditional techniques and require very skilled professionals, this makes the prices really high because their labor as well as their time needs to be compensated. Being able to design equipment in glass that will serve a purpose for specific experiments and need to have different complex shapes and then have them 3D-printed in glass with this technology will be very beneficial. Specifically, in the cost, basically because the cost of the material that is used to make glass pieces ranges from 15 to 20€/kg, and this will save a lot of money to the users. We need to take into account that, as it will be 3D printed and not made by hand, the time it takes for a piece to be completely ready will be reduced as well.
In what concerns the material, each customer can choose either quartz or borosilicate, and this will help them with their special needs.
In the specific case of medical equipment, our main concern is the fact that most of the equipment made nowadays is single-use and it is made of plastic. This generates an enormous amount of residues that could be completely vanished if these pieces would be made out of glass. As it has been mentioned, glass can be completely sterilized and reused, so all of these pieces would not be thrown away every time they need to be used.

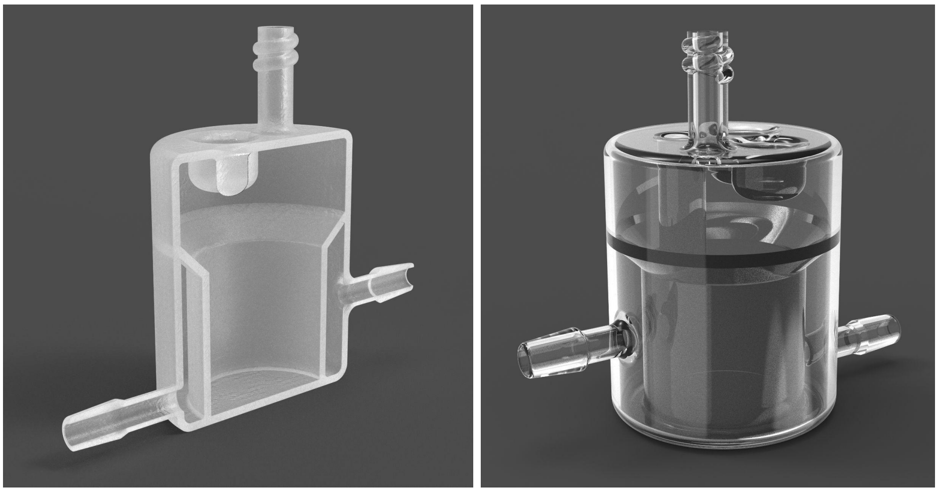
b. Description of the solution

In our case we present two solutions: lab equipment and medical devices.
In the particular case of medical devices, our main goal is to substitute plastic single use equipment for glass equipment. This can be progressively done, and could be easily implemented in hospitals because they have the proper sterilization machines such as autoclave. As an example of equipment that is thrown away every time it is used, we have an invasive blood pressure sensor.



The plastic part that covers the sensor could be done in glass so that it is not disposed of every time it is used.

As for the lab equipment, as it has been mentioned, every customer could design their own equipment and have it 3D-printed in the material that is chosen by them. An example of this can be seen in the following figures, where the design of a jacketed bioreactor is shown.

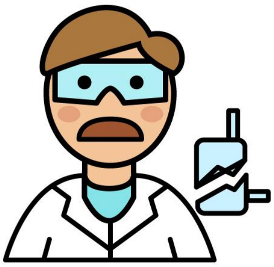


c. Implementation (type of product, business model, etc)

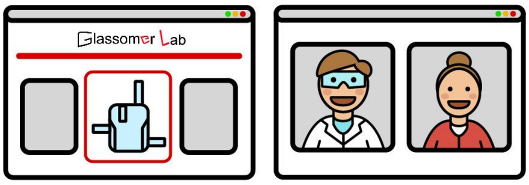
As we provided two solutions, the implementation phase would be different for each one.
On one hand, speaking about medical devices, the first step would be to supply the hospitals with enough glass equipment to operate normally. This would be a progressive transition, introducing our products in low quantities in order that doctors and nurses get use to the glass ones but still having plastic equipment if they need it. Then, the plastic ones will be completely removed once they have already controlled the use of the glass equipment. As hospitals already have glass equipment which need to be sterilized this transition won't be excessively difficult.
During this process, there would be an initial investment that overtime would save more money than constantly buying disposable tools and would reduce the plastic waste of hospitals all over the world.

On the other hand, in order to help explain the lab equipment solution this following figure has been designed. In it it can be seen the steps which a scientist or researcher has from the moment he wants to manufacture a product until it arrives made of glass. As it can be seen in the second step, there are two options for the customer on how to create the design of the product. Doing the design on his own and then sending the file to us or having a phase of designing with the manufacturers on how he wants the design so that they can design it.

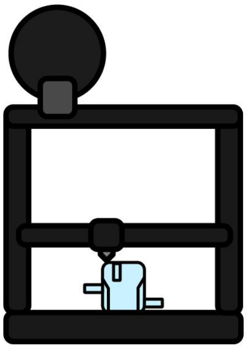
Glassomer Lab



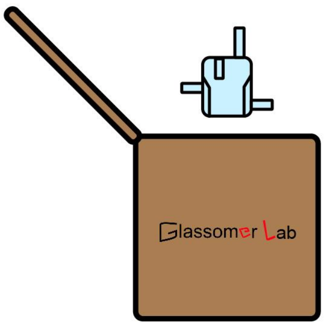
Scientist or researcher has an issue for not having the proper equipment.



Glassomer Lab receives the model and specifications to produce the special equipment provided by the costumer. Or a call can be coordinated to discuss the design of the piece.



Production/print of the desired piece.



Delivery of the pieces or Glassomer material in case that the costumers wants to print it themselves.

d. Social impact

As has been commented in the report the main impact for our solutions would be environmental, as the fabrication of the final glass is a fully recyclable product and moreover, the plastic used in the fabrication process is extracted and reused for the next pieces.

As glass pieces are able to be sterilized and reused unlimited times the main advantage is to reduce the number of single use devices per hospital. Thus also preventing doctors and nurses from having to reuse plastic tools which could generate some infections to the patients. Also reducing the plastic packaging that comes with every tool.

In current processes of manufacturing special products there is a phase where the customer and the manufacturer do some iterations (around two weeks) to make sure they are going to manufacture the exact piece. This could be solved if it is possible for the client just to send the 3D file and the time would be reduced to just 24h.

Since the process of fabrication is easier it would be possible to produce more than one piece if needed.

With this technology the price would be around 15-20€/kg, this would reduce the prices of the glass products compared to the existing ones in the market.

Moreover, another possibility would be to provide these equipment to underdeveloped countries with machinery for sterilization. Therefore, these countries would be able to use this equipment without risks and with only one shipment of materials.

5. Ideas of possible expansion - future work

During the research process, during the interviews part, we have been asked to print a lab piece with our technology. This shows us that this solution could be applied now and this request would come from more than just one customer. However, it would be necessary to develop a website where all this can be properly managed.

As regards to the medical solution, this one is at a very premature stage and requires more development steps. We would have to do extensive research on medical devices which could be replaced by glass pieces and study its viability. Moreover, a study of which hospitals this could be implemented on and on which areas this is more needed.

On the other hand, do a study or contact some organizations, such as UNICEF, in order to find out which underdeveloped countries our solution could be a viable solution.

6. Conclusions and lessons learned

The conclusions that can be extracted from this project are that this technology is a game changer for a lot of applications, and that, used in a thoughtful way, taking into consideration the benefits that can provide to society, it can help many users.
This project has been very interesting because we have been able to delve into topics that are not in our respective fields of study, and we have been able to discover very interesting topics.