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Aer

Cleaner air for everyone.

Project Aer, is an innovative material-forward design approach solving for sustainable and affordable home air filtration. Project Aer explores the inherent values, versatility and beauty of the material active charcoal by using it to replace plastic parts and as act as a filtration mechanism.

Bay Bridge air quality montage 2021

Acknowledgment

I would like to express my sincere thanks to the following who supported me on this journey.

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Abstract

Global air pollution is a growing health concern. The health risks of chronic exposure to air pollutants are many and include respiratory disease, emphysema, bronchitis, asthma cardiovascular disease, and cancer. According to the World Health Organization, 99% of the world's population breathes air that contains high contamination of pollution that exceeds health guidelines. Abating indoor air pollution is a critical issue, because air pollutants inside the home, where Americans spend 90% of their time, can be 2-5 times higher than pollutants outside the home.

The most common approach to improving indoor air quality - the consumer home air filter - carries a number of significant downsides. Most home units follow a narrow design pattern: an exterior plastic housing, an interior fan, and a dual filtration system (one for fine particulate matter and one for gasses). They are costly to own (many in the $300 to $1000 price range), and expensive to maintain. (new sentence here) Filters must be replaced often, and are not eco-friendly, since most of the components are not biodegradable or recyclable, and become landfill.

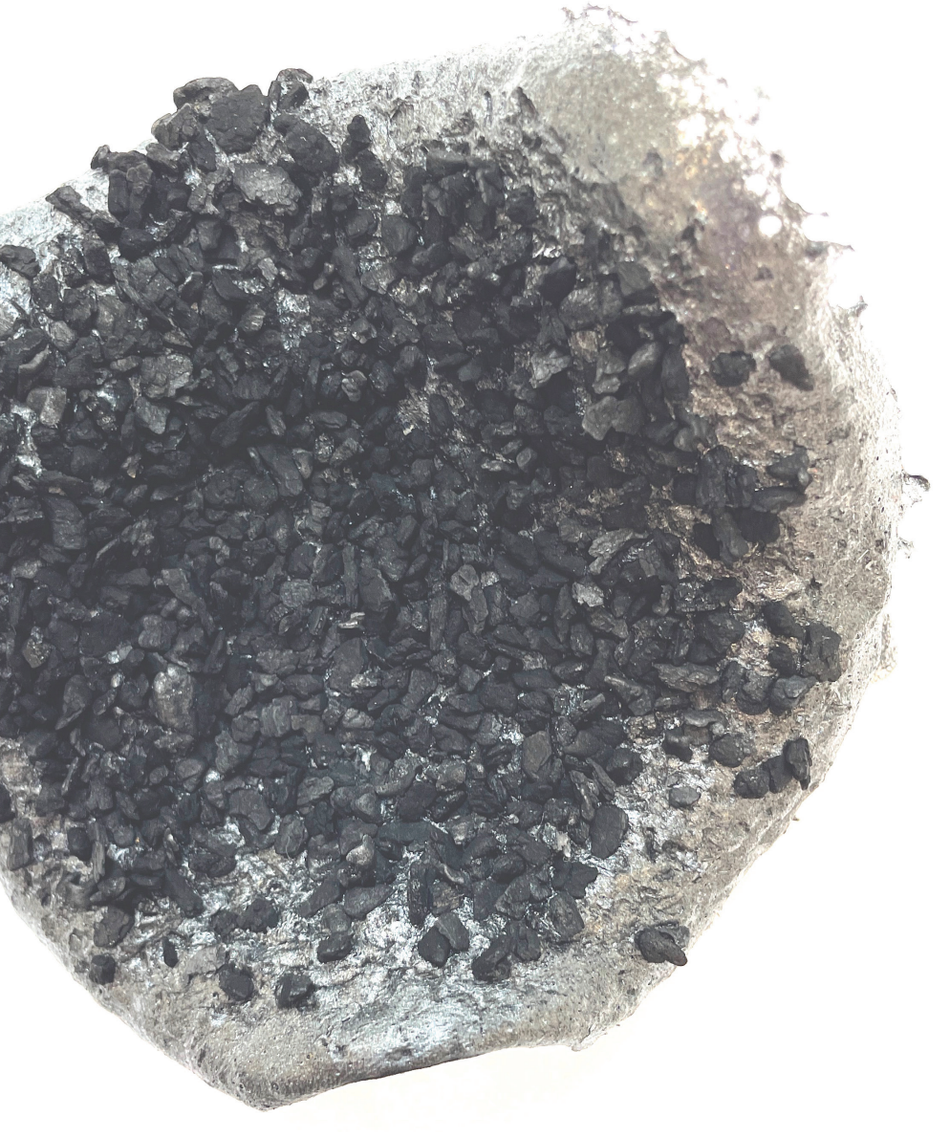
Not only are existing consumer products expensive and bad for the earth, they add to our unhealthy material culture of low-tech plastic appliance clutter. We need eco-friendly and accessible solutions, but we also need to engender an entirely new relationship with the objects and materials that

surround us. A relationship of direct engagement with the materials and processes that govern our lives. When it comes to air filtration, nothing performs and communicates as clearly and honestly as carbon.

The current model of eco-unfriendly plastic enclosure filter systems paired with the costly price and maintenance of home filtration is a barrier to clean air for lower-income households. Because of these downsides, the most widely used design pattern for home air filtration systems fails to address the urgent problem of improving indoor air quality in an affordable and eco-friendly way.

In response, this project, Aer, proposes a new approach that employs innovative and eco-friendly manufacturing and filtrations methods, creating a more accessible and affordable design solution. The project proceeds through a well-established industrial design methodology including research, exploration, concept design, iteration, refinement, and product development.

In that charcoal is a vital component in improving air quality, this material is explored not only for its functionality as a filtration medium capable of removing VOCs, but also foregrounded strongly in the design of the housing, thereby highlighting the prominence of this castable and moldable bioplastic, and also removing the need for traditional plastics from the product life-cycle ecosystem.



While the project is deeply engaged with research into the design affordances of charcoal as a filter and bioplastic and explores this potential in combination with other materials, and with industry-standard manufacturing techniques and design process, some important steps remain out of scope. For example, the project does not accommodate the engineering resources required to properly test the prototype for air quality filtration and purification values, nor to conduct exhaustive manufacturing and cost analysis.

Project Aer elegantly solves two problems - accessible home air filtration and the removal of plastic from the product lifecycle - each of which represents a significant and innovative advance in the specific field of industrial design, and contributes in a small way to the larger goal of democratizing global health.

An evolutionary next step for project Aer would be to develop a family of products using a theme, methodology, and design language with the goal of creating an expanded consumer marketplace for the product line. In tandem, we envision the further development of the material science and manufacturing optimization with a team of engineers with the goal to refine the product for consumer market applications.

History

There is a growing awareness of environmental and home air pollution, creating a consumer demand for home filtration products. Methods of home air filtration include whole-home air filtration systems, which are costly and fouwnd in newer homes and dwellings, HEPA filters for existing furnace systems, and stand-alone home consumer air filtration products.

The most common approach to improving indoor air quality - the consumer home air filter - carries a number of significant downsides. Most home units follow a narrow design pattern: an exterior plastic housing, an interior fan, and a dual filtration system (one for fine particulate matter and one for gasses). They are costly to own, costing as much as $1,000, and costly to operate, as they contain filters that must be purchased and replaced on a regular basis. These filters are costly to purchase, are not biodegradable or recyclable, and become landfill. Consumer home air filter units are expensive to own, have an operational recurring cost and they create a cycle of landfill.

The consumer air filter marketplace has many offerings ranging in quality, price, size, and capabilities. A typical active home air filter is comprised of an intake fan and a dual filter system that combats airborne fine particulate matter such as dust, pet dander, pollen, and wildfire smoke. This fine particle filter is typically a fabric of nonwoven polyester filament and

comes in different grades of filtration from HEPA (High Efficiency Particulate Filter) to a fine mesh fabric filter. The second filter is a carbon or active charcoal-based filter designed to filter out vapors known as VOCs (volatile organic compounds).

Charcoal, a substance of carbon and ash is often derived from peat, coal, wood, coconut shell, bamboo, or petroleum. Activated charcoal is charcoal that is heated with a gas that causes the charcoal to develop crevices. Most activated charcoal in the United States is made with excess coconut shells or bamboo providing an inexpensive, eco-friendly, and sustainable alternative to fossil-based charcoal.

The porous crevices in the activated charcoal provide an ideal environment for gasousmolecules and vapors to chemically react with, and become trapped in, the charcoal in a process called adsorption. It is this process of adsorption, that is the act of filtration for active carbon filters. As part of the adsorption, and air filtration mechanism, charcoal material can be embodied in a few ways, either in a loose granular form inside of a filter or embedded into a fabric or plastic sponge-like material. The more porous the activated carbon is, the more contaminants it will capture through adsorption.

Within the scope of this project, I explored ubiquitous air filtration in the home. I was interested in how air might be filtered within the home by existing home products, HVAC solutions, and devices using new technology and methods. I learned that there are interior home wall

Consumer home air filters 2022

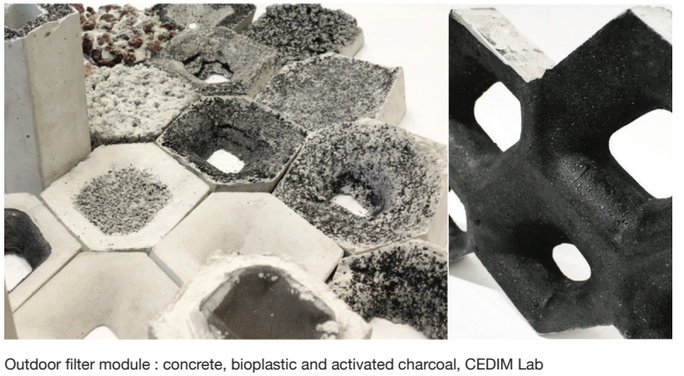
paints with the ability to filter VOCs, from the air. The affordable global home brand IKEA has developed an air-purifying window curtain, (Gundig). The IKEA Gundig is composed of a textile that breaks down common indoor air pollutants including odors and formaldehyde. The IKEA fabric consists of a mineral-based, photocatalyst coating that is applied to the textile. When activated by light – both indoor and outdoor light – the fabric breaks down these pollutants. While this fabric curtain has limited capabilities, (it does not filter fine particulate matter) I found the application and method of ubiquitous air filtration through an everyday home object such as a curtain to be an under-utilized approach with significant design potential.

Much has been written about, and many design concepts feature, houseplants as fresh air generators and air filtration solutions. While houseplants are generally healthy additions to the home and biophilic home design is a rising trend, the ability of plants to filter any substantial pollutants from the air is extremely minimal with questionable impact. This data regarding houseplants was confirmed when I met with air filtration expert, Stefano Schiavon, Associate Professor of Architecture and Civil and Environmental Engineering, and CED Associate Director at UC Berkeley to discuss air filtration methods and ideas. Professor Schiavon confirmed that houseplants have little to no impact as a home air filtration device. Professor Schiavon also noted

Indoor filter module : bioplastic and activated charcoal, CEDIM Lab
by Restology project, 2017

that design concepts exploring captive algae as a home filtration device also had little to no impact on filtering or refreshing air in the home. In discussion, Professor Schiavon pointed out that home air filtration would need a device to capture air, an active fan to bring the filter into the device including an interior filter for fine particles as well as a filter for VOCs. Professor Schiavon stressed the following points in creating a successful air filtration device; active airflow from a fan to force air through a device at volume, as well as time inside the filter. The more time the air spends inside the filter the cleaner it will be.

I explored filtration materials and methods, finding a few design innovative concepts which have a commonality with active filtration, charcoal, and air purification. YouTube hosts many instructional videos of homemade air filter boxes constructed of box fans and existing filters to filter everything from the viruses to active charcoal to filter VOCs in grow houses. Perhaps one of the most interesting data was published by the Barcelona-based design collective FabLab in 2017 in which the group ran a design research project exploring charcoal bioplastic as a filtration device. The FabLab exploration manipulated the charcoal bioplastic to exploit its passive filtration abilities. The FabLabs charcoal work and open-source findings were inspirational and a stepping stone to my creative exploration.



Outdoor filter module : concrete, bioplastic and activated charcoal, CEDIM Lab
by Restology project, 2017

Page 20 (top to bottom)
Ikea Grundig fabric
VOC filtering paint
EcoLogic Studio, Bit.Bio.Bot 2021 (alge air filtration)

Kengo Kuma air filtration sculpture 2018

San Francisco, CA Fire Season 2020

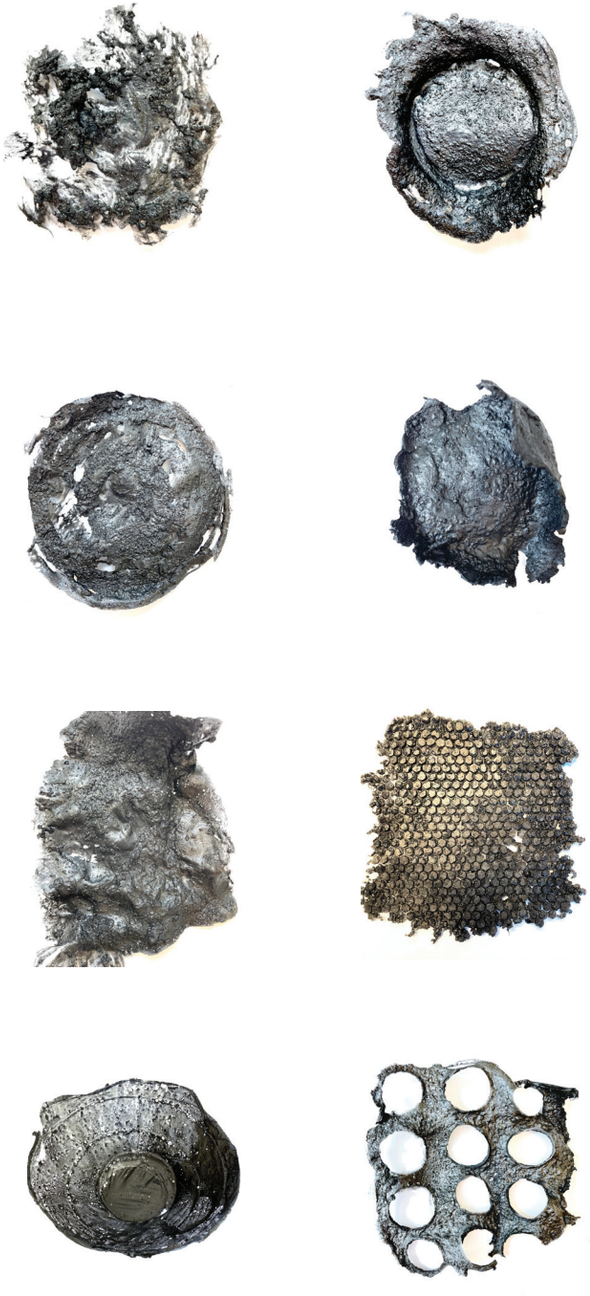
Motivation

As a Californian, firsthand exposure to chronica As a Californian, firsthand exposure to chronically poor air quality from smog and, increasingly damaging, seasonal wildfires has made me acutely aware of issues surrounding air quality. I have experienced the health implications of poor air quality and am concerned not only for myself but for my family, and all members of my local urban communities here in the Bay Area and around the world.

Global air pollution is a growing health concern. The health risks of chronic exposure to air pollutants are many and include respiratory disease, cardiovascular disease, and cancer. According to the WHO, (World Health Organization), 99% of the world's population breathes air that contains high contamination of pollution that exceeds healthy guidelines. Abating indoor air pollution is a critical issue because air pollutants inside the home, where Americans spend 90% of their time, can be 2-5 times higher than pollutants outside the home. According to the NIH (National Institute of Environmental Health Sciences), North American studies consistently indicate that lower-income communities experience higher concentrations of air pollutants because these homes are often located closer to known pollutant sources including transportation and industry.

Accessibility to clean air should be a right, not a privilege. Owning and maintaining a home filtration device should not be prohibited by cost, nor should home air filters be a cycle of landfill and plastic.

As a designer I am driven to work towards solutions that serve a larger purpose, to reimagine the problem space and develop product solutions through a unique designerly lens to produce elegant and innovative solutions. I see the opportunity to design an innovative, elegant and affordable air filtration solution using eco-friendly materials, removing plastic from the consumer ecosystem while working with the material charcoal as a new design medium. I am interested in working with the material charcoal not only for its natural filtration abilities but for its elastic beauty as a design material and medium of form expression. It's this duality and beauty that motivates me to explore new design territories in elegant sustainable design solutions.



Series of charcoal bioplastic explorations

Method

Project Aer proceeds through a well-established industrial design methodology of research, exploration, concept design, iteration, refinement, and product development.

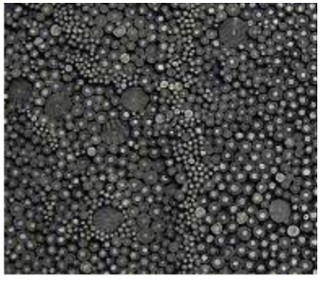
In my work I investigate and research existing methods of home filtration of fine particulate matter and VOCs. Carbon air filters remove pollutants from the air with a process known as adsorption. During the activated carbon adsorption process, compounds in the contaminated air react with the carbon to stick to the surface area, effectively removing these contaminants from the air. Another important investigations are the materiality of charcoal as a bioplastic within applicable manufacturing methods for a consumer home product as well as existing methods of using charcoal as a medium in design applications.

I found beautiful examples of charcoal bamboo textiles fabric woven into garments for it's hypoallergenic properties, as well as charcoal as a medium for design expression in furniture. The Japanese tradition of Shou Sugi Ban, of scorching and carbonizing wood cladding for exterior architecture serves a dual purpose of not only weather resistant beautiful black cladding but for the preservation properties that the charred wood provides in keeping insects and bacteria out of the wood.

The scope of this project work is based on the design framework of creating a design solution for an eco-friendly product that could be produced efficiently at scale. Knowing that the biomaterial charcoal is a vital part of the air filtration system I explored the material attributes of charcoal as a filtration medium and a bioplastic to be used in the manufacturing of the product housing. I limited my charcoal bioplastic recipes to the ingredients of charcoal, water, vegetable glycerin, and gelatin all-natural ingredients. I referenced the open-source formulas published by the group FabLab and experimented with my own formulas working with variations to create delicate lacelike bowls inside silicon castings and solid castings that could be formed. Within

Shou Sugi Ban cladding

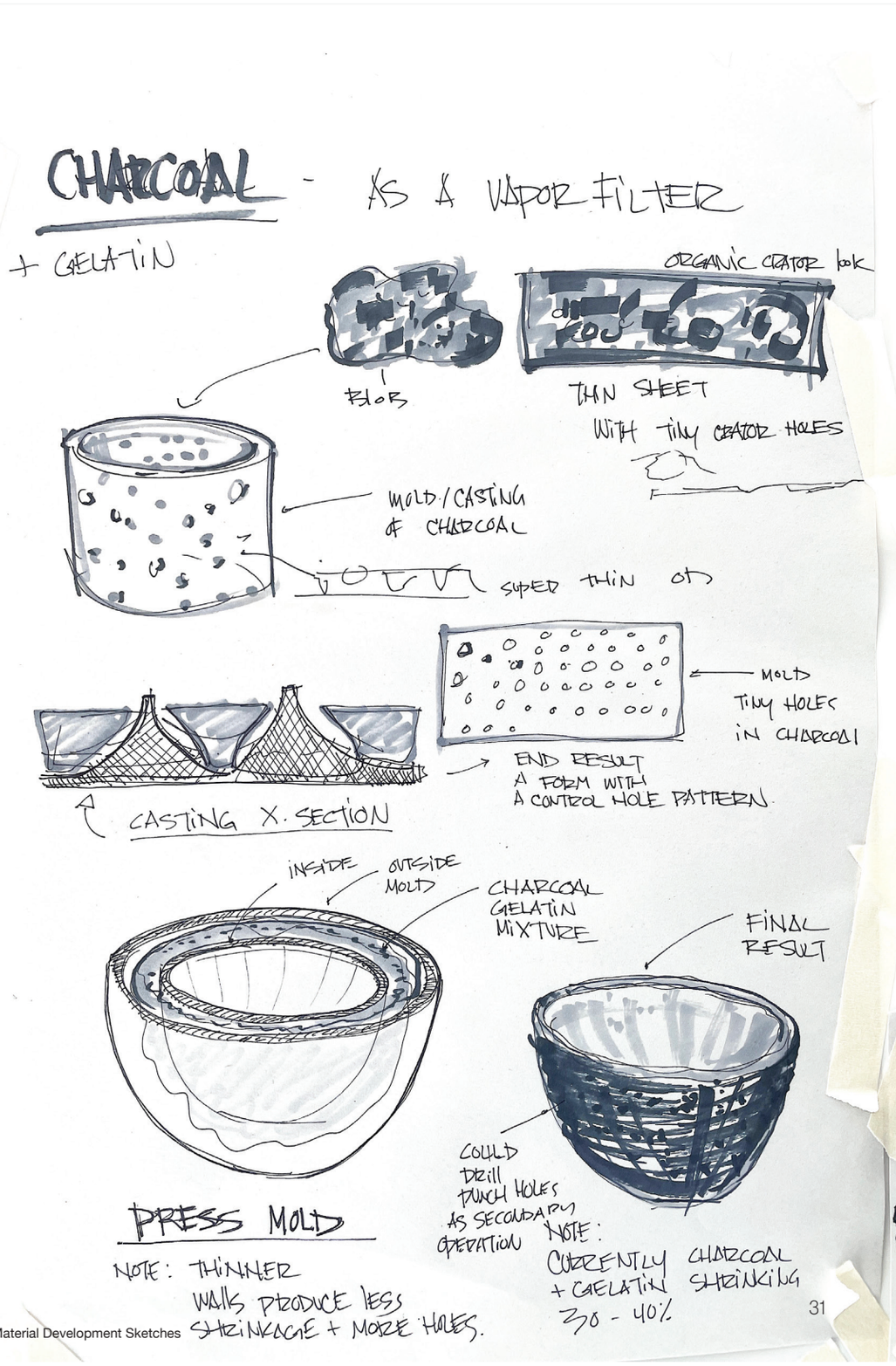
Charcoal bamboo textile clothing



Charcoal table by Anke Weiss

these casting explorations, I experimented with a variation of charcoal bioplastic recipes not only for manufacturing capabilities in moldings but for final color, material, finish the evaluation, and potential filtration effectiveness. I started by grinding the charcoal into different size particles to create a variety of results and finishes, the finer grind particles created a smooth more traditional consumer product like finish, and when mixed with a higher proportion of glycerine, the fine particle mineral deposits within the charcoal would come forward creating a beautiful metallic sheen while the mixtures with larger charcoal particles created a more organic look and feel more suitable to the action of adsorption. I found this range of materiality and contrast appealing and used the variation in texture, sheen, and color as an integral element of the design to further enhance the final design of the project.

In my process work, I explored molding the charcoal bioplastics. It was while working with these moldings that I realized the possibility of using the bioplastic as a material to replace plastic as a housing material in a consumer air filter



Material Development Sketches

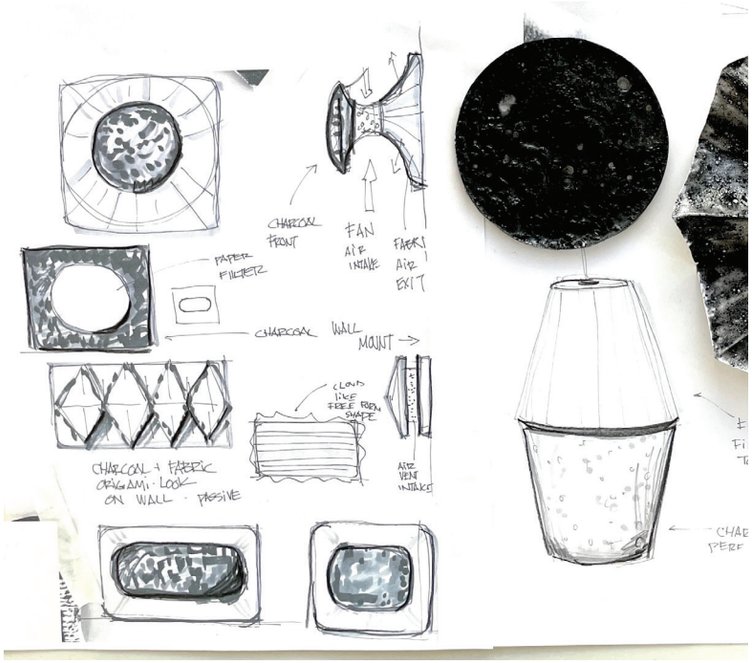
Process

I started my process with charcoal. Activated charcoal is ecologically sound with purifying properties. It is essentially a form of highly microporous carbon, processed from natural carbon-rich materials by applying various gasses or chemicals to 'burn' in tiny holes and thus exponentially increasing its surface area. These tiny holes efficiently filter out all manner of impurities and toxins creating a 'charcoal super sponge'. Knowing this, I explored mixing biomaterials such as gelatin and glycerin with charcoal and water to create a charcoal-based bioplastic. I created dozens of variations in the recipes and formulas to create outputs for castings, moldings, sheets, 'paintable' material and more. In some of the recipes that had more glycerin, I found the shrink rate difficult to predict as well as the warpage and finish. I also found that working with warm water and a finer grind of charcoal gave me a fine finish and greater control over the molding process.

In the concept phase, I built volume models in paper and cardboard to explore desirable sizes and form factors, I also explored designs and form factors expressing a more aesthetic home design direction rather than a home appliance design direction, this included wall tiles, hanging and wall-mounted fans and lanterns and chandeliers made of a pleated paper coated in charcoal. I explored concepts and methods of incorporating the fine particle filter paper with a coating of charcoal bioplastic to create designs such as pleated fans. I found these designs very

Page 32, Charcoal bioplastic moldings (fine grind)

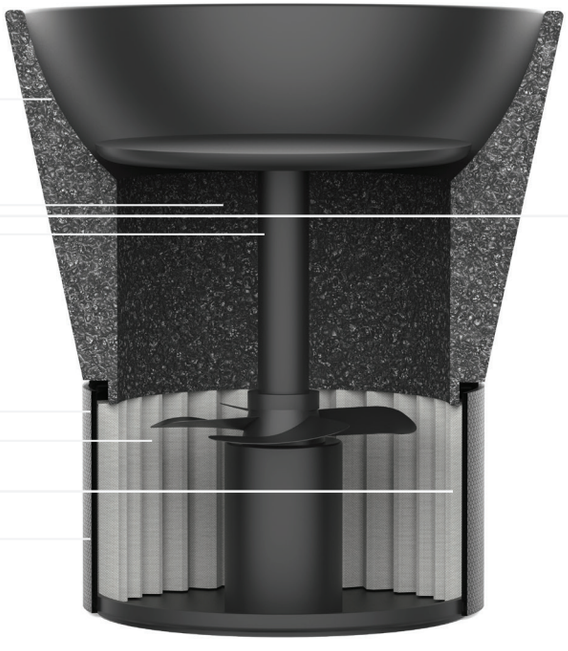
promising in their aesthetic potential as well as their ability to adapt to vertical spaces and passive filtration techniques. I found this design direction extremely intriguing with seemingly limitless design potential. Ultimately, and upon assessment in the concept evaluation phase, I found that these design concepts were difficult to implement and stay true to my original design parameters of active filtration which requires a certain volume inside and outside the product housing to maximize the filtration as well as the product cord. Knowing this, I shifted my exploration away from wall-mounted and hanging filtration solutions to focus on a tabletop form factor that would be able to handle a fan and the volume required for adequate filtration.



Design sketches with process material samples

Final Design

Aer's consumer product air filtration solution is an elegant design employing a duality of material and function combined with a form factor communicating iconic simplicity The final design delivers an ecologically, material-first solution consisting of three primary components, a bioplastic charcoal housing to filter the VOCs, and a paper filter base to filter the fine particulate matter (both of which are compostable biomaterial). The third main part is an interior assembly unit that supports the base, the baffle, and a mechanical fan. The interior assembly unit is a reusable, serviceable part The act of filtration is such; that the interior fan pulls air in through the fabric prefilter that covers the paper base, filtering out large fine particles, the air then travels upward through the interior chamber of the charcoal housing where the VOCs are deposited on the charcoal walls through the act of adsorption. This act of adsorption is aided by the baffle that slows the exiting air allowing it to spend more time engaging with the filtering characteristics of the charcoal before exiting out through the top of the device. The unit is turned on and off by gently pressing down on the baffle to engage, and disengage the fan's motor.

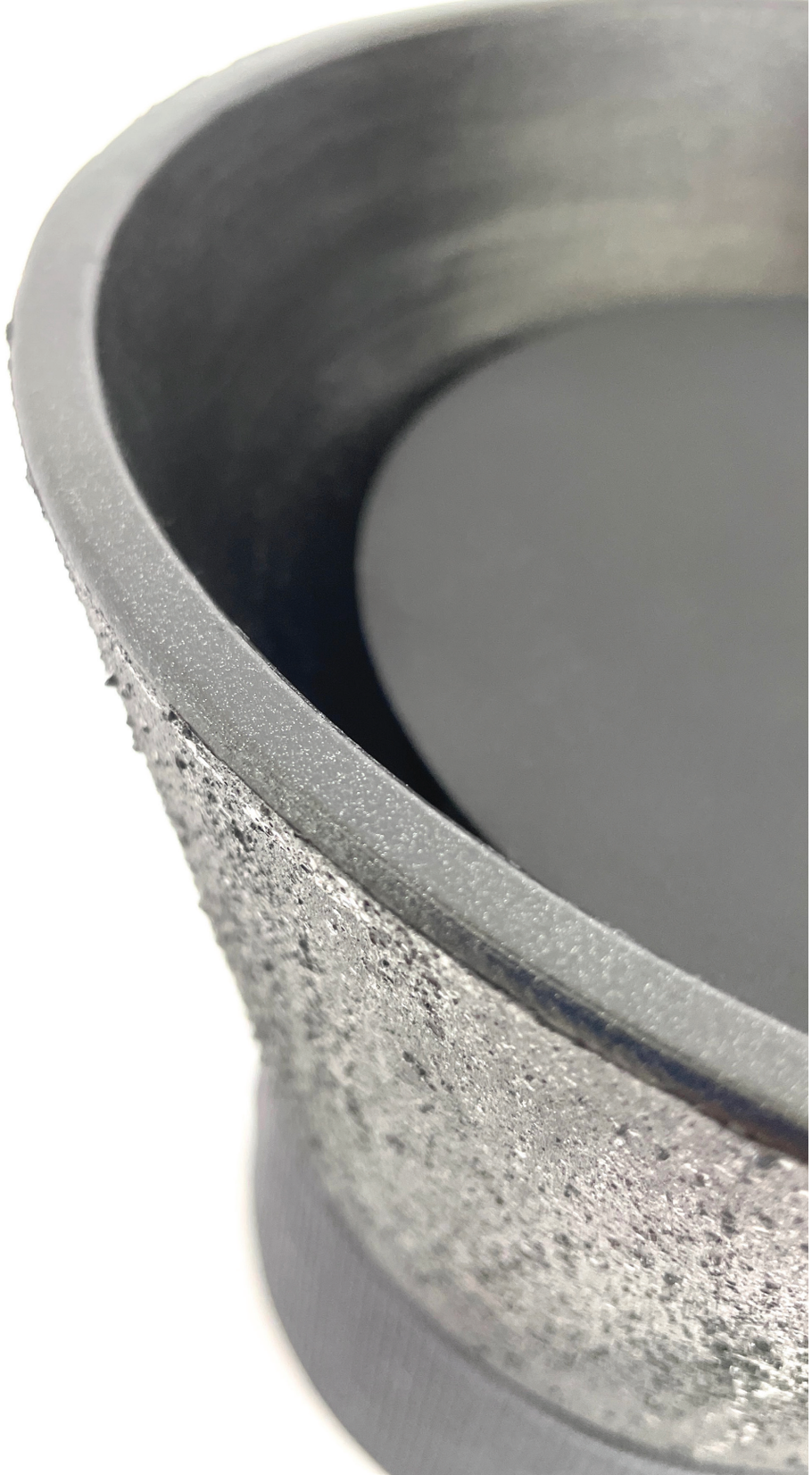


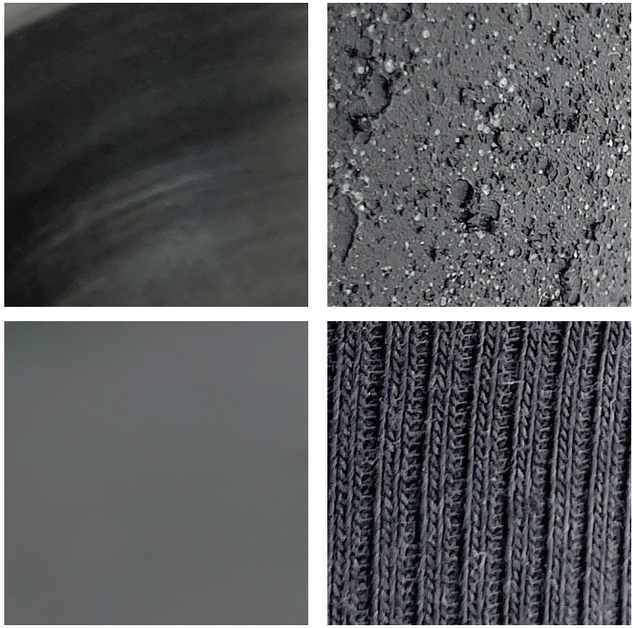
Aer's iconic design is a strong material-based edgeless design consists of a conical charcoal form that sits seamlessly atop a cylindrical base. The visual design intent of the upward-facing conical housing is evocative of the power of a silent trumpet seamlessly delivering an outward flow of clean air. This iconic shape as realized in the beautiful materiality of the bioplastic charcoal creates a meaningful and powerful design connection of materiality and function.

Designing with the bioplastic material charcoal I found it important to the design story to integrate the inherent beauty and versatility of charcoal into the visual and functional CMF (Color, Material, and Finish) experience of Aer. Bringing into alignment the narrative of the material as a filtration device and as a product housing, strengthening the connection through design. The iconic black form of Aer has a seemingly simple design yet when examined closer layers of design intent are revealed in the design execution of color, material, and finish revealing a level of sophisticated design intent and use of materiality.

Aer's charcoal housing features two distinct and opposing textures that fulfills a design narrative linking the form and utility of the design. The exterior texture of the charcoal housing is a high-impact visual highlighting the organic composition and utility of the active charcoal. The natural rough texture brings out the metallic carbon composition, the bioplastic sheen, and the inky blackness of carbon creating a striking visual communicating the beauty and value of charcoal. The interior of the charcoal housing I designed to be a smooth texture in an inky black colored finish. A smooth finish is achieved with a finer charcoal grind that produces a soft black sheen conveying a sense of cleanliness where fresh air exits freely and in contrast

Page 38, Aer cross section, part and material breakout

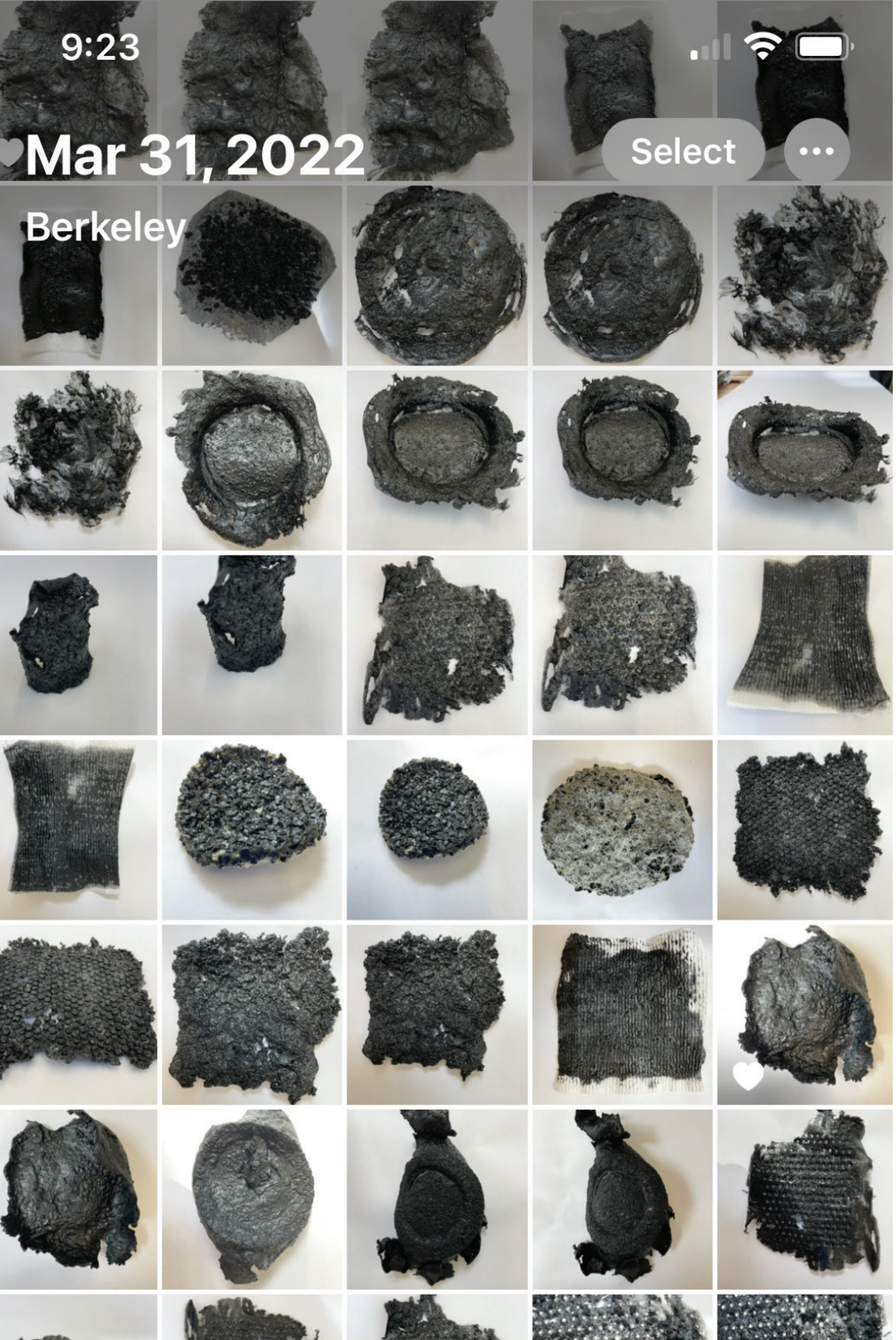




CMF images: Top Left: Interior Housing, Top Right: Exterior, Bottom Left: Baffle, On/Off, Bottom Right: Knit Fabric Cover

to the rough finish of the housing exterior. The interior plastic baffle, also serving as an integrated on/off button is a fine black matt finish, standing in mid-contrast to the two finishes of the charcoal housing. The exterior black knit fabric compliments the charcoal housing. The vertical knit traps and hides larger dust particles and conveys a sense of strength and directional airflow.

Aer's innovative design methodology and material implementation are central to Aer's successful design. Where the charcoal bioplastic acts as both filter and housing, facilitating simplicity and duality and the opportunity for the creation of an elegant iconic design that celebrates the value of the materiality of charcoal. In addition, unlike the millions of air filters that end up in landfills every year, Aer's compostable parts will decompose in the soil creating a truly sustainable product solution.



Discussion

Project Aer provides simple material-based hardware solutions that address innovative and sustainable eco-friendly solutions for clean air accessibility. The scope of this project did not afford the time or resources to fully explore and validate the use of a bioplastic charcoal material as a filtration mechanism or the development of material specifications for fine particle filtration. It would be beneficial to the project to know more about the needs of the mid to lower-income consumers this project seeks to serve, including cost thresholds, market maturity and awareness of air quality issues, access to resources, and the average square footage of rooms of homes as well as data surrounding the average AQI of home spaces. This additional information regarding Aer's material specifications and target consumer profiles would be beneficial in steering the project in the right direction for the next phase of development and validation.

Page 46, Process photos from my iphone

Future

Looking forward, the next steps in product development for project Aer would be to engage with engineering resources, to further develop the charcoal bioplastic material as well as the design for manufacturing and sustainable material plan for the charcoal VOC filter housing and fine particle filtering paper base. Additional technical pursuits would be to build accurate material and volume prototype models as well as engagement with a lab to develop an air quality test plan to determine design changes or modifications for air filtration capabilities.

A future design envisionment for project Aer would be to develop a family of charcoal-based filtration products from passive wall tiles, to hanging sculptures. An exciting extension of the exploratory work I did designing with charcoal would be a new design exploration of objects that are strictly design and art-based from textiles to home goods to public art installations.

Conclusion

Project Aer afforded me the opportunity to dive deeply into a material-driven industrial design project. Through this exploration, I investigated and appreciated the limitations and capabilities of a new material to produce an innovative design outcome satisfying my project goals and producing a beautiful design solution. My solution is supported by the significant body of exploratory work that was delivered, as well as a completed industrial design solution that included a finished model that may be further developed to deliver a final product for market release.

The design work of project Aer contributes to a new design model of accessible air filtration, as well as a new applications for the charcoal bioplastic; as a viable eco-friendly sustainable material for a product housing, as a compostable filtration device, and as a beautiful design material with multiple CMF applications. The final outcome and design solution is a successful model of sustainable design thinking for innovative design solutions that could be studied, taught, or replicated.

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