Chapter 5: Bio-Plastic

Bio-Plastic

Bio-Plastic is a synthetic material made from organic polymers, a material that has been used in the built environment for thousands of years. For example, natural plant gum was traditionally used as a wood glue in the construction of houses.  In early oceanic exploration natural plant gum was also applied as a waterproof coating to boats. However, natural plant resins were never chemically modified until Charles Goodyear vulcanized rubber in 1845 thus creating the first man made biopolymer.[[1]](#footnote-1)

Patented in 1857, Parkesine was the first commercial grade man-made [plastic](https://en.wikipedia.org/wiki/Plastic) made from cellulose, a wood fiber, that was treated with [ni](https://en.wikipedia.org/wiki/Nitric_acid)tric acid and a [solve](https://en.wikipedia.org/wiki/Solvent)nt to create what is known as “synthetic ivory”. Objects such as combs, buttons and cutlery handles were crafted from this earth/man made plastic. Parkesine’s successor was [Celluloid](https://en.wikipedia.org/wiki/Celluloid), the material that transformed the film industry. Celluloid is considered the first thermoplastic because of its ability to be easily molded and shaped into any form: filmstrips, phones, toys, jewelry, and furniture are just a few examples of how this transformative material was used.

In the early 1900’s synthetic polymers were developed and there are now hundreds of thousands of them in use. Synthetic plastics are strong, cheap to produce, lightweight and can seemingly last forever. Unfortunately, the attributes that make plastic so popular are also the ones that make them so problematic. It is estimated that the world produces almost 300 billion tons of plastic a year and only 10 percent of that is recycled.[[2]](#footnote-2) Much of it ends up as floating junkyards in our ocean’s gyres, as litter on our streets and in landfill and around the world, plastic pollution is a very serious issue. Furthermore, the production of plastic from oil-based materials releases carbon dioxide into the air, contributing to global warming, and most oil based plastics take hundreds, if not thousands, of years to degrade. For example, a small thin phone card will take almost exactly 100 years to degrade compared to an apple core, which takes only 3 months.[[3]](#footnote-3) Ideally, all plastic products need to degrade naturally at the end of their life and not cause adverse effects to the environment. The use of cellulose-based materials, rather than non-renewable crude oil derived materials, has proved to be an important solution for creating plastics with a low environmental footprint.

PLA, or polylactic acid, is a bio-plastic, derived from renewable resources such as cornstarch, tapioca roots, or sugarcane, it is also biodegradable. [Figure 58] PLA was discovered in the 1800’s and was designated a pre-polymer because of its low production and low purity values. Today however, PLA is the largest industrial scaled biodegradable plastic made with renewable materials. It is a plastic that is principally made of carbon, oxygen and hydrogen so as it degrades, or is incinerated, it only releases those elements into the atmosphere or the soil. PLA can be used for extrusion, injection molding, film and sheet casting, and spinning which means there are a lot of ways to process this material to turn it into products. It is also one of the most common feedstock materials used in desktop 3D printers today.

For decades, PLA has been used primarily for biomedical applications. When used for medical implants it can serve many functions—as bones, screws, plates, pins, and meshes- because it is a bio-reabsorptive material that is transformed into innocuous lactic acid in the body in a time frame between six months and two years. Outside your body PLA can break down in 45 days in a composting facility. However, under stable environmental conditions, it will take hundreds of years to biodegrade, which means that it shows promise as a long-term building material for specific applications.

Plastics are frequently used in the construction of buildings. One can find plastic pipes, insulation, window frames, roofing, screws, hinges, flooring, wall coverings, waterproofing and even plastic doors in almost every building. We don’t always see the plastic parts of buildings as they are sometimes hidden, such as in the foam core of a door, but buildings today are increasingly made of plastic. In some buildings, plastic is celebrated as the building material. The Laban dance center in London, designed by Herzog and deMeuron, is clad with plastic panels made of impact resistant polycarbonate and The Eden project, designed by Nicholas Grimshaw, is a series of domes covered with inflated plastic pillows made of ethylene tetrafluoroethylene, or ETFE, which is corrosion resistant and very strong even in response to temperature fluctuations. These projects from the turn of the twenty first century that embrace the use of plastic as a cladding material have paved the way for bio-plastic buildings of the future.

3D Printing with PLA

Branch Technology, based in Tennessee, recently 3D printed a very large bio-plastic structure for Design Miami 2016 called “Flotsam and Jetsam”. The structure was printed using Kuka robot arms and PLA made from bamboo. Amsterdam based architecture firm, Dus Architects, are currently building a Canal House entirely 3D printed in biodegradable plastic parts that are filled with a lightweight foamed concrete that provide structural reinforcement. The Canal House is being printed on a machine called the *Kamermaker*, quite literally a “roommaker”, a room-sized printer that extrudes PLA pellets into forms that are up to nine feet tall. Oak Ridge National Laboratory, in Tennessee, has a Big Area Additive Manufacturing (BAAM) machine that is capable of 3D printing components up to 20 x 8 x 6 feet, which has produced the largest 3D printed object in the world to date—a trim-and-drill tool to be used in the production of Boeing airplanes that weighs 1,650 lbs. The cellulose-based materials that PLA is made of is an ever widening field. It is now possible to 3D print with PLA made not only of cornstarch but also hemp, bamboo, and barley. Additionally, materials such as coffee, glass and powdered metals can be added to PLA to give it special properties including color, strength, and sheen respectively. Dye’s can also be added to the PLA filament in order offer a wide range of colors that are integral to the material.

Emerging Objects fabricated one of the largest PLA based 3D printed structures built to date, the *Star Lounge*. [Figure 59] The *Star Lounge* is unique from many other large scale 3d printed structures in that it demonstrates the architectural potential of using a farm of inexpensive, small desktop printers to 3D print a building. The freestanding dome structure is 8 feet 6 inches tall with a footprint that measures approximately 11 feet by 11 feet. [Figure 60] The PLA dome is composed of 2073 hexagonal blocks printed in various translucent colors that correspond to a particular block type, which helps simplify the construction process and creates a beautiful, yet logical, pattern of stars and hexagons that comprise 21 larger panels that are riveted together. The color-coded facade is an aesthetic choice, but also encodes the instructions for fabrication and assembly by color. The patterning of the Star Lounge is inspired by cut tile Arabic star motifs and mid-nineteenth century American star quilts—a shared motif prevalent in both traditional Islamic and American genres. [Figure 61]

The hexagonal blocks that make up the large star and hexagon panels were printed using a ‘Bot Farm’ of over 100 3D printers. The design of each individual component that makes up the domed structure maximizes the efficiency of the printer and the print volume. Two blocks could be printed per printer without support material in just over an hour. To facilitate file management only twenty-eight unique block types make up the doubly curved dome structure and, in addition to the color coding, each block has a number printed on the interior surface to locate the block in the assembly. [Figure 62] [Figure 63] [Figure 64] Holes for rivets were also printed into the blocks. [Figure 65] The Star Lounge demonstrates that prefabricating small scale, hand size and efficiently designed 3D printed parts for architectural assembly is feasible, cost effective and opens the door to creating 3D printed bricks, tiles, walls, ceilings, partitions and cladding for a sustainable architecture of the future. [Figure 66] [Figure 67]

Objects:

*Romanescos*

These study models are the first experiments conducted by Emerging Objects using customized gcode to inform the surface texture of a 3D printed object. By controlling each line of filament we are able to take a line of filament for a walk in a zigzag, sawtooth, sinewave, or step pattern. The repetition, offsetting, cycling and amplitude of the line creates unique and often porous textile like surfaces using a minimum amount of material. [Figure 68] [Figure 69] [Figure 70] [Figure 71] [Figure 72] [Figure 73] [Figure 74] [Figure 75][Figure 76]

*Starlight*

*Starlight* is the precursor to the *Star Lounge* and an experiment building upon the knowledge generated in the Romanescos studies, combining the intent of creating a spherical structure with the minimum number of parts, with the intent to create diffuse light through woven patterns created by custom gcode. At this size, the object is comprised of 20 hexagons and 12 pentagons and is a buckminsterfullerene or “buckyball”. The difference between a buckyball and *Starlight* is that the geometry of the starlight extends beyond the ball to make a stunning light-filled star. This particular *Starlight* is 3D printed in PLA mixed with fine aluminum particles to give it luster and reflectivity.

A fine woven mesh generated by the gcode, the computer language that speaks to the 3D printer, creates a textile-like surface that is loopy with a soft texture that glows due to the translucency of the material, but also allows for direct light to be transmitted through the surface of the cone itself. [Figure 77]

*Picoroco Wall in Orange*

*The Picoroco Wall* is constructed using the [*Picoroco Block*](http://www.emergingobjects.com/projects/picoroco-block-in-pla/), a modular 3D printed building block for wall fabrication printed in translucent orange PLA. [Figure 78] The wall is comprised of blocks with a dimension of 5.75″X5.75″X5.75″. Three different blocks are used in the construction of the wall—a 2, 3 and 4-hole block. Each block can be randomly rotated to create the variable pattern found in the wall. The blocks are held in place with 3D printed orange PLA clips that have four prongs that connect the blocks at the corners. [Figure 79] The wall takes advantage of the translucency of the bio-plastic giving it a softly scalloped, diaphanous quality when light filters through. [Figure 80]

*The Hut was Never Primitive*

*The Hut was Never Primitive* is a series of conceptual study models for houses that represent ideas about the earliest forms of 3D printed architecture. They are concepts for buildings that explore how gocde, can act as the mediator between machine and architecture, interior and exterior and wall and ceiling. The Primitive Hut conceptualizes the most fundamental components of 3D printed architecture—wall, floor, roof and foretells its emergence. Each “hut” explores, surface, texture, material, form, space, light, and shadow and serve as study models that provide a point of reference for all speculation about the essentials of 3D printing buildings. Gcode, slicing, customization, hacking, and parametrics represent some of the first 'ideas' for a 3D printed house and build upon technologies that have been in development for 10,000 years of human civilization, such as puddling, rusticating, embossing, shagging, vermiculation, and thatching. [Figure 81] [Figure 82] [Figure 83] [Figure 84] [Figure 85] [Figure 86] [Figure 87] [Figure 88] [Figure 89]

*The Damask Wall*

The first damasks used a satin weaving technique to weave filament in such a way that created areas of different sheens in the cloth to reveal the raised animal and botanical patterns. Because it was a weave and was 3-dimensional, the textile was always reversible. Traditionally, damask textiles were always monochromatic, made from a single color, the pattern was distinguished by the way light played off the warp, or vertical, and weft, or horizontal, filaments. Some damasks even look different depending on the time of day.

Damask was invented in China around 300 B.C. These richly woven textiles were traded along the Silk Road, which stretched from the Far East to the Mediterranean, and may have gotten their name from Damascus, one of the cities merchant caravans passed through en route to Europe. Damasks have had a long-standing status as a luxury fabric because they were originally made of silk filament, which was very expensive. At the height of their popularity in the 1700’s damask patterns could be found on walls, furniture, and curtains filling entire domestic interiors of the wealthy. The Industrial Revolution ushered in mass production, making woven and printed fabrics more affordable for the growing middle class. Later, during the Arts & Crafts movement — whose advocates saw machine-made designs as inferior and dishonest — damasks were once again handcrafted, often depicting stylized images of plant and animal life.

Over the last century, the definition of damask has expanded to include fabrics made with two or three colors and other filaments, such as cotton and wool. Even more recently, patterns that are 2D printed to look like damask are considered “damask”, but these, of course, are not reversible and they are not three dimensional. 3D printing however brings back the 3 dimensionality and reversibility of the original damask using new filament - PLA. The 3D printed PLA damask is also quite rigid and strong. The pattern or motif printed within the surface gives it structure and rigidity, embedding new functionality, allowing it to not only be a pattern or motif applied to the surface of a wall or a piece of furniture but to literally become the wall or the furniture itself. [Figure 90] [Figure 91] [Figure 92] [Figure 93]

*Hairline Drawing*

The use of hair, fur, and fibers has long been expressed in architecture as a textural phenomenon. Flocking can be traced back to circa 1000 BC, when the Chinese used resin glue to bond natural fibers to fabrics. Fiber dust was strewn onto adhesive coated surfaces to produce flocked wall coverings in Germany during the Middle Ages, and in France, flocked wall coverings became popular during the reign of Louis XIV of France. Camel and Yak hair continues to be collected today, either by shearing or combing, and felted or woven by nomadic cultures to create a durable textile for tents.

If architecture can be hairy, how might we draw hairy drawings? In 1925, the architect Le Corbusier, asked the then 21-year-old artist Salvador Dalí if he had any thoughts on the future of architecture. Dali retorted, with some disdain for Le Corbusier’s work, as he viewed Le Corbusier as the inventor of the architecture of self-punishment, that the architecture of the future would be “soft and hairy”. *Hairline Drawing* explores the use of custom gcode scripting for 3D printing to create a surface, not unlike a technological flocking or a bio-plastic weaving, that depicts Notre Dame du Haut, a work where, perhaps influenced by Dalí, Le Corbusier expressly sought to deny the “machine age aesthetic” of his previous work—a return to the soft, and drawn here with a 3D printer, as hairy. [Figure 94] [Figure 95]

1. Lee Tin Sin, Abdul R. Rahmat and W.A.W.A. Rahman, *Polylactic Acid: PLA Biopolymer Technology and Applications* (Oxford: Elsevier, 2015), 5. [↑](#footnote-ref-1)
2. “Raising Awareness of Plastic Waste”, last modified August 14, 2011, http://www.nytimes.com/2011/08/15/business/energy-environment/raising-awareness-of-plastic-waste.html [↑](#footnote-ref-2)
3. Lee Tin Sin, Abdul R. Rahmat and W.A.W.A. Rahman, *Polylactic Acid: PLA Biopolymer Technology and Applications* (Oxford: Elsevier, 2015), 3. [↑](#footnote-ref-3)