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Crystals as Co-creators

An investigation of growing crystals as a methodology for jewellery designers

ABSTRACT
Grown crystals are used for a range of novel innovations supporting a wide array of industries. Within the jewellery industry however, grown crystals are only used in a limited capacity and mainly as a surrogate for mined gemstones. This paper investigates the methodology of Crystal Growing Design, through conducting experiments testing four hypotheses developed around the practice. Through utilising a DIY approach the author investigates the opportunities and challenges presented by incorporating the methodology into her jewellery design practice. Sugar, alum and salt are experimented with to provide a theoretical experimentation of the methodology to justify the further incorporation and adaptation of more enhanced growing processes as used for the growing of gemstone quality crystals.

Keywords:
Crystal Growing Design, methodology, jewellery.

INTRODUCTION
Jewellers around the world have used crystals for the creation of jewellery for centuries (Arem, 1977; Philips, 2012). Within the field, expert identification and optimisation techniques have developed and a worldwide gemstone trade was established. Today however, some significant innovations in the materials and processes naturally associated with jewellery have been achieved in other sectors. Bespoke man-made crystals are revolutionising technology and engineering; diamonds grown microscopically on sheet to optimise conductivity (American Institute of Physics, 2017) are present in high performing microchips and the laser industry has seen major improvements due to the introduction of synthetic sapphire components developed to specifications (Stone-Sundberg, 2013), to name just a few. In the jewellery industry, where crystals are used most visually and in significant numbers however, there has been limited innovation in the creative use and adaptation of man-made crystals, aside from investing in the creation of man-made crystals to imitate mined crystals. Limited attention is spent on the exploration of the possibilities man-made crystals and related processes provide in a creative jewellery design context.

Meanwhile outside the jewellery industry, the democratisation of science has led to an increasing number of designers interested in DIY approaches to growing materials (Karana & Camere, 2017). Even though the materials used in biodesign/art (Kac, 2020; Myers, 2012) are not crystals, the processes to grow crystals have clear commonalities with those related to the growth of 'alive' materials in biodesign/art. Scholars in the field (Kac, 2020; Karana & Camere, 2017; Myers, 2012; Rognoli et al., 2015; Van Dijk, 2016) have commented on the opportunities the methodology of growing materials holds for designers, ranging from achieving novel aesthetics, their grow-ability and their sustainability credentials. With the number of product designers involved with growing materials expanding, and the emerging practice of DIY growing evolving (Karana & Camere, 2017; Rognoli et al., 2015; Van Dijk, 2016) this paper documents and reflects on the jewellery designs produced with DIY grown crystals. This in order to identify whether the methodology of growing crystals holds further possibilities for enhanced creativity when designing jewellery as well as exploring other benefits.

GROWING MATERIALS AS DESIGN METHODOLOGY

> In a crystal we have clear evidence of the existence of a formative life principle, and though we cannot understand the life of a crystal, it is nonetheless a living being. (Nikola Tesla, 1900)

Contemporary jewellery design situates itself between design and art (den Besten, 2011). Since examples of the use of grown materials are more prevalent in the design discipline, the contextual review has been extended to this neighbouring discipline. Writings from the field of mostly design, and less prevalent art, are therefore reviewed in order to establish commonalities in the practice that can be considered crossdisciplinary.

Biodesign/art apply biotechnological methods in order to manufacture artefacts with living organisms (Koivumen, 2005). Even though the materials used in biodesign/art (Kac, 2020; Myers, 2012) are not crystals, the processes to grow crystals have clear commonalities with those related to the growth of *alive* materials in biodesign/art. Also referred to as *The New Artisans* (Collet, 2013) these makers consider nature as co-creator and utilise natural growth for fabrication (Karana & Camere, 2017), taking advantage of the self-controlled production process (Rognoli et al., 2015) and the diverse form of expressions that are achievable (Antonelli, 2012). In the article 'Materials for Product Design' Serena Camere and Elvin Karana (2017) reflect on the distinct characteristics and advantages of *Growing Design*. They indicate designers employ living organisms to achieve specific design purposes and materials for the use in products.

Their outcomes bring higher sustainability, not only because what they are made of is often compostable and biodegradable, but the way they are produced is increasingly efficient in contrast with the production of artefacts from materials that have often taken ages to form. Additionally, the *grow-ability* of the material provides new opportunities for designs as well as increases efficiency, for example through the growing of the material directly in a pre-determined shape using moulds. The article also highlights the importance and opportunities linked to time and scale as a characteristic of *Growing Design*. Often requiring weeks instead of days, and working on a microscopic level, the design process is impacted and designers have to adapt to working methods generally applied by scientists. Which as a benefit enables them to increase control over the qualities of the material and the fabrication process. The variables designers can manipulate range from the material ingredients and growing conditions to the processing. Finally the article reflects on the symbiotic relationship between the designer and nature as co-creator, as stimulation to reflect on our relation to nature. 'Growing Designers forge the conditions for the invention of new matter, which would not exist otherwise.' (Karana & Camere, 2017). Designers set up processes in which nature as co-creator, with some degree of unpredictability, completes some key elements of the process.

GROWING CRYSTALS FOR JEWELLERY DESIGN

Crystals, gemstones and gems

The word crystal has Greek roots and used to mean clear ice, and still to date is called upon for a range of confusing uses from signifying cut glass and a clear ball to predict the future, to a gem in a piece of jewellery (Holden & Morrison, 1982). To physicists and chemists however, a crystal is a solid material with atoms arranged in an orderly way.

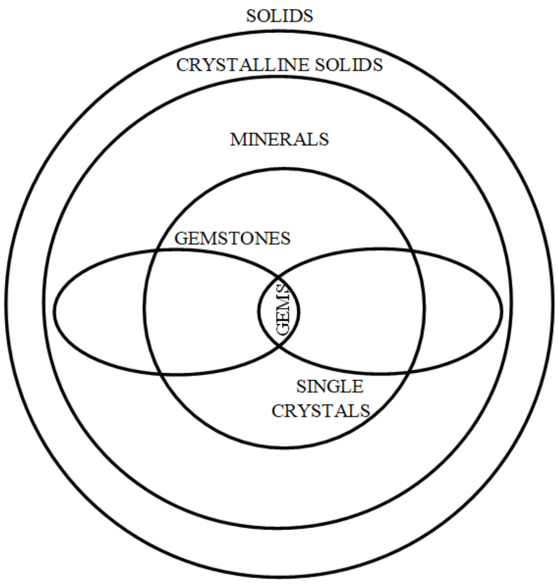


FIGURE 1. The classification of solids, crystalline solids, minerals, gemstones, single crystals and gems.

Not all gemstones are crystals (Arem, 1977) and even though a range of the minerals considered gemstones can be classed as single crystals (gems), there are exceptions: for example opal, which is a non-crystalline material; and agate, which is a microcrystalline material. Furthermore, not all single crystals are considered gemstones, since the minerals generally considered suitable for jewellery designs are usually expected to be adequately resistant to the conditions in which jewellery is worn. Therefore most crystals used for jewellery are durable in addition to displaying appealing optical properties. A table (Table 1) with the properties of four common single crystal gemstones (gems) used for jewellery are documented below.

TABLE 1. Properties of common gems.

Crystal	SPECIFIC GRAVITY	HARDNESS	REFRACTIVE INDEX	LUSTRE	COLOUR
Diamond (Carbon)	3.4-3.5	10	2.42	Adamantine	All colours
Sapphire (Aluminium Oxide)	4-4.1	9	1.76-1.77	Adamantine to vitreous	Most colours
Emerald (Aluminium Berryllium Silicate)	2.7-2.8	7.5-8	1.565-1.602	Vitreous	Green, yellow-green to blue
Quartz (Silicon Dioxide)	2.65	7	1.54-1.55	Vitreous	All colours

Crystal growth

The quest to reproduce materials found in nature can be traced back to the Egyptians (Pearl, 2011) and most gemstones have been reproduced in the lab (Webster, 2011) through a range of techniques, many of which are still in use today (Arem, 1973, 1977; Carter, 2015; Holden & Morrison, 1982; Scheel, 2003). Focussing here on the growth of single crystals, these techniques enable the perpetuation of the pattern or order of atoms either through vapour growth, melt growth, flux growth or solution growth (Arem, 1977) and display many parallels in methodology with the growth of *alive* materials in biodesign/art. Furthermore, since crystal growth is theoretically simple to do (Holden & Morrison, 1982), some of these processes lend themselves well to a *DIY material practice* (Karana & Camere, 2017; Rognoli et al., 2015). The process chosen for the experiments conducted as part of this paper is solution growth, one of the most familiar crystal growth environments (Arem, 1977).

Chosen for its major advantages, including high mobility of dissolved elements, convenience and relative controllability, it provided the ideal process for initial testing as part of the research. In the solution growth process a seed crystal is used to attract unattached atoms present in the solution. Growth takes place when the solution contains more loose atoms than the solution can handle at a specific temperature (Arem, 1977), also called saturation (Holden & Morrison, 1982). Because the growth of gemstone grade crystals in solution (for example emerald, amethyst, quartz and citrine) generally requires more elaborate and high cost equipment, in order to achieve higher temperature and pressure, the first experiments set to test the methodology of Crystal Growing Design for jewellery were conducted with crystals not considered gemstone quality. Alum, sugar and salt can all be disolved in water and the growth of these crystals can be achieved at normal room temperature and pressure. The low-cost equipment needed, and subsequent process to grow the chosen crystals, is relatively straightforward to set up within the jewellery studio, easing the shifting between traditional jewellery and crystal growing processes.

Crystal selection and their use for jewellery design to date

Alum, sugar and salt (Table 2), are not considered gemstone quality and evidently have only been used by a handful designers to date.

TABLE 2. Properties of alum, sugar and table salt.

Crystal	SPECIFIC GRAVITY	HARDNESS	REFRACTIVE INDEX	LUSTRE	COLOUR
Alum (Aluminium Sulfate)	1.47	2-2.25	1.47-1.48	Vitreous	Clear to amber or light green
Sugar (Aluminium Oxide)	1.1	2-2.25	1.76-1.77	Vitreous	Clear to light yellow
Table Salt (Sodium Cloride)	2.17	2-2.25	1.54	Vitreous	Clear to white

Among those designers incorporating salt is Naama Bergman (Anderson & Carboo, 2016; Bergman, n.d.) whose pieces are made out of crystallised salt on iron structures. The brooches are a celebration of the geometric patterns both created by the structures and the salt crystals and celebrate the material's nature. Similarly, the collection titled 'Eclats the Roche' (Figure 2 and 3), in which silver necklaces and earrings were crystallised with sugar, the fragile nature of the crystals also formed an inherent part of the concept for the pieces, which once the sugar has broken off or disolved, change appearance and shape. As a final example, the choice of salt in the work of Jiyoon Hyun (Creativity Oggetti, n.d.; Hyun, n.d.) in contrast, aims to elevate the status of salt in our current society and here the crystals' fragile nature has been bypassed by protecting them with a layer of varnish. The associated material experience (Karana et al., 2014) is a key factor for the choice of salt and sugar by the respective designers. The material experience of the materials used for the experiments in this paper will not be further explored, instead the paper will investigate the methodology of growing crystals for the development of creative designs incorporating grown crystals as pre-cursers to justify the further incorporation and adaptation of more enhanced growing processes as used for the growing of gemstone quality crystals.

FIGURE 2. Eclats De Roche 1, by Sofie Boons, Maga Hermans, Lien Herreijgers, 2009, photography by Max De Cock.

FIGURE 3. Eclats De Roche 2 by Sofie Boons, Maga Hermans, Lien Herreijgers, 2009, photography by Max De Cock.

Review of four Crystal Growing Design experiments for jewellery

To evaluate the growing of crystals as a methodology for jewellery designers, four sets of experiments were developed in response to four hypotheses. The multiple experiment approach was chosen in order to evaluate and compare different approaches in growing crystals within the jewellery studio environment. Below each hypothesis is explained and images of the set up, various stages of the design (to document the growth) and the final outcomes are discussed. The results of the experiments selected for this paper represent only a small fraction of the total number of experiments conducted over a six-month period. The incorporated results were chosen to illustrate the theoretical examination of the methodology.

Environment and equipment

All experiments were conducted in the jewellery studio (Figure 4) at room temperature and room pressure over a period of 6 months.

FIGURE 4. Jewellery studio. All following photographs in this article are by the author.

All crystals were grown in glass bowls, located on a shelf (Figure 5 and 6). The equipment used was: steel and brass wire, glass bowls, plastic measuring cups, portable electric hob, a pan, plastic stirrers and a scale. For some experiments silicon moulds were produced. No additional specialist equipment was purchased. Plant based transparent resin (to enable the inspection of the growth) or green wax (to enable casting) models were created using a small UV 3D printer. Silver and brass models were produced through casting wax models or direct forming techniques.

FIGURE 5 AND 6. Saturated solutions in glass containers (Figure 5) and crystal growing set up (Figure 6).

Seed crystals and saturated solutions

All experiments required the preparation and monitoring of supersaturated and saturated solutions and production, placement and suspension of seed crystals. The solutions were a selection of de-ionised water or tap water and alum, sugar or salt. Both de-ionised water and tap water were used to compare the resulting crystals, which resulted in a difference of colour for sugar (de-ionised water grown crystals were less yellow in tone), but seemed to have little impact in the appearance of alum and salt crystals. The working procedure and the recipe for alum is documented in the book 'Crystals and Crystal Growing' by Alan Holden and Phylis Morrison (1982). The recipe for sugar and salt was 1:2 water/sugar or salt ratio, and was based on previous experimentation. The *growing by evaporation method* and *sealed jar* method were both trialled for a selection of the experiments. From the tests, both methods worked more or less as described (Holden & Morrison, 1982), and neither were found to have distinct advantages. In all experiments seed crystals were used as a basis for developing the designs. These were then suspended in saturated solutions until a desired size was achieved, after which they were removed and washed with tap water.

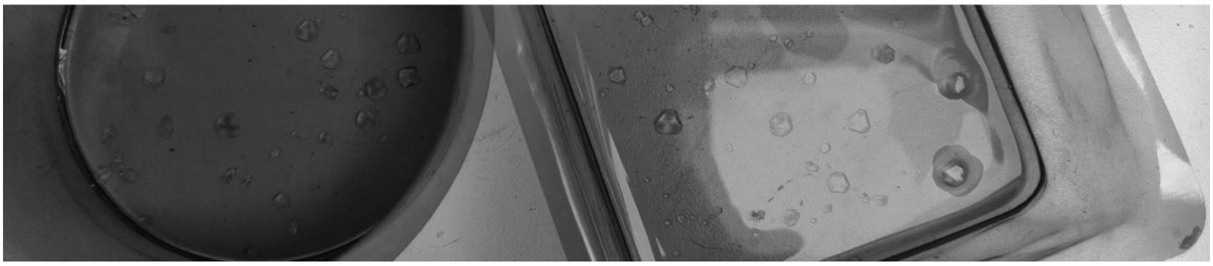


FIGURE 7. Alum seed crystal growth.

Hypothesis 1: growing crystals in situ

The first hypothesis identified to be tested is the growing of crystals in situ in a design. Generally gemstones are incorporated in designs by *setting*. The art and craft of setting gemstones in jewellery has mostly revolved around the creation of a setting, or creating a suitable space in the metal where the stone is held into place in the design. There are many varieties and approaches to setting gemstones (Cheadle, 2018; Hunt, 2013; McIntyre, 2020; Young, 2012). Growing a stone in situ in the design would enable the designer opportunities to reimagine how stones could be incorporated and fixed into their designs. To test this hypothesis a range of experiments were conducted in which a range of produced rings were fitted with a seed and suspended from a steel wire in the saturated solution (Figure 8, 9 and 10). In these experiments the hypothetical growth of crystals was kept in mind whilst designing pieces.

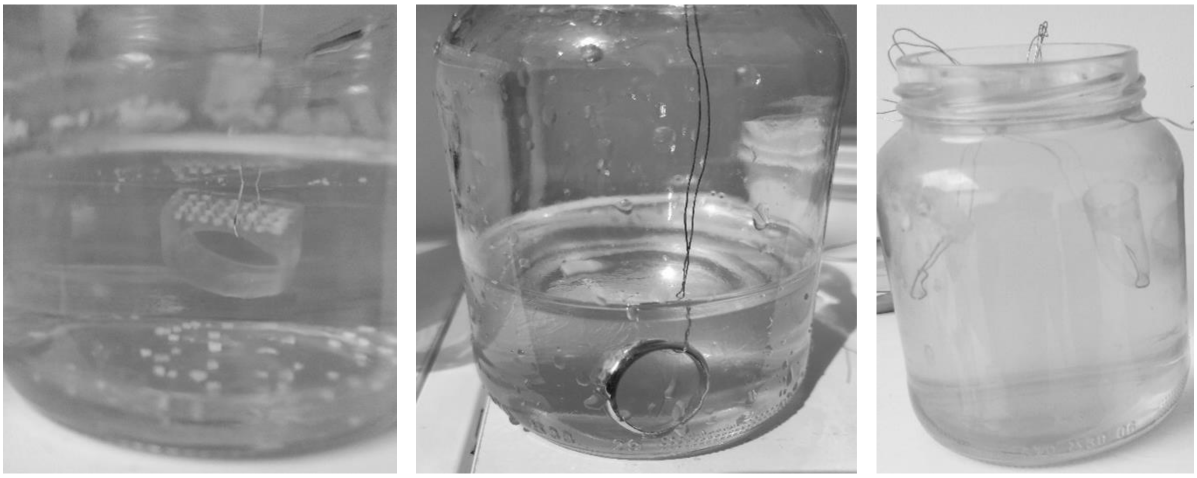
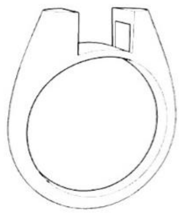
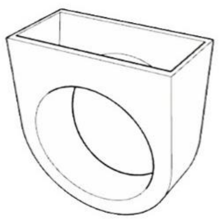


FIGURE 8, 9 AND 10. Salt crystal growing experiment with resin model (Figure 8). Alum crystal growing experiment with silver ring (Figure 9). Sugar saturated solution with resin models suspended from brass wire (Figure 10).

In a first range of tests it was the intention to grow a single crystal in a predetermined open space. The designs of the pieces were simple in terms of shape in order to enable the close monitoring of the crystal growth. Evident in these experiments is the individual shapes each crystal displays, and the unpredictable direction the growth of the crystal has. Sugar atoms grow in a monoclinic structure resulting in a hexagonal prism shape, whereas alum atoms grow in a cubic structure resulting in octahedras with flattened corners. Salt on the other hand grows in the cubic structure resulting in cubelike crystals. The single crystal sugar ring (Table 3), which was grown over a period of 3 weeks, started growing over the edge of the ring. It did however not grow in the other directions.

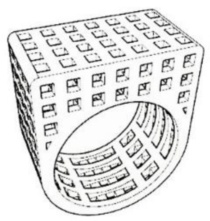
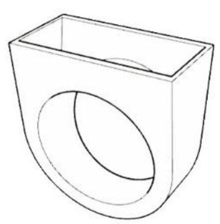
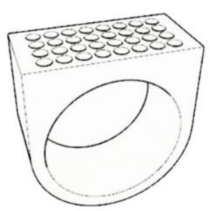
TABLE 3. Single crystal experiments.

Crystal	3D DESIGN	RESIN 3D PRINT	MODEL + SEED	OUTCOME
Alum				
Sugar				

Interestingly, when a solution became unsaturated the crystals suspended inside them would decrease in size. This process, albeit challenging to control without further tools to monitor the solution, could be useful to correct crystals that have grown too large.

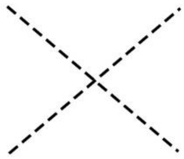
In further experiments the base model allowed for multiple seed crystals to be grown simultaneously, in order to incorporate a range of crystals in an organised or unorganised pattern and study the formation of *polycrystalline crystals*.

TABLE 4. Polycrystal formation experiments.

Crystal	3D DESIGN	RESIN 3D PRINT	MODEL + SEED	OUTCOME
Alum				
Sugar				
Salt				

The resin 3D printed models posed no issues for the glueing and attaching of crystals. To test whether the same would be true for metal, some experiments were conducted with silver models (Table 5). There was no distinct difference between the growth of crystals on silver or resin. Further research could test whether this applies to all precious metals and their various alloys, albeit most logically this research takes place with gemstone quality solution growth crystals instead.

TABLE 5. Crystal growth on metal experiments.

Crystal	3D DESIGN	RESIN 3D PRINT	MODEL + SEED	OUTCOME
Alum				
Sugar				

Hypothesis 2: growing single crystals with inclusions

For the second hypothesis the fact crystals can contain impurities, by for example growing around obstacles, was discovered as an opportunity whilst testing the growing of a single sugar crystal, suspended in its saturated solution through a brass wire. Since the crystal faces exposed continued to connect with sugar molecules in the saturated liquid the wire eventually became encapsulated by the crystal (Figure 11, 13 and 14). Within gemmology, inclusions are generally considered ‘faults’, however, the design opportunity present with growing crystals incorporating *designed inclusions*, seems very promising.

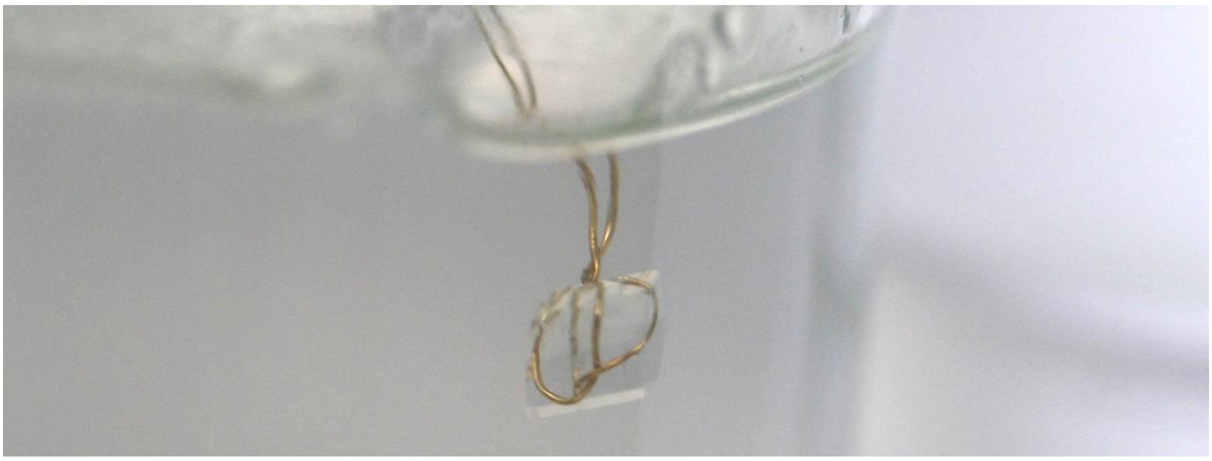


FIGURE 11. Single sugar crystal suspended from brass wire in supersaturated sugar solution.

Therefore, for the second single crystal growth experiment, the brass wire was shaped into the number 2020 before it was wrapped around an alum seed crystal and suspended into a saturated solution. The resulting crystal incorporated the shaped brass wire as an inclusion. Even though there was some distortion of the number, the result was promising. Further experiments currently under development will be investigating the opportunities which designed inclusions can provide jewellery designers in more detail.

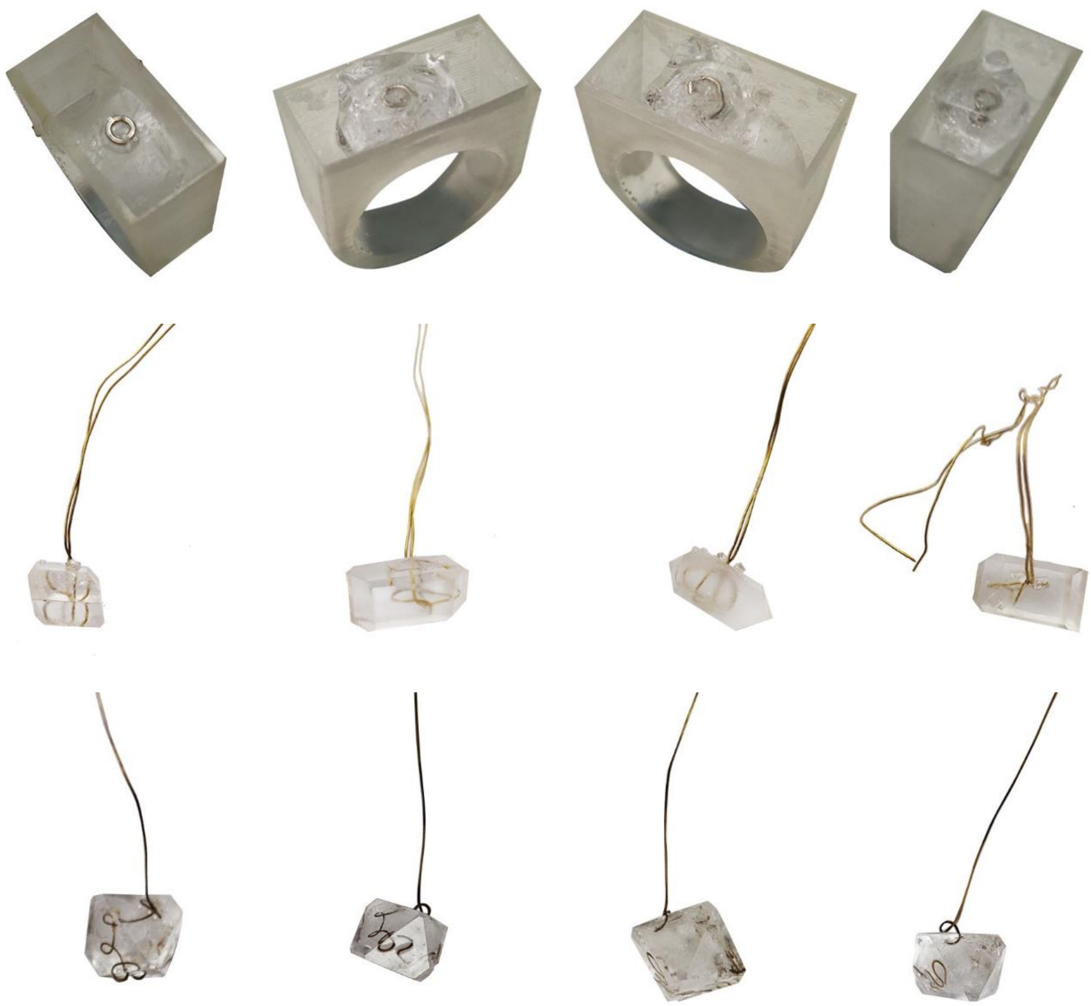


FIGURE 12, 13 and 14. Single crystal alum with silver inclusion grown in resin model – before image on the left and after growth images on the right (Figure 12). Various views of a grown single sugar crystal with brass wire inclusion (Figure 13). Various views of a grown single alum crystal with brass wire inclusion (Figure 14).

Hypothesis 3: grow-ability: controlling the shape of the crystals whilst growing

The third hypothesis at the basis of further experiments was the *grow-ability* of the crystals, which is comparable to the *grow-ability* (Karana & Camere, 2017) of materials generally associated with bio design/art. Since crystals grow until something gets in their way, stopping nourishment from reaching the now blocked face of the crystal (Holden & Morrison, 1982), it seemed possible to *shape* the crystal by restricting growth in certain locations. To do so, a range of tests were conducted, placing seed crystals in silicon moulds before suspending them in the saturated solution. When left undisturbed, many tests resulted in polycrystalline masses, which, albeit shaped as the mould, were not formed of substantially sized single crystals, and therefore remained fragile.

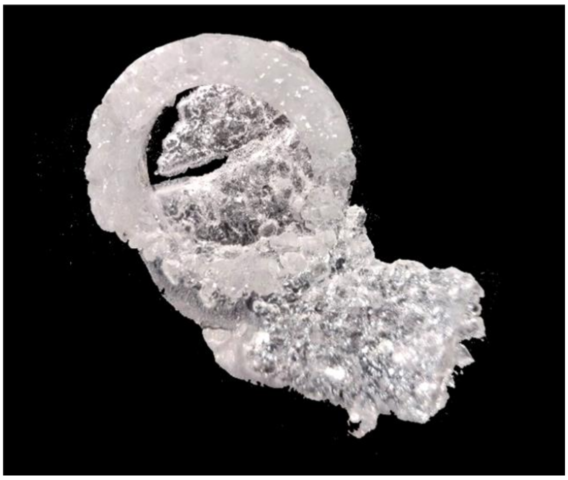



FIGURE 15 and 16. Alum crystals grown in silicon ring mould over 10 days (Figure 15). Sugar crystals grown in silicon ring mould over 6 days (Figure 16).

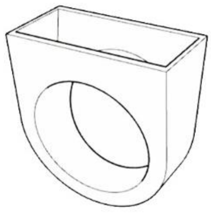
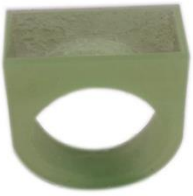
Quite quickly it appeared necessary for the moulds to be checked daily for excess crystal seed deposits, which needed to be removed, and for growing equally spaced larger single crystals to avoid deposits in the first place. When certain single crystals nearly reached one another, one was removed, in order to allow the others to continue growing. To date it has been possible to use this method to achieve single crystals that have been grown in a predetermined shape (Figure 17), however, further research will require the trial of various shapes and sizes of moulds (also in order to prevent the growth of the crystal in height) in order to draw detailed conclusions between the various variables and the outcomes. The opportunity for the controlling of the shape of crystals is promising for the development of new stone shapes, which would perhaps currently prove too wasteful in relation to their naturally occurring shape.


FIGURE 17 and 18. Sugar crystals grown in ring mould over 8 days (Figure 17). Alum seed crystals distributed across a ring mould, suspended in saturated solution days (Figure 18).

Hypothesis 4: growing crystals as models for casting in metal

The shape of crystals as they grow will always be structured in an orderly way, yet allows for many variations in size and orientation. The shapes produced, even when applying the exact same conditions, will always be unique. This is the basis for the fourth hypothesis, in which experiments were conducted using crystals' shapes (some grown on wax models) to cast in metal.

TABLE 6. Crystal growth on wax models experiments and outcome of casting in brass.

Crystal	3D DESIGN	WAX + SEED(S)	WAX + GROWN CRYSTAL	BRASS CASTING
Alum				
Sugar				

Even though the pieces provided interesting designs, their departure from the preservation of the stone in the design was deemed less relevant to the aims of this research.

FIGURE 19 and 20. Alum crystals (Figure 19). Silver earrings produced from cast crystals (Figure 20).

Growing crystals as a methodology for jewellery designers

Understanding the growth of crystals

In order to successfully plan, set up and conduct experiments for the growing of crystals, an understanding is required of the physics and chemistry involved with crystal growth. Since crystal growth is a key scientific endeavour, a large amount of literature from scientific authors is available documenting various highly complex procedures and findings related to crystal growth across the spectrum. It was however more challenging to locate literature communicating the process in laymens' terms. The book 'Crystals and Crystal Growing' by Alan Holden and Phylis Morrison (1982) proved to be the most accessible, yet detailed introduction to crystal growth with the specific purpose of growing *DIY crystals*. The prior knowledge requirement could be a barrier for jewellers to implement it as a design methodology into their practice. This understanding of the process would also be required in order to design more complex crystal innovations even if ultimately the growth would be organised by a crystal growing company providing it as a service. The jewellery designer, designing bespoke crystals or crystal growth designs, will ultimately need to understand the process in order for it to become an additional tool in their design repertoire.

Crystal Growth Process

As a jewellery designer/maker techniques and processes are generally learnt by experiencing and practicing (Untracht, 1982). The more traditional techniques (forming, joining, finishing, etc) require constant hand-eye coordination, which inform progress. This process, in which models are investigated by touch and both visual and haptic information inform the further development of the piece, provide the jeweller - who is used to working on a small scale - more or less full control. When reflecting upon the general use of gemstones in jewellery this is no different. The stone is often purchased from a dealer, either in response to a design or prior to the design is produced and it is generally a known element prior to the production of the piece. In the methodology of growing crystals, the shape of the crystals is significantly less predictable, and hands-on tactile feedback of the stone as well as measuring it can only be done once the stone has been removed, washed and dried. To avoid contamination and disturbing the solution (which could result in failed growth) the removal of the stone for handling and measuring has to be minimised. The growth of the crystal is therefore mainly monitored by visually checking the shape in solution, which as an approach highly differs from the approach generally applied by jewellers working at the bench. In Figure 21 a visual diagram is pictured of the crystal growth process as applied for the experiments in this paper.

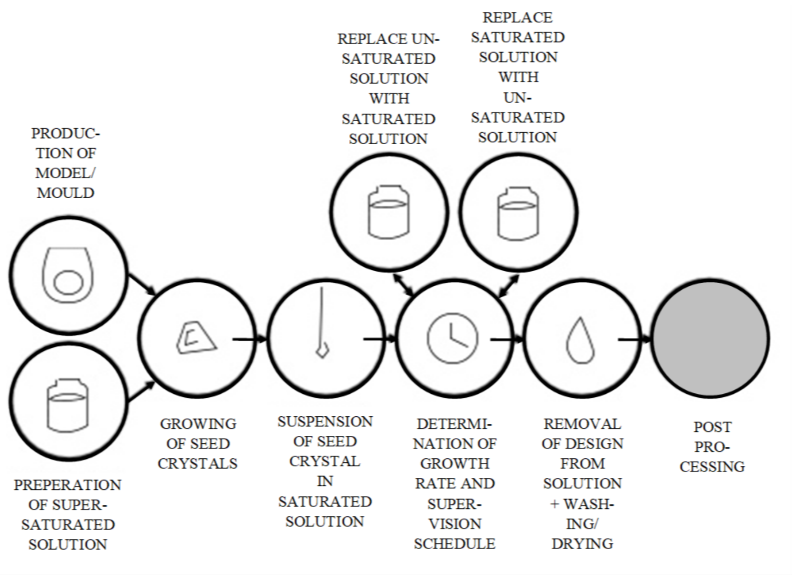


FIGURE 21. Crystal growth process schematised.

Similarly, to *Growing Design* (Karana et al., 2018; Karana & Camere, 2017; Rognoli et al., 2015), the growing of crystals additionally also requires the monitoring of growing conditions, which ultimately will affect the outcome. The fluctuations in temperature, pressure, moisture, and the various options in which to contain and store the solution, all have an impact on the growing crystal. As a jeweller, temperature is controlled only for metallurgical purposes (casting, soldering, annealing, etc.). Most of the materials jewellers generally work with do not *respond* to changes in room temperature, room pressure, and even reasonable fluctuations in moisture levels. Even though some control of these conditions was achieved to conduct the experiments referenced in this paper, more control and measurement tools would be advisable for further research to be meaningful. Figure 22 provides a first attempt towards a material taxonomy, identifying the various variables and categorisations of affecting conditions.

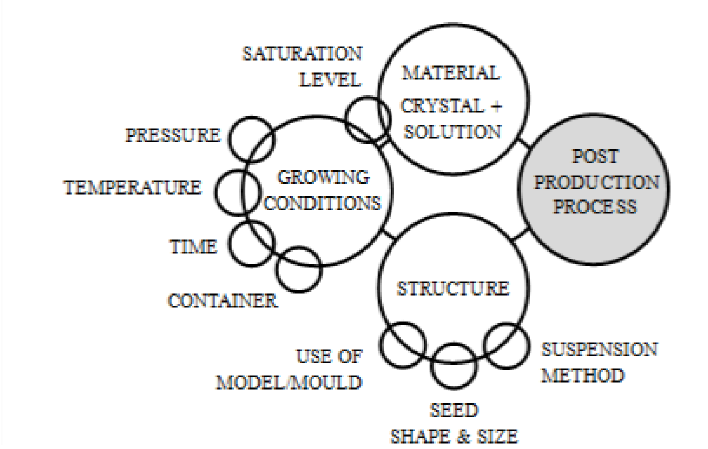


FIGURE 22. First draft of crystal growing material taxonomy to support experimentation.

The opportunity to shape, alter and adjust the grown crystals in the post production process has not been explored in the experiments conducted for this paper. The cyrstals chosen would likely not survive traditional lapidary post production processes (cutting, facetting and polishing). This is however an exciting prospect for crystals grown of gemstone grade quality, providing some additional control to the designer and reintroducing a process allowing tactile feedback.

FIGURE 23. Silver ring with in situ grown sugar crystal.

Opportunities and Challenges

The growing of crystals as a methodology for jewellery design holds great potential, but also poses a number of challenges. With additional control of the growing conditions, designers could influence the process significantly which could lead to opportunities for the creation of innovative crystals that could not be found in nature. However, to gain additional control over the growing conditions, additional equipment and resources would have to be brought into the studio environment, which could be costly. The alternative, growing at a location that resembles a lab, would further distance the growing process from the making process. Furthermore, the *grow-ability* of the material, influenced by the use of models/moulds, the characteristics and attachment of the seed and the suspension method, also provide designers opportunities to re-think the way crystals can be incorporated in designs. The integration of the methodology in the studio environment allowed for model designing and making to take place whilst monitoring solutions and growth simultaneously. When certain problems were observed, model redesign and development enabled the set up of additional experiments faster. Distancing this process from the studio environment would therefore disadvantage this flow. The incorporation of more complex equipment to grow gemstone grade quality stones into the jewellery studio would require further investigation in terms of practicality. For alternatives to be considered: e.g. a collaborative approach where the designer works with a company providing the growth of crystals as a service, or when a designer uses an alternative location for the growth of crystals, mitigations in order to increase the seemless interaction between studio practice and crystal growth processes would have to be considered.

Even though the growing of crystals can be a lengthy process for the designer, who generally does not need to spend this time when purchasing a stone from a dealer, the process is in fact significantly more sustainable when compared to the supply chain of most stones extracted from the earth. Further experiments with more specialist equipment in order to grow gemstone grade stones might result in less energy efficient growth processes, but the impact of the growth could be calculated and analysed in detail. It is expected that it would still be significantly more sustainable to grow stones locally, eliminating the need for extraction and transportation.

FIGURE 24 and 25. Resin ring with in situ grown alum crystal, top view (Figure 24) and side view (Figure 25).

The opportunity to co-create with nature (Karana & Camere, 2017) invites an element of chance which could in turn lead to unique outcomes. This uncertainty, on the other hand, can also be a challenge for designers who are generally used to having full control. The immediate impact of environmental changes and resulting changes to saturation levels of the solutions, the lack of control on the direction of growth, as well as the delay in achieving results, separating the production of the pieces and final (tactile) evaluation process (Karana & Camere, 2017), all posed challenges to the usual making practice. A significant period of time dedicated to the tinkering (Barati et al., 2015; Karana et al., 2015, 2018) with the material to consider the process impact on quality and its constraints, led to a greater understanding and acceptance of the uncertainty. All designers who in future would wish to implement the growing of crystals in their practice would be recommended to dedicate time to explorative and evaluative tinkering.

Ultimately the growing of crystals displays a range of advantages and challenges similar to those of *Growing Design* (Karana & Camere, 2017), and in a future where sustainability and unique designs are highly valued charactristics, the application of the methodology of growing crystals for jewellery designers warrants continued research.

FIGURE 26. Silver ring with in situ grown alum crystal from various views - before image on the left and after growth images on the right

CONCLUSION

This paper explored the growing of crystals as methodology for jewellery designers through conducting a range of experiments in response to four hypotheses. The goal was to provide an account of the hands-on experience of DIY growing crystals in the jewellery studio, and an insight into this material-driven process. Furthermore, a critical analysis was conducted of the methodology exploring the overlap with biodesign/art as well as its suitability for jewellery designers.

It was illustrated that the methodology holds a range of opportunities, whilst at the same time posing a number of challenges for the designer. A good understanding of the chemistry and physics of growing crystals and additional equipment to control the growing conditions are barriers to be overcome. Furthermore, a shift in approach was needed in order to apply the methodology: an openness to uncertainty, patience and a reliance on visual rather than tactile inputs differs from the usual bench based method of production. Nevertheless, the conducted experiments and their outputs clearly demonstrated the opportunities for innovation, enhanced understanding and potentially localised sustainability practice, which all warrant the continuation of the research into the methodology of Crystal Growing Design.

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