Boons Sofie
Research Associate/Crafts Council Research Fellow
University of the west of England
sofie.boons@uwe.ac.uk
https://orcid.org/0000-0003-2994-4921

Crystal Growing Design Method: An investigation into the growing of crystals for jewellery designs

Abstract:
Grown crystals are used for a range of novel innovations supporting a wide array of industries such as technology, medicine and electronics. Within the jewellery industry however, grown crystals are only used in a limited capacity and those of gemstone quality mainly as a surrogate for mined gemstones. They have remained largely underused, despite their potential sustainability credentials and the creative possibilities the incorporation of the process of crystal growth holds for jewellery designers. The bespoke growth of gemstone quality crystals could lead to highly unique jewellery designs which would result in higher consumer attachment. This in addition to the potentially more sustainable production of these stones, would lead to overall more sustainable products. To address the barriers that are holding jewellery designers back from exploring the growth of crystals in their practice, and to address the knowledge gap that underpins this barrier, this article presents a practice-based exploration into the method of Crystal Growing Design for jewellery. Alongside reviewing a selection of the limited number of jewellery designers who have explored organic crystal growth, the article discusses the results of the practice-based explorations done. Three hypotheses derived from the characteristics and advantages of growing design were tested in three case studies and aimed to explore the design opportunities the method provides designers when (i) growing in situ either in designs or (ii) around shapes, or (iii) when utilizing the grow-ability of the process as a feature. Because the growth of gemstone quality crystals requires more elaborate and high cost equipment, sugar, alum and salt were experimented with as a prelude to further experimentation with the technique using gemstone grade crystals. Through utilizing an explorative DIY approach the author documents and discusses the opportunities and challenges presented by the incorporation of a crystal growth method into the jewellery design practice. The research article will additionally reflect on the DIY growth of these non-gemstone quality crystals as a meaningful learning process for jewellery designers wishing to gain a deeper understanding of crystal growth. The DIY growth of crystals can be considered a valuable tinkering process to investigate design ideas. Which is particularly relevant since the method of growing crystals holds creative potential when designing jewellery in collaboration with crystal growers, or through incorporating gemstone crystal growth processes, which are the topic of the author’s overarching PhD research.

Keywords:
Crystal Growing Design
Method
Jewellery

Introduction

Jewellers around the world have used mined crystals for the creation of jewellery for centuries (Arem 1977: 1). Within the field, expert gemmological gemstone identification and optimisation techniques have developed and a worldwide gemstone trade has been 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 revolutionizing technology and engineering; diamonds grown microscopically on sheet to optimise conductivity are present in high performing microchips (Lui et al. 2017) 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 gemstone quality crystals to imitate mined crystals. Limited attention is spent on the exploration of the possibilities man-made gemstone crystals and their related processes provide in a creative jewellery design context. This despite the fact the growth of crystals can result in aesthetic and creative designs, as demonstrated and documented in this article through the case studies and through the review of a small selection of jewellery designers who have incorporated the growing of non-gemstone quality crystals in their practice. In order for more jewellery designers to become interested in the designing of bespoke crystals or crystal growth designs this article will additionally aim to underline the need to understand the crystal growth process in order for it to become an additional tool in a jewellery designers' repertoire.

Growing materials as a design method

Even though crystals were historically considered to have magical powers, they are in most scientific contexts conversely not considered to be alive materials. Outside the jewellery industry the democratisation of science has led to an increasing number of designers interested in DIY approaches to growing materials (Karana and Camere 2017: 101). Bio design/art apply biotechnological methods in order to manufacture artefacts with living organisms (Koivunen 2005: 1). Even though the materials used in bio design/art are not crystals, the processes to grow crystals have clear commonalities with those related to the growth of *alive* materials in bio design/art. Also referred to as *The New Artisans* (Collet 2013) these makers consider nature as co-creator and utilize natural growth for fabrication (Karana and Camere 2017: 101), taking advantage of the self-controlled production process (Rognoli et al. 2015: 698) and the diverse forms of expressions that are achievable (Antonelli 2012: 7). Scholars in the field (Kac 2021; Karana and Camere 2017; Myers 2012; Rognoli et al. 2015; Van Dijk 2016; Collet 2020) have commented and documented the opportunities the methodology of growing materials holds for designers, ranging from achieving novel aesthetics, their grow-ability to their sustainability credentials. The artist Kac coined the term 'bio art' in 1997 and has created and described the processes deployed as well as their aesthetic and social ramifications (Kac 2021: 1367). Venturing beyond art, with the number of product designers involved with growing materials expanding, the emerging practice of DIY growing is also evolving (Karana and Camere 2017: 102; Rognoli et al. 2015: 701; Van Dijk 2016: 3). In the book Bio Design (Meyers, 2012) a range of design projects and artefacts are reviewed for their incorporation of living materials, and how they serve the sector in various ways across design disciplines. Do-It-Yourself Biology is described by Van Dijk (2016: 24) as a global movement that aims to spread and popularize the use of biotechnology beyond academic and industrial contexts and those operating within. This paradigm shift promises to open up new possibilities for bio fabricating future intelligent materials as well as for engaging with new sustainable processes as described by Collet (2020: 1331), who examines the approaches to designing with living systems and proposes a framework for design to engage with a prospective future bio-materiality.

In the article ‘Growing Materials for Product Design’ authors and experts in bio design Camere and 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 biodegradable, but the way they are produced is increasingly efficient in contrast with using materials that have often taken ages to form. Additionally, the *grow-ability* of the material provides new opportunities for designs, for example through the growing of the material directly in a pre-determined shape. 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, 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. Reflecting on the symbiotic relationship between the designer and nature as co-creator they state: ‘Growing Designers forge the conditions for the invention of new matter, which would not exist otherwise.’ (Karana and Camere 2017: 111). Designers set up processes in which nature as co-creator, with some degree of unpredictability, completes some key elements of the process.

Another key author on the subject, is Collet, who established a framework for the designing with the living which has informed the Design and Living Systems Lab at Central Saint Martins at the University of the Arts London. The framework aims to portray a hierarchy: Nature as model, where designers explore biomimicry principles; Nature as co-worker: where designers combine biomimicry approaches with husbandry techniques resulting in a *designer cultivator* and; Nature as a ‘hackable’ system, where designers use the advances of synthetic biology to create bespoke genetic engineered simple living organisms resulting in a *designer biologist* (Collet 2021: 1334). Anchoring the framework within the changing cultural perception of nature, she highlights a divergence of position: Nature as model acknowledges the supremacy of natural models; Nature as Co-worker endorses a partnership with nature and; Nature as a ‘hackable’ system aligns with values of dominance over nature which is inherent to contemporary thinking positioning nature as an exploitable commodity. The growth of DIY crystals aligns comfortably with Nature as Co-worker, however, those growing bespoke crystals in the lab, altering their chemical composition, could be situated under Nature as a ‘hackable’ system.

In this article I present the research and related reflections I have made on the jewellery designs produced with DIY grown crystals. This in order to demonstrate that the DIY growth of crystals can be a powerful learning process for jewellery designers wishing to gain a deeper understanding of crystal growth, and that it is expected to be valuable tinkering process to investigate design ideas involving the process of gemstone quality crystal growth in the development of jewellery. Particularly since the method of growing crystals holds creative opportunities when designing jewellery in collaboration with crystal growers, or gemstone crystal growth processes.

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 different uses from signifying cut glass containing lead and a clear ball to predict the future, to a gem in a piece of jewellery (Holden and Morrison 1982: 17). To physicists and chemists however, a crystal is a solid material with atoms arranged in an orderly way, in line with its lattice structure.

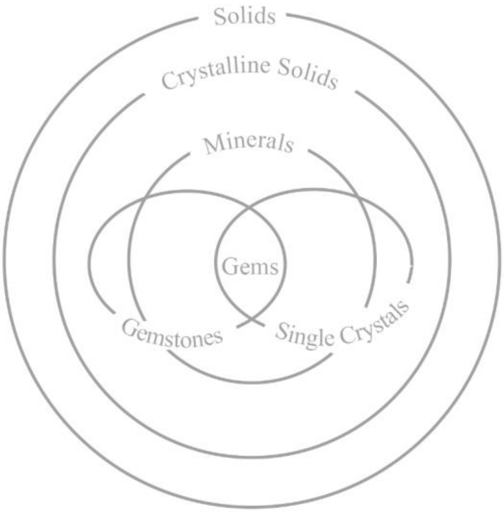


Figure 1: The classification of solids, crystalline solids, minerals, gemstones, single crystals and gems.

Not all gemstones are crystals (Arem 1977: 2) 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 4 common single crystal gemstones (gems) are documented below.

Table 1: Properties of common gemstones assembled by the author from several public sources.

Crystal	Specific Gravity	Hardness	Refrective 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: 26) and most gemstones have been reproduced in the lab (Webster 2011: 43) through a range of techniques, most of which are still in use today (Arem 1973, 1977; Carter 2015; Scheel 2003). Focusing here on the growth of single crystals, these techniques enable the perpetuation of the order of atoms either through vapor growth, melt growth, solution growth (Arem 1977: 212) and less commonly solid state growth, and some display parallels in methodology with the growth of *alive* materials in bio design/art. Furthermore, since crystal growth can be theoretically simple to do (Holden and Morrison 1982), some of these processes lend themselves well to a *DIY material practice* (Karana and Camere 2017; Rognoli et al. 2015).

The process ultimately chosen for the experiments conducted as part of this article is *solution growth*, one of the most familiar crystal growth environments (Arem 1977: 215). Chosen for its major advantages, including high mobility of dissolved elements, convenience and relative controllability, it provided the ideal process for initial testing. 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: 215), also called saturation (Holden and Morrison 1982: 76). 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 method of Crystal Growing Design for jewellery were conducted with crystals not considered gemstone quality. Alum, sugar and salt can all be dissolved 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 limited number of jewellery designers to date.

Table 2: Properties of alum, sugar and salt.

Crystal	Specific Gravity	Hardness	Refrective Index	Lustre
Alum (Aluminium Sulfate)	1.47	2-2.25	1.47-1.48	Vitreous
Sugar (Aluminium Oxide)	1.1	2-2.25	1.76-1.77	Vitreous
Salt (Sodium Cloride)	2.17	2-2.25	1.54	Vitreous

Among those designers incorporating the crystal growth process of sugar in jewellery accessories is Helmond (Fairs 2007) who produced necklaces by delicately controlling the growth of sugar. A designer who has incorporated the growth of salt crystals in their jewellery designs on the other hand is Bergman (Anderson and Carboo 2016; Bergman, n.d.) whose pieces are made by crystallizing iron structures. The resulting brooches are a celebration of the geometric patterns both created by the structures and the salt crystals. Similarly, the collection titled ‘Eclats the Roche’ (Boons 2010), for which the author collaborated with Herreijgers and Hermans, uses a silver base for crystallization and contains crystallized silver chain. This resulted in pieces where the fragile nature of the crystals also formed an inherent part of the concept for the designs, which once the sugar has broken off or dissolved, changed their appearance and shape. A concept jeweller Smith (Smith 2010) also explored in her jewellery pieces around the same time, and in her collaboration with Clarke in 2014 also applied to silver tableware (Decker 2016). As a final example, the choice of salt in the work of Hyun (Creativity Oggetti, n.d.; Hyun, n.d.) in contrast, aims to elevate the status of salt in our society and here the crystals’ fragile nature has been bypassed by protecting them with a layer of varnish.

All pieces discussed demonstrate that the incorporation of the growth of crystals into the jewellery design process can result into aesthetic and creative jewellery designs. The use of these relatively fragile materials (salt and sugar respectively) is in itself innovative, when incorporated into jewellery designs, and the associated material experience (Karana et al. 2014) is in most examples also a key factor for them being chosen by the respective designers. The material experience of the crystals used for the experiments in this article will however not be further explored, because the material experience of gemstone grade crystals would not be comparable. Instead the article will investigate the method 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, potentially in collaboration with industrial growers.

Despite the evidence of some use of organic crystal growth by jewellery designers, there remains very limited practice-based research documentation of these processes in the field and context. To fill this gap the article will report on the process and outcomes of the conducted case study experiments. This is of importance particularly since the DIY growth of crystals can be an important learning process for any jewellery designer wishing to gain a deeper understanding of the process of crystal growth, and is additionally expected to serve as a valuable tinkering process to investigate design ideas involving the process of gemstone quality crystal growth in the development of jewellery.

Review of three Crystal Growing Design case study experiments for jewellery

To evaluate the growing of crystals as a method for jewellery designers, and craft educators, three sets of experiments were developed in response to three hypotheses. The three hypotheses aimed to test the distinct characteristics and advantages of *Growing Design* as referenced, and aimed to explore the design opportunities crystal growth provides when (i) growing in situ either in designs or (ii) around shapes, or (iii) when utilizing the grow-ability of the process as a feature. The multiple case study approach (Yin 2018: 98) 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 article 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 main arguments of this article.

Environment and equipment

All experiments were conducted in the jewellery studio at normal room temperature and room pressure over a period of six months. All crystals were grown in glass bowls, located on a shelf. 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) models were created using a small UV 3D printer. Silver models were produced through casting wax models or direct forming techniques.

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 Holden and 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 and Morrison 1982: 93), 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.

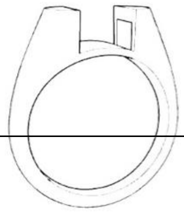
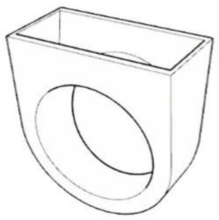
Hypothesis 1: Can the growing of a single crystal or multiple crystals in situ in designs be introduced as part of the design process?

The first hypothesis identified to be tested is the growing of crystals in situ in a designed space. 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. 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. In these experiments the hypothetical growth of crystals was kept in mind whilst designing pieces.

In the 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 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 octahedra with flattened corners. Salt on the other hand grows in the cubic structure resulting in cube like crystals. The single crystal sugar ring (Table 3), which was grown over a period of three weeks, started growing over the edge of the ring. It did however not grow in the other directions.

Table 3: Single crystal experiments.

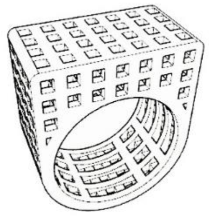
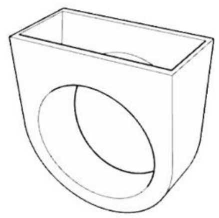
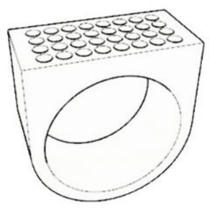
Crystal	3D Design	Resin 3D Print	Model + Seed	Outcome
Alum				

				
Sugar				

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.

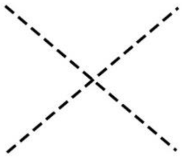
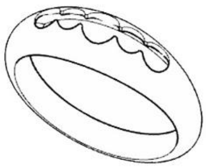
In further experiments (Table 4) the base model allowed for multiple seed crystals to be grown simultaneously, in order to incorporate a range of crystals in an organised or unorganised pattern and study the formation of *polycrystalline crystals*.

Table 4: Polycrystal formation experiments.

Crystal	3D Design	Resin 3D Print	Model + Seed(s)	Outcome
Alum				
Sugar				
Salt				

The resin 3D printed models posed no issues for the gluing and attaching of crystals. To test whether the same would be true for metal, the most common material used for the production of jewellery, 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	Silver Model	Model + Seed	Outcome
Alum				
Sugar				

Hypothesis 2: Can the process of growing single crystals in situ in designs be adapted to result in the growth of 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 (Figure 2). Since the crystal faces exposed continued to connect with sugar molecules in the saturated liquid the wire eventually became encapsulated by the crystal. Within gemmology, inclusions are generally considered ‘faults’, however, the design opportunity present with growing crystals incorporating *designed inclusions*, seems very promising.

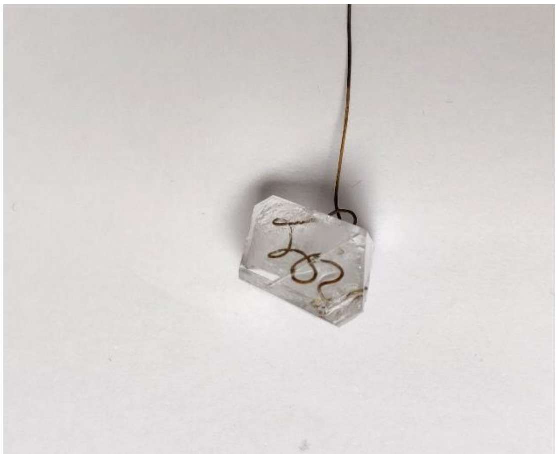


Figure 2: Single sugar crystal suspended from brass wire in supersaturated sugar solution. Figure 3: Grown single alum crystal with shaped brass wire inclusion.

Therefore, for the second single crystal growth experiment (Figure 3), 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.

Another experiment conducted involved the growing of a single crystal in a resin ring design, with an inclusion (a silver wire shaped as a small ring) positioned so the crystal would grow to embed it. The result once more indicated that there are challenges with the control of the growth of the crystal in relation to the inclusion. The outcome however still provided a range of distortions of the inclusion, which would be of interest if the cut of the stone could be altered. Further experiments currently under development will be investigating the opportunities which designed inclusions can provide jewellery designers in more detail. The feasibility of designing inclusions in gemstone grade stones could however prove more challenging due to the nature of the processes used.

Hypothesis 3: Can the grow-ability of crystals and the resulting controlling of its shape whilst growing be exploited as part of the design process?

The third hypothesis as a basis of further experiments was the *grow-ability* of the crystals, which is comparable to the *grow-ability* (Karana and 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 and 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, a number of tests resulted in polycrystalline masses, which, albeit shaped as the mould, were not formed of substantially sized single crystals, and therefore remained fragile.

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 4), 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 4: Sugar crystals grown in ring mould over 8 days.

Growing crystals as a method for jewellery designers: understanding the growth of crystals
The DIY growth of crystals is an important learning process for any jewellery designer wishing to gain a deeper understanding of the process of crystal growth, and is expected to serve as a valuable tinkering process to investigate design ideas involving the process of gemstone quality crystal growth in the development of jewellery. 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 endeavor, a large amount of literature from scientific authors is available documenting various highly complex procedures and findings related to crystal growth. It was however more challenging to locate literature communicating the process in laymen's terms. The book 'Crystals and Crystal Growing' by Alan Holden and Phyllis 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 method 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 organized 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 Reflections
As a jewellery designer/maker techniques and processes are generally learnt by experiencing and practicing (Untracht 1982). The more traditional techniques (forming, finishing, etc) require constant hand-eye coordination. 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 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 and it is generally a known element prior to the production of the piece. In 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 can result in failed growth) the removal of the stone 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. In Figure 5 a visual diagram is pictured of the crystal growth process as applied for the experiments.

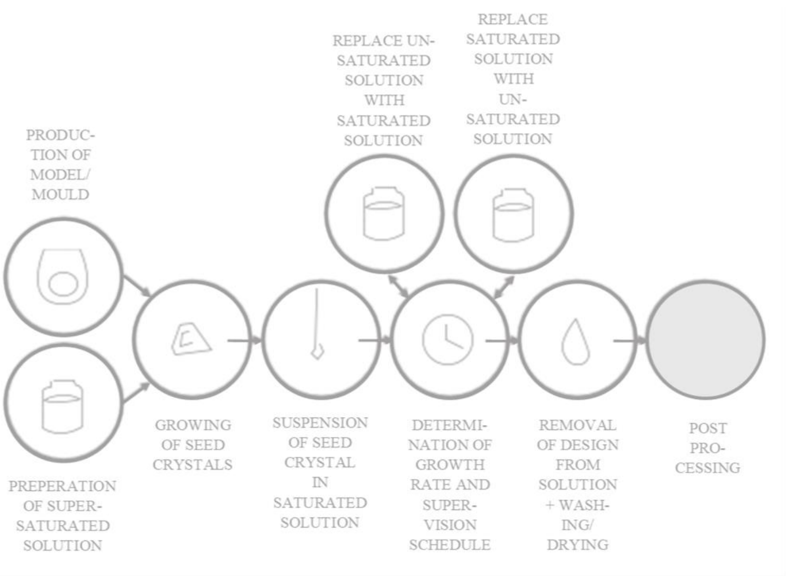


Figure 5: Crystal growth process schematized.

Similarly to *Growing Design* (Karana et al. 2018; Karana and Camere 2017; Rognoli et al. 2015), the growing of crystals 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, 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, more control and measurement tools would be advisable for further research to be meaningful. Figure 6 provides a first attempt towards a material taxonomy, identifying the various variables and categorisations of affecting conditions.

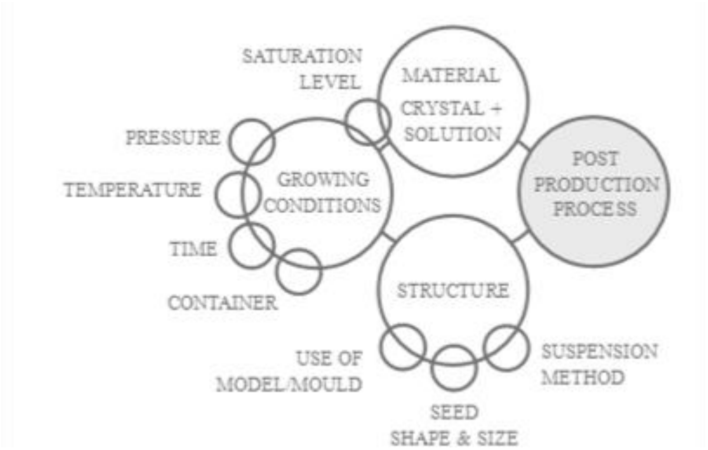


Figure 6: First draft of crystal growing material taxonomy to support experimentation.

The opportunity to shape, alter and adjust the grown crystals in the post production process has not been explored in the experiments. The crystals chosen would likely not survive traditional lapidary post production processes (faceting, polishing, etc). 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.

Opportunities and Challenges

With limited resources available for designers to explain the process in layman's terms this article aimed to reflect on a jewellery designer's starting point on the growth of crystals. The experiments were relatively easy to set up and conduct, and the outcomes enabled close inspection of the technique in relation to the production of designs which resulted in an enhanced understanding of the theory. For these reasons the DIY Crystal Growth Design experiments conducted would lend themselves well to being introduced in jewellery design educational settings which could prove to be a valuable contribution towards addressing the knowledge and skills gap jewellers face.

When reflecting upon the growing of crystals as a method for jewellery design, it can be stated it holds great potential, but does also pose a number of challenges beyond the initial barrier to understanding and implementing the process. With additional control of the growing conditions, designers could influence the process significantly which could lead to 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 provides designers opportunities to re-think the way crystals can be incorporated in designs. The integration of the method 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 (such as RSA in France) 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 seamless 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. Additionally, the bespoke nature of the outcomes would benefit the uniqueness of the resulting designs and likely influence consumer attachment, therefore affecting their longevity.

The opportunity to co-create with nature (Karana and Camere 2017) shifting from manufacture to *biofacture* and become a designer cultivator (Collet 2021) 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 and 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 using organic crystal growth (using a material like sugar, alum and/or salt).

Future research: flux growth of gemstone grade crystals

Flux growth, which is considered a solution growth technique, likely bears most resemblance to the DIY solution growth experiments conducted for this article. Further research in the incorporation of flux growth and the collaboration with experienced crystal growers, will aim to compare the method of the growth of gemstone grade crystals in flux with the method documented for this article.

Figure 7: Silver ring with in situ grown alum crystal.

Conclusion

This article explored and documented the growing of crystals as a method for jewellery designers through conducting a range of case study experiments in response to 3 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 in order to demonstrate that the DIY growth of crystals is expected to be a valuable tinkering process to investigate design ideas involving the process of gemstone quality crystal growth in the development of jewellery. Since a good understanding of the chemistry and physics of growing crystals and additional equipment to control the growing conditions remain barriers to be overcome, it can be a powerful learning process for any jewellery designer wishing to gain a deeper understanding of crystal growth and its processes. The introduction of DIY crystal growth experiments in educational settings could be a first step towards addressing this knowledge gap more broadly. Following a short critical analysis of the method's overlap with bio design/art, it was illustrated that the method holds a range of opportunities, whilst at the same time posing a number of challenges for the jewellery designer. It will therefore require jewellers to undergo a shift in their approach when incorporating the processes as demonstrated, which is needed in order to apply the method: an openness to uncertainty, patience and a reliance on visual rather than tactile inputs, all differ from the usual bench-based methods of production. The additional potential benefits of localized sustainability practice and more sustainable products both through process and longevity of outcomes through enhanced consumer attachment, warrants the continuation of the research into the method of Crystal Growing Design. Particularly since the method of growing crystals holds further possibilities for enhanced creativity when designing jewellery in collaboration with crystal growers, or gemstone crystal growth processes, which are the topic of the author's overarching PhD research.

Acknowledgements

This article was written as part of an overarching PhD study. For their encouragement and guidance in the conducting of my research I would like to thank my Director of Studies, Dr Bodman, and supervisors Dr Morgan and Associate Professor Huson. A special thanks also to my mentors: Dr Geisow, Dr Rytz, Dr Hall and Dr Potticary. This research was funded by UKRI, Research England, Expanding Excellence in England (E3) Fund.

Author biography

Sofie Boons is an award-winning jewellery designer currently working as Craft Council Research Fellow and Research Associate for the Centre for Print Research at the University of the West of England. She is completing a PhD investigating the design implications, possibilities, and limits of utilising man-made crystals in the development of jewellery. Prior to starting her research Sofie worked as the Head of Academy for the British Academy of Jewellery. After graduating from the Royal College of Art she has continually exhibited her jewellery internationally and her artefacts are held in the collections of a range of industry leading galleries.

List of Illustrations

References

Anderson, K. R. and Carboo S. S. (2016), '10 Best Newcomers at Munich Jewelry Week 2016', accessed 5 October 2020 at https://artjewelryforum.org/10-best-newcomers-at-munich-jewelry-week-2016.

Antonelli, P. (2012), 'Vital Design', in *BioDesign: Nature, Science, Creativity,* High Holborn: Thames & Hudson, pp. 6–7.

Arem, J. E. (1973), *Man Made Crystals*, Washington: Smithsonian Institution Press.

Arem, J. E. (1977), *Encyclopedia of Gemstones*, Second Edition, New York: Van Nostrand Reinhold Company Inc.

Barati, B., Karana E. and Hekkert P.P.M. and Jönsthövel I. (2015), 'A case of designing with an underdeveloped computational composite for materials experience', in *Proceedings of the International Conference of the DRS Special Interest Group on Experiential Knowledge (EKSIG)*, Kolding: Design School Kolding, pp. 118–32.

Bergman, B. (n.d.), 'Naama Bergman', accessed 5 October 2020 at https://www.naamabergman.com/.

Boons, S. (2010), *Eclats De Roche*, accessed 14 April 2022 at http://sofieboons.com/portfolio/eclats-de-roche-2/.

Carter, W. (2015), *Crystals and Crystal Growth*, New York: Nova Science Publishers, Inc.

Collet, C. (2013), 'Alive | About', accessed 14 September 2020 at http://thisisalive.com/about/.

Collet, C. (2020), 'Designing our future bio-materiality', *AI & Society*, 36, pp.1331–1342, accessed 1 May 2022 at https://link-springer-com.ezproxy.uwe.ac.uk/content/pdf/10.1007/s00146-020-01013-y

Creativity Oggetti (n.d.), 'Jiyoon Hyun', accessed 5 October 2020 at https://www.creativityoggetti.it/en/artist/item/1491-jiyoon-hyun.html.

Decker, A. P. (2016), 'David Clarke : A Cup Half Full', accessed 14 April 2022 at https://objektion.wordpress.com/2016/04/24/david-clarke-a-cup-half-full/.

Fairs, M. (2007), 'Unsustainable by Greetje van Helmond', accessed 14 April 2022 at https://www.dezeen.com/2007/06/27/unsustainable-by-greetje-van-helmond-2/.

Holden, A. and Morrison P. (1982), *Crystals and Crystal Growing*, 1st ed., Cambridge, Massachusetts: MIT Press.

Hyun, J. (n.d.), 'SaLux', accessed 5 October 2020 at https://www.comomatilda.com/copia-de-object.

Kac, E. (2021), 'Bio art', *AI & SOCIETY*, 36, pp. 1367–1376, accessed 26 August 2020 at http://link.springer.com/10.1007/s00146-020-00958-4.

Kappenberger, R., Aswartham S., Scaravaggi F., Blum C. G. F., Sturza M. I., Wolter A. U. B., Wurmehl S. andBüchner B. (2018), 'Solid state single crystal growth of three-dimensional faceted LaFeAsO crystals', *Journal of Crystal Growth*, 483, pp. 9–15.

Karana, E., Barati B., Rognoli V. and Zeeuw Van Der Laan A. (2015), 'Material Driven Design (MDD): A Method to Design for Material Experiences', *International Journal of Design*, 9 (2), pp. 35–54.

Karana, E., Blauwhoff D., Hultink E.-J. and Camere S. (2018), *When the Material Grows: A Case Study on Designing (with) Mycelium-Based Materials*, 12 (2), pp. 18.

Karana, E. and Camere S. (2017), *Growing Materials for Product Design*, Delft: Delft University of Technology, pp. 101–15.

Karana, E., Pedgley O. and Rognoli V. (2014), *Materials Experience: Fundamentals of Materials and Design*, Amsterdam: Butterworth-Heinemann.

Koivunen, H. (2005), *Bio Design Products: Co-Design with Nature*, Helsinki: University of Art and Design Helsinki, pp. 4.

Liu J. W., Oosato H., Liao M. Y., Koide Y. (2017), 'Enhancement-mode hydrogenated diamond metal-oxide-semiconductor field-effect transistors with Y2O3 oxide insulator grown by electron beam evaporator'. *Applied Physics Letters*, 110 (20), pp. 203502

Milisavljevic, I. and Wu Y. (2020), 'Current status of solid-state single crystal growth', *BMC Materials*, 2 (1), pp. 2.

Myers, W. (2012), *Bio Design: Nature, Science, Creativity*, London: Thames & Hudson.

NGK Insulators Ltd (1982), *Method for Producing a Single Crystal of Ferrite*, accessed 23 August 2021 at https://patents.justia.com/patent/4339301.

O'Donoghue, M. (2007), *Artificial Gemstones*, London: NAG Press.

Pearl, R. M. (2011), 'Popular Gemology', in *Artificial Gemstones: A Collection of Historical Articles on the Productio of Synthetic Gemstones*, Milton Keynes: Read Books Ltd.

Rognoli, V., Bianchini M., Maffei S. and Karana E. (2015), 'DIY materials', *Materials & Design*, 86, pp. 692–702.

Scheel, H. J. (2003), *Crystal Growth Technology*, West Sussex: John Wiley & Sons Ltd.

Sefat, A. S. (2008), *Flux Method for Preparing Crystals*, accessed 23 August 2021 at http://www.icmr.ucsb.edu/programs/documents/Sefat1.pdf.

Smith, N. (2010), 'Natalie Smith: Crystal World: 2010', accessed 14 April 2022 at http://natalielsmith.blogspot.com/p/crystal-world-2010.html.

Stone-Sundberg, J. (2013), *Sapphire Series Part 3: Modern Synthetic Sapphire Applications*, accessed 15 June 2020 at http://www.gia.eduhttps://www.gia.edu/gia-news-research-sapphire-series-modern-applications.

Tesla, N. (1900), ‘Problem of Increasing Human Energy. With Special Reference to the Harnessing of the Sun’s Energy.’, *The Century Magazine,* 60 (2), pp. 175–211, 1 May 2022 at https://teslauniverse.com/nikola-tesla/articles/problem-increasing-human-energy

Untracht, O. (1982)*, Jewelry Concepts and Technology*, London: Robert Hale.

Van Dijk, E. S. (2016)*, Bio Art, DIY Biology, and Academics*, Leiden: Leiden University, accessed 11 December 2020 at https://studenttheses.universiteitleiden.nl/handle/1887/37421.

Way, M. (2017), ‘“What I cannot create, I do not understand”’, *Journal of Cell Science*, 130 (18), pp. 2941–2.

Webster, R. (2011), ‘Practical Gemmology: A Study of the Identification of Gemstones, Pearls and Ornamental Minerals’, in *Artificial Gemstones: A Collection of Historical Articles on the Productio of Synthetic Gemstones*, Milton Keynes: Read Books Ltd.

Yin, R. K. (2018), *Case Study Research and Applications: Design and Methods*, Sixth edition, Los Angeles: Sage Publications.