

Microjewels: Digital Enchantment and New Materiality

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ABSTRACT

This article is an extended version of a paper presented at the xCoAx 2015 conference, and explores how smart materials, and in particular thermochromic silicone, can be integrated into a wearable object in combination with microelectronics to create aesthetically coherent stimulus-reactive jewellery. The different types and properties of thermochromics are discussed, including experiments with layering pigments that react at different temperatures within three dimensional silicone shapes. The concept of creating digital enchantment through playful interaction is introduced, illustrating how accessible microelectronics can be used to facilitate the creation of responsive jewellery objects. Bringing together digital methods of fabrication with craft methodologies to create objects that respond intimately to changes in the body of the wearer and the environment is presented as an outcome of this research project. Moving towards the notion of a posthuman body, potential practical applications for these jewellery objects exist in the areas of human-computer interaction, transplant technology, identity management and artificial body modification, where such symbiotic jewellery organisms could be used to develop visually engaging, multifunctional enhancements.

KEYWORDS

Smart Materials; CAD; Posthuman; Microelectronics; Jewellery; Thermochromic; Arduino.

1 | INTRODUCTION

The idea of creating a jewellery organism that comes alive on the body has fascinated and inspired my research ever since learning about the potential of smart materials to generate vitality in static objects almost twelve years ago (Saburi, 1998). While smart materials have been known to scientists for far longer (Huang et al., 2010), and have been used to great effect in engineering and aeronautic applications as actuators, their use in contemporary art and craft has been sporadic, most likely because of the challenges posed in processing and shaping them. With the increased prevalence of digital technologies in our everyday lives, the questions posed to the contemporary craft practitioner regarding the creation of a more refined interaction between the digitally enhanced object and its wearer have become progressively more prominent in the applied arts (Wallace, 2007). Through examining the notion that human biology is a part of material culture, where the body can be shaped, customised or altered through surgical intervention and scientific innovation, my research explores how recent developments in material science and wearable technologies can be viewed as moving towards a future embracing the posthuman body, bridging the gap between craft practitioner and scientific discovery (Hayles, 1999). Developing a holistic approach, whereby material experimentation and digital production processes are used to facilitate the development of aesthetically and biologically integrated wearable technologies, is the

goal my research moves towards. More immediately, however, I am challenging the perception of smart materials and their application within the field of contemporary jewellery in both an artistic and scientific context through proposing the development of symbiotic stimulus-reactive jewellery organisms.

Taking David Rose's concept of the enchanted object (Rose, 2014) and playful interactions as a starting point, my research addresses aesthetic considerations alongside functionality, thus developing material and technological solutions that constitute an integrated and functional yet unified part of the jewellery object as a whole. While previous projects have placed a strong emphasis on simply creating receptacles to accommodate electronic components within a wearable object, the possibilities offered by digital manufacturing technologies such as rapid-prototyping and computer aided design (CAD) have expanded the aesthetic vocabulary available to the practitioner. Furthermore, the development and increasing availability of a range of stimulus-reactive smart materials, in addition to the progressive miniaturisation of electromechanical components, has turned the prospect of developing jewellery objects that appear to be responsive to their environment, yet depend closely on an interaction with the physiology of the wearer's body to stimulate these responses, from a distant imagining into a feasible goal.

2 | TOWARDS A NEW MATERIALITY

Since the first institutional materials library in the UK opened at the Royal College of Art in 1974 (Wilkes, 2011), the increasing desire by designers, visual artists and materials enthusiasts to explore a wide range of both commercially available and highly experimental materials in an open, collaborative environment has given rise to the exponential growth of materials libraries over the last decade. Within the UK alone, nine materials libraries currently operate, each with different foci and access parameters, ranging from those based at academic institutions to fee-paying commercial consultancy ventures. While some libraries select materials by focusing on a particular discipline, such as architecture, interior design or the construction industries, others specialise in rare, laboratory-grade materials. Most commercial materials libraries also have extensive searchable

online databases, whilst others exist only online and have no physical site to examine materials first hand.

However, while the agenda of sharing knowledge and creating connections between materials scientists, the materials industry, designers and artists is a worthwhile one that should be encouraged, particularly at a time when collaborations between the arts and sciences are essential for the development of new cross-disciplinary approaches, there are still significant barriers in place when it comes to creating such exchanges. Advocates of materials libraries such as Mark Miodownik of the Institute of Making in London praise their ability to encourage scientists to think about the senso-aesthetic properties of materials rather than their functionality by consulting artists, designers and crafts practitioners, whose main focus arguably lies in identifying how users connect with materials on a more intuitive level:

Characteristics such as smell and feel are almost impossible to capture in simple numbers, [Miodownik] noted, and many modern products show evidence of the fact that these properties were ignored during their design. The only way that people can gain an understanding of these other material properties, suggested Miodownik, was by experiencing the materials directly – touching them, manipulating and interacting with them in different ways. (Ward, 2008)

Miodownik's plea applies to materials scientists and arts practitioners alike – with one group needing to explore ways of designing materials that contain optimum functionality while also taking into account senso-aesthetic properties, and the other engaging with how such materials could be used sensitively in designing an object with maximum functionality whose tactile and aesthetic qualities capture the imagination of the end user.

However, the constraints currently faced by materials libraries in achieving such a goal are still significant. While the idea of the materials library as a collection of unusual materials to be made available to arts practitioners, researchers, and scientists alike may have been around for thirty-nine years, the serious progression of a strategic agenda in terms of building such collections and making them available to a larger audience, is a fairly recent development and has only

really gained momentum since the beginning of the 21st century. Even those materials libraries that have been established over the last decade, both in academic institutions and as commercial ventures, are limited in the scope of their expertise. As Miodownik points out:

[...] they serve very specific design communities, their materials collections are extremely limited, they only deal with commercial materials, but most importantly, they are almost completely dissociated from the materials-science community. (Miodownik, 2009)

Additionally, the ties between industrial suppliers of materials and materials libraries are tentative at best, with many suppliers reluctant to provide experimental materials in quantities small or large enough to be useful to arts practitioners in their research and development, or indeed at all. In her conversations with materials librarians, Sarah Wilkes extrapolates that:

[...] in the eyes of many involved in materials education, concerns over corporate secrecy and ownership on the part of materials producers are a hindrance to both creativity and technological progress. (Wilkes, 2011)

The questions of intellectual property and pending patent applications loom large during such exchanges between supplier and practitioner, and frequently a satisfactory conclusion cannot be reached. While some of the most interesting materials represented in materials libraries are often in a pre-commercial stage of development, suppliers are worried about providing such materials to researchers before potential revenue-generating avenues have been exploited. This quickly turns into a catch twenty-two situation, with many materials never reaching financial viability at all due to their lack of practical applications and thus commercial demand. Often such demand might have been created if designers and arts practitioners had been encouraged to experiment with these materials and thus potentially discovered novel and previously unanticipated ways of using them. To recognise the potential of such mutually beneficial relationships, a liaison between industrial suppliers and creative practitioners, experienced in dealing with the

concerns of either party would be necessary – something a lot of materials libraries are struggling to provide as of yet.

3 | EXPLORING THE FUTURE – SMART MATERIALS

I initially became aware of a group of smart materials known as Thermochromics through a presentation given by Dr. Sara Robertson at the CIMTEC 2012 conference in Montecatini Terme, Italy, exploring the potential of temperature-sensitive thermo-chromic dyes and heat-profiling circuits in textile design (Robertson, 2011). Intrigued by their ability as a smart material to respond directly to a change in body temperature through colour change, I began to explore their potential in combination with the three dimensional silicone shapes I had been developing. Thermochromics are commonly available as either dye slurry or in powdered pigment form, and fall into the two main categories of leuco or liquid crystal thermo-chromics. Either variety is available in a range of colours and with different temperature change points, displaying a visible colour change with an increase or decrease in exposure temperature. Leuco dyes change from pigmented to colourless when a heat or cold source is applied, depending on their change temperature, and assume pigmentation again as soon as the source of temperature change is removed. Analogue Liquid Crystal dyes cycle through a set of colours that correspond to the temperature they are exposed to, with the most recognisable form being the ‘peacock’ colour pallet ranging from red through yellow, green and deepening shades of blue. After a certain peak temperature is reached towards the dark blue spectrum, usually about 20 degrees above activation temperature, visibility of the pigment ceases and only returns in the cooling phase when it cycles through the previous colour shifts in reverse until it once more falls below its activation temperature. Digital Liquid Crystal technology, in which the pigment appears to be either in an ‘on’ or an ‘off’ state according to the temperature it is exposed to, has also recently become available. The colour change reactions of thermo-chromic dye systems are available as reversible and irreversible types. However, as one of the defining conditions of smart materials is full reversibility, only the former type can be categorised as such and is of interest to me in this respect.

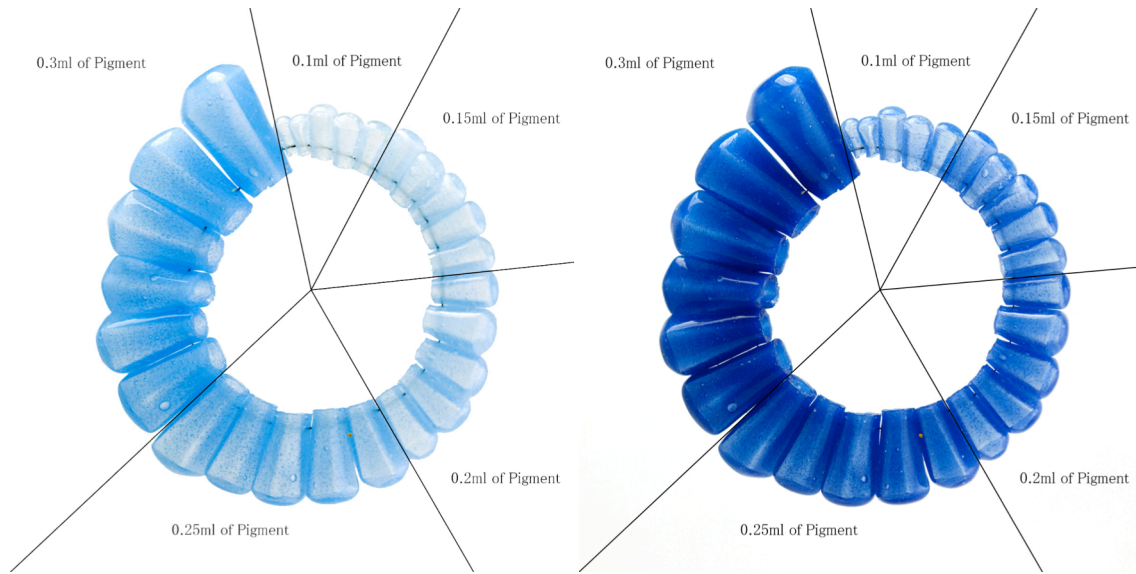


Figure 1 | Example of a Single Pigment Test: Blue 27°C in its unchanged and changed state.

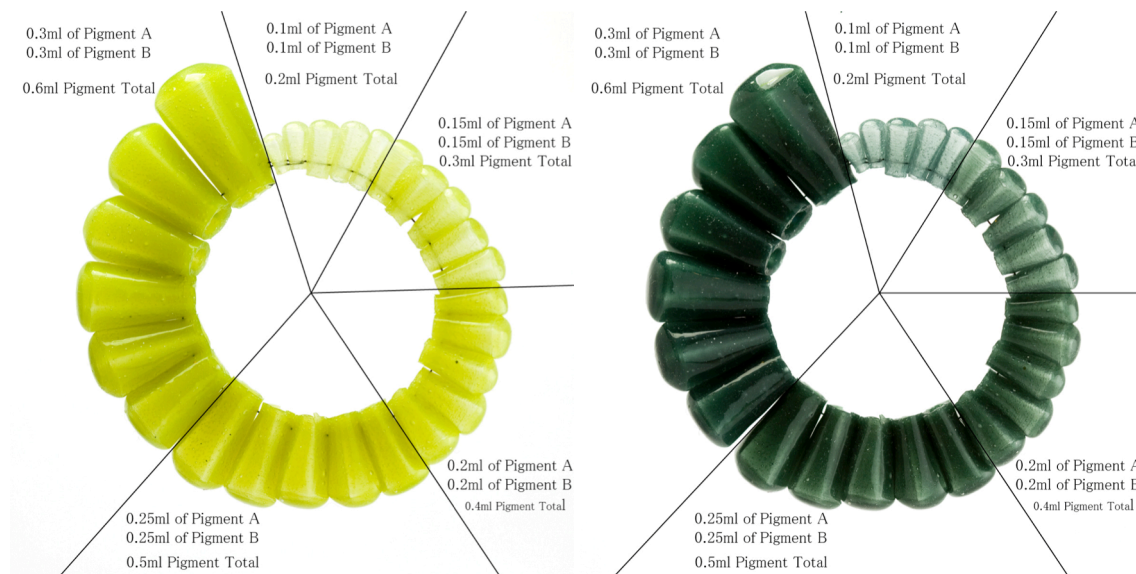


Figure 2 | Example of a Dual Pigment Test: Blue 27°C and Yellow 38°C in its unchanged and changed state.

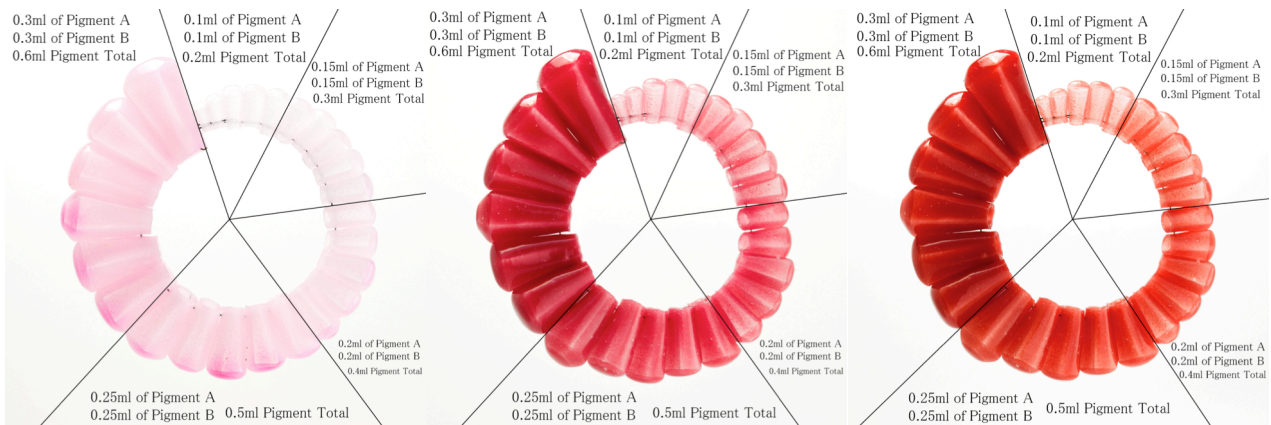


Figure 3 | Example of the progressive stages of change in a dual pigment sample of Magenta 41°C and Yellow 38°C.

There are a variety of practical and industrial applications for thermochromic pigments, dyes and paints. One of the most well known is the inclusion of liquid crystal technology in forehead thermometers, where each degree of measured body temperature is assigned a corresponding colour. Similarly, Leuco dyes are widely used in fuel assemblies, to test combustion engines and as friction markers in engineering, effecting an irreversible colour change when heated and thus signalling a state change of the monitored component (Robertson, 2011). My research currently focuses on exploring the potential of layering Leuco and liquid crystal pigments in silicone to explore the interplay of colours created by different colour and temperature combinations. I have adopted a rigorous testing protocol for these experiments, starting with four liquid leuco pigments in different colours and each with a different change temperature (Blue 27°C, Yellow 38°C, Magenta 41°C, and Red 47°C), and a corresponding set of four powdered leuco pigments with very low change temperature thresholds (Red 19°C, Orange 19°C, Turquoise 22°C, and Vermillion 22°C). Each batch of samples is made using the same process, requiring 15g of mixed silicone for a full set of 25 with one extra shape as a spare. An initial set of shapes of each single colour was prepared, starting with 0.1 ml of liquid pigment and adding 0.05 ml of liquid pigment per every five shapes (Figure 1) or 0.1g and 0.05g of powdered pigment respectively. To dispense accurate amounts of pigment, I used a syringe to measure the liquid type, and a custom designed 3D-printed set of measuring spoons for the powdered type.

Next, two pigments were combined in a single mix, starting with 0.1ml/g of each colour (a total of 0.2 ml/g) and adding 0.05 ml/g of each colour (a total of 0.1 ml/g) per every five shapes. The resulting colours were then evaluated for hue, transparency and strength of pigmentation in both their changed and unchanged states. In their unchanged state, pigmentation strength is greatest in the final segment of each colour, with saturation levels nearing opacity, and weakest in the first segment, creating a translucent finish. Translucence yields to opacity at around 0.3 ml/g of added pigment. This result was predicted and corresponds to expectations formed from my past research in combining artists' pigment with silicone. The resulting colours of the combination

samples follow the general rules for colour mixing as demonstrated on a colour wheel, and the resulting hues range from slightly disappointing to very pleasing although this is arguably a matter of taste and artistic intent. With the application of heat, the samples using pigments with increasing change temperatures go through a variety of colour changes. In their first changed state, the lower temperature colour fades and reveals the underlying higher temperature pigment. The samples appear as a lighter version of their unchanged colour at this stage, with some combinations such as blue and yellow displaying a very distinctive change, while others such as magenta and yellow display a subtler outcome (Figure 2). If heated again the second pigment fades and reveals a milky base colour with the dominant pigment in evidence as a pastel shade (Figure 3).

For the samples using the powdered pigments with lower change temperature thresholds, the process differs in that at an average room temperature of 22°C, the shapes have begun to enter their changed state and only display a very light version of the original pigment. If heated further, the colour fades to a milky base shade as with the higher threshold pigments, while cooling the shapes reveals the full strength of pigmentation achieved by different quantities (Figure 4). Working with leuco pigments with such low threshold temperatures presents its own challenges, as often touching the mixing vessel is enough to achieve transition temperatures, making it hard to gauge the colour of the end product. To achieve reliable colour values, it is therefore imperative to use a repeatable and accurate process for pigment measurement and dispensation, as well as documenting the various colour outcomes of different temperature combinations and heating stages as a future reference. The powdered pigments also contained some larger particles of pigment that did not fully dissolve when mixed with the silicone, which in turn resulted in areas with a visibly speckled appearance. This effect appeared to occur more in some colours than others (Figure 5), but it was present in all powdered pigments I tested to some degree, depending on how finely milled the original material was. As a remedial measure, I tested grinding of the pigment with a pestle and mortar, as well as sifting it using small enamelling sieves with meshes in a range of densities. Grinding the pigment proved to

be successful in eradicating the speckled appearance, but also diminished its thermochromic characteristics, while sifting the pigment first through an 80 mesh

sieve and finally a 120 mesh was effective in removing larger particles and therefore the speckles (Figure 6), but also proved to be a very time-consuming process.



Figure 4 | An example of a reverse colour change with low-temperature powdered leuco pigments. Both pigments (Turquoise 22°C and Orange 19°C) appear as pastel colours at room temperature (far right sample). Full colour saturation (left sample) occurs at around 5°C.



Figure 5 | Large Pigment speckles are clearly visible in the silicone shapes made with unsifted powdered Leuco pigment.



Figure 6 | After sifting the pigment prior to use through a 120 mesh sieve, the speckles have disappeared, leaving only the pure pigment behind.

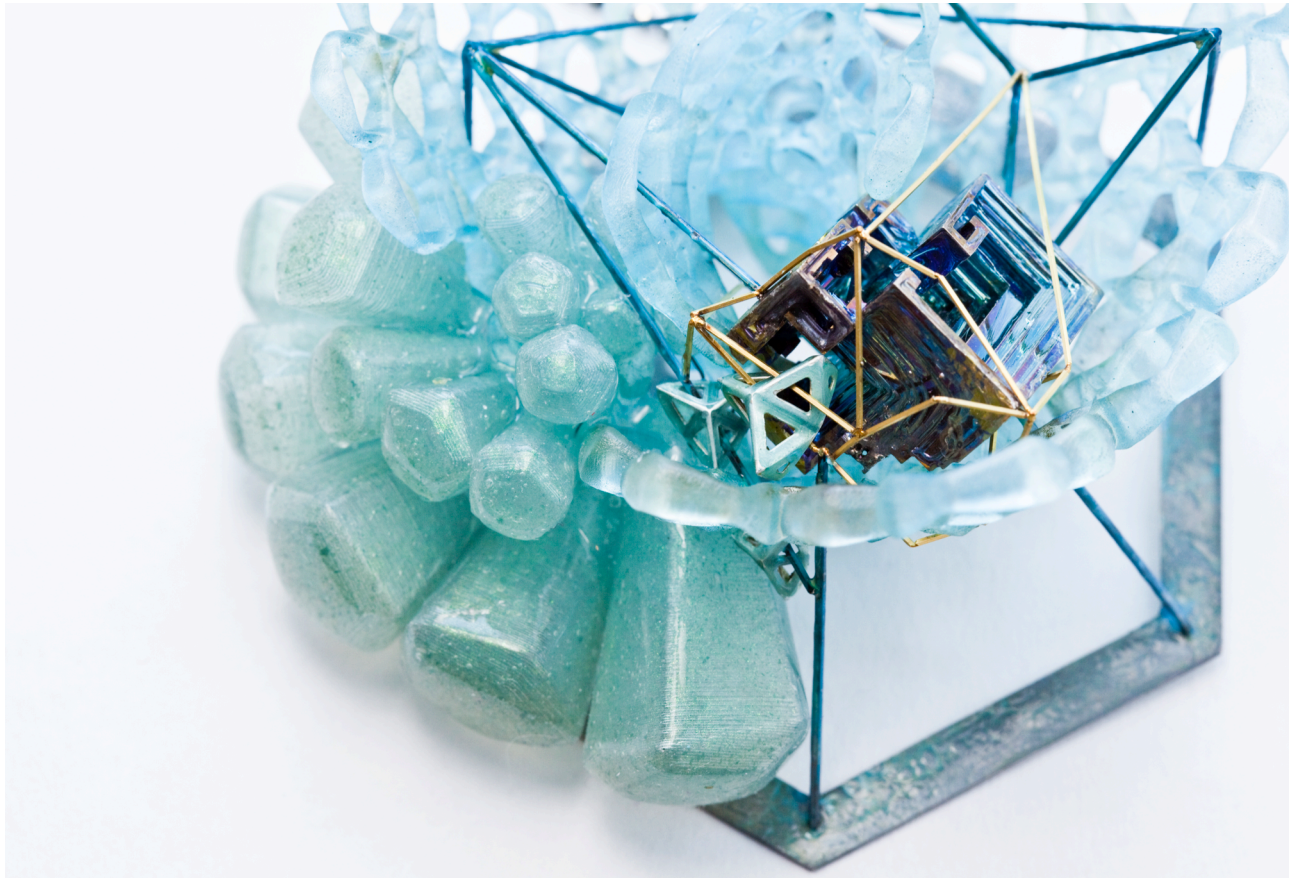


Figure 7 | *Ice Crystal* Necklace in its unchanged state, Katharina Vones (2014).

Using different types of pigments in a range of temperature thresholds and colours opens up a host of possible combinations such as subtle colour-on-colour transitions when a piece is touched, or more dramatic ones when the wearer moves from one temperature zone into another. Adding other smart pigments such as liquid crystals or photochromics to achieve multiple transitions that react to different stimuli or modifying the colour response by introducing a permanent base shade consisting of artist or special effects pigments to the mixture further expands the list of possibilities. I am currently conducting tests to investigate the aesthetic vocabulary inherent in these suggestions, and two pieces which explore this idea are the *Ice Crystal* Necklace (Figure 7) and the *Xylaria* Brooch (Figures 8 and 9). Both feature thermochromic silicone shapes which react to environmental temperature changes but also contain a stable base pigment which becomes visible once the thermochromic pigment fades. Thus the *Xylaria* Brooch changes from raspberry pink to bright orange, whereas the *Blue Crystal* Necklace contains shapes that appear pale turquoise and then deepen in colour when the piece is cooled. The latter also has an oxidised sterling silver

framework that has been treated with liquid crystal technology and changes through a peacock spectrum of hues of green and blue when the piece is placed on the body.

4 | DIGITAL ENCHANTMENT

While the exploration and use of smart materials constitutes one area of my research, another equally important aspect is the creation of an elusive characteristic defined by the term digital enchantment (Rose, 2014). Within the context of wearable futures, this could best be described as the sensation of wonder and surprise created by an unexpected, captivating and apparently spontaneous reaction between the object, its user, discreetly embedded technology and its environment. It stands in direct opposition to recent developments to commercialise the wearable futures market by focusing on miniaturising and adapting already existing technologies to be worn on the body. Examples of this include a number of smart watches such as the Samsung Gear and the Apple Watch, as well as the much talked-about Google Glass.



Figure 8 | *Xylaria* Brooch in its unchanged state on custom made stand, Katharina Vones (2013).



Figure 9 | *Xylaria* Brooch in its changed state (detail), Katharina Vones (2013)

However, these devices have so far failed to capture the imagination of users, with the Samsung Gear reportedly suffering from poor sales (Amadeo, 2013) and Google Glass having recently been removed from the consumer market altogether in order to be developed solely for institutional and business use (Hedgecock, 2015). Whilst sporting a multitude of arguably useful functions such as cameras and internet access, these wearable devices are very much rooted in the semiotics of traditional gadget culture, introduced through popular culture icons such as James Bond and Dick Tracy as early as the 1930s (Johnson, 2011). Instead of discovering new ways to engage the wearer through playful interaction, this recent incarnation of wearable devices has maintained an aesthetic and modes of usage firmly rooted within established parameters by simply imbuing familiar types of body adornment with novel technological content. A different approach to digital jewellery is suggested by practitioner Jayne Wallace. Focused on creating objects which hold personal emotional significance, Wallace convincingly criticises the way in which gadget culture with its neverending cycles of planned obsolescence has failed to incorporate a deeper meaning into wearable objects than that of perpetual ‘newness’ (Wallace, 2004). As a response, Wallace’s jewellery objects employ contemporary craft methodologies to connect the wearer to their inner and outer environments through a series of interactions that are often influenced by chance events and environmental conditions (Wallace, 2007).

My research incorporates these perspectives and addresses these issues by exploring the ways in which an object worn on the body is imbued with digital enchantment through encouraging playful interaction with changes in the environment and biological impulses of the wearer.

4.1 ARDUINO – ACCESSIBLE ELECTRONICS

The Arduino system of microelectronic components offers an accessible starting point for those less experienced at assembling electronic components and programming (Margolis, 2011). As the boundaries between digital art, craft and technology proceed to become more blurred, the need for craft practitioners to become fully versed in the vernacular of the digital becomes more pressing. Embedding electronics within wearable objects poses its own set of challenges, in particular that of miniaturisation and power supply. While the latter is at the present time dependent upon technological developments that would exceed the scope of my research project, the former is an issue that successive generations of ever smaller components, such as the recent Adafruit Gemma, Flora and Trinket microcontrollers, have begun to address (Fried, 2015). In order to imbue the wearable objects I am creating with a sense of being ‘alive’ I initially started experimenting with a variety of LED components that respond in some way to their environment. The first such circuit I created is a light sensitive colour organ (Figure 10). Using an Arduino

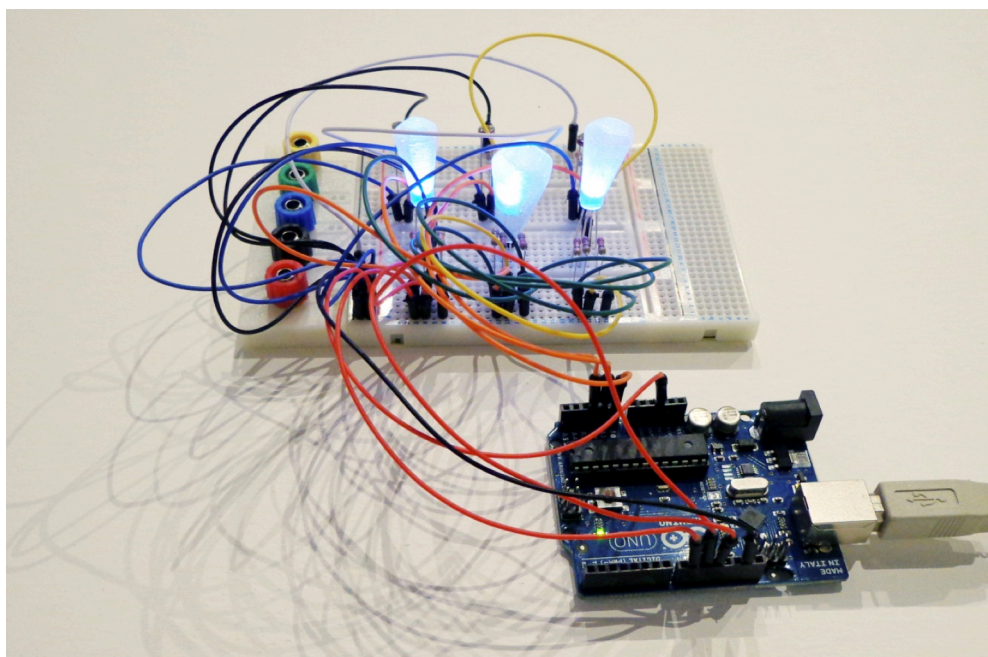


Figure 10 | Arduino Uno RGB LED Colour Organ, Katharina Vones (2012).

Uno microcontroller board, three RGB LEDs and three miniature photocells, the light sensitive colour organ responds to changes in light levels to each of its three photocells by sending a corresponding colour value to the RGB LEDs and changing the colour accordingly. By sensing different light levels and expressing them through changing colours, the jewellery object reacts to environmental circumstances as a photosynthetic organism might. After testing on a breadboard, the circuit is then recreated with an Arduino Pro Mini microcontroller board to miniaturise the assembly for integration into a wearable jewellery object. As a development of the idea of creating an interactive synergy between wearer and object through the use of light, the *Geotronic* Brooch (Figures 11 and 12) incorporates a programmable RGB LED that simulates the rhythm of a beating heart through its pulsations. Further advances towards creating synergetic jewellery objects are evident in the *Hyperhive* series of stimulus-reactive pendants (Figures. 13 and 14). Sensors that measure the heart rate, proximity and touch of the wearer are integrated into 3D printed pendants and react to intimate contact by changing colour, lighting up or generating movement in combination with thermochromic silicone, this could generate a very dynamic and playful interaction between the object, its wearer and the environment.

4.2 THERMOCHROMIC SILICONE AND THE WEARABLE OBJECT

To fully exploit the colour responsiveness of thermochromic silicone without having to rely on a spontaneous reaction to changes in environmental temperature, it is necessary to incorporate a heat generating circuit into the wearable jewellery object which in turn is activated by a sensor/microcontroller assembly. While the use of heat sinks cut from thin copper foil or woven from conductive thread has been well established in the works of digital textiles artists Maggie Orth (Orth, 2015), Sara Robertson (Robertson, 2011) and Lynsey Calder (Calder, 2015), these approaches are less suitable for use within thermochromic silicone, primarily because of its low shore hardness and inherent high flexibility, making the integration of such circuits at the manufacturing stage precarious. An additional complication arises from incorporating effectively uninsulated conductive materials into a jewellery object made from precious

metals such as silver or gold, that are highly conductive in themselves and could cause short circuits if accidental contact between the heating element and components of the object was established. As a viable alternative, a ceramic Peltier element can be used. Based on the principle of the Peltier Effect of heat displacement through electric current, Peltier elements rapidly heat on one side while equally rapidly cooling on the reverse. This makes them very suitable for use in wearable technologies, where a current driven, predictable and directional heat source is often desirable, particularly where the element might come into contact with the wearer. While copper heat sinks can radiate heat on both sides of the circuit and thus need to be fully embedded to protect the wearer, the cool side of the Peltier element remains safe to handle, while generating enough heat to trigger the thermochromic reaction on the reverse. Temperature can be controlled by current supplied to the element, making it possible to effect subtle colour changes in the silicone shapes. One slight disadvantage is the relatively slow cooldown cycle of the Peltier element once current is removed, making rapid successive colour changes impossible.

5 | CONCLUSION – TOWARDS A POSTHUMAN FUTURE

Jewellery and the concept of adorning the body have a rich and well-documented history of being imbued with meaning that stretches beyond notions of wealth, value, social status, aesthetics and consumerist desire into the realms of emotional and conceptual significance (Skinner, 2013). Digital jewellery practitioners such as Sarah Kettley (Kettley, 2007) and Jayne Wallace (Wallace, 2007), through their body of work, have explored ways in which technological developments can be used in a jewellery context to forge and enhance emotional connections through stimulating a meaningful interaction between the jewellery object and its wearer. Other practitioners such as Norman Cherry (Cherry, 2006) have gone further by suggesting that eventually the boundaries between ornament and body will become indistinguishably blurred through extreme modifications and implantable jewellery, a development that radical jeweller Peter Skubic had already foreshadowed in 1975 with his performance *Jewellery Under the Skin* (den Besten, 2013).



Figure 11 | *Geotronic Brooch*, Katharina Vones (2013).

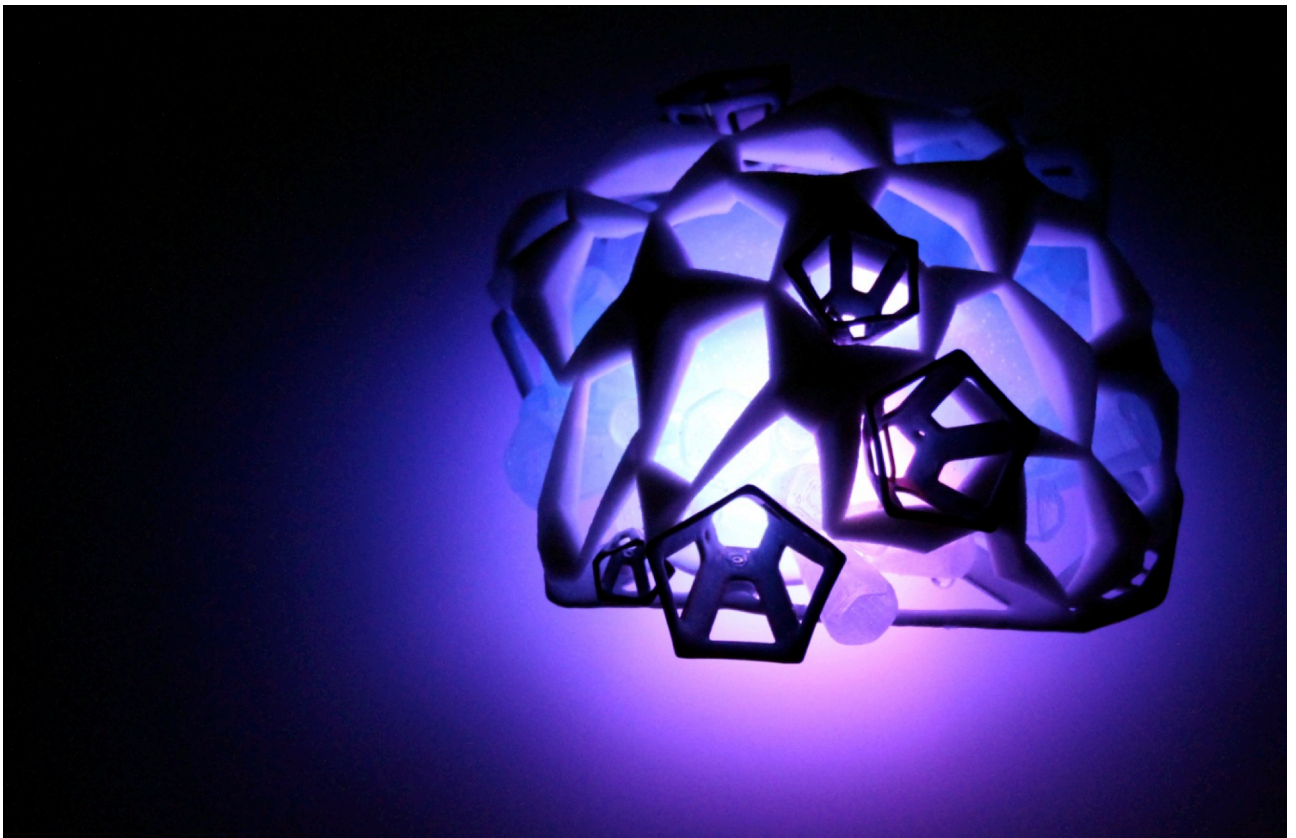


Figure 12 | *Geotronic Brooch* in its active state, Katharina Vones (2013).



Figure 13 | *Hyperhive: Hypertilt Pendant (3 of 5)*, Katharina Vones (2015).



Figure 14 | *Hyperhive: Hypertilt Pendant in active state (3 of 5)*, Katharina Vones (2015).

The development of the 'Carnal Art' manifesto by French artist Orlan as part of her project *The Reincarnation of Saint-Orlan* from 1990 onwards, in which the artist's body serves as the site of repeated surgical interventions and modifications, can be seen as a logical trajectory of this line of enquiry, albeit sited within the discourse of feminist performance art (Hirschhorn, 1996). Against this backdrop of ongoing exploration, the development and expansion of the concept of the Posthuman body to question the role technology and body modification could play in shaping the physical realities of the future, both on a functional and aesthetic level, has gained increasing momentum (Hayles, 1999).

Having developed a range of stimulus-responsive jewellery objects using smart materials and microelectronics, the question remains how these wearable futures could be integrated even more comprehensively into the body of the wearer. At present still recognisably autonomous objects, current advances in transplant technology and the ability to use human cells as a material in 3D printing offer tantalising glimpses of a future where the body could become host to near-organic, possibly artificially intelligent jewellery organisms. Moving towards a future in which technology could become permanently integrated into the complex systems of the Posthuman body I am intrigued by the possibilities and challenges facing the contemporary jeweller in advancing the debate surrounding the Posthuman and interactive adornment.

Potential practical applications for this line of investigation exist in the areas of human-computer interaction, transplant technology, medically assistive objects, identity management and artificial body modification including prosthetics, where such symbiotic jewellery organisms could be used to develop visually engaging yet multifunctional enhancements of the body. The intersection between technological refinement, the exploration of smart materials and new manufacturing technologies as well as the development of an aesthetic expression that supersedes ideas of mere gadgetry is a challenge in this area of research and one which I am in the process of addressing with my contribution to the field.

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BIOGRAPHICAL INFORMATION

Originally from Cologne, Germany, Katharina Vones is a practising jewellery artist and digital craft researcher at the University of Dundee, currently in the final stages of completing an AHRC funded PhD investigating the use of smart materials and microelectronics in the creation of stimulus-responsive jewellery. Katharina has exhibited her work widely, both nationally and internationally, and actively blogs about her research and material explorations as a way to encourage craft practitioners to learn about and get involved in digital technologies: www.smart-jewellery.com and www.kvones.com