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Digital Symbiosis: The Aesthetics and Creation of Stimulus-Reactive Jewellery with Smart Materials and Microelectronics

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This article 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.

1 Introduction

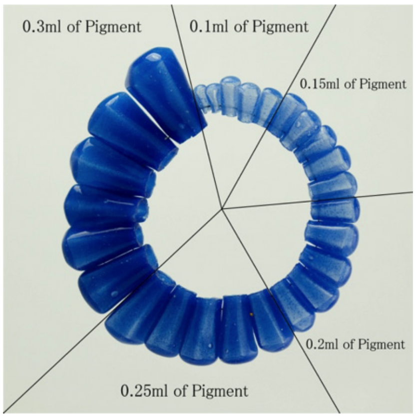
The idea of creating a jewellery organism that comes alive on the body has fascinated and inspired my research ever since learning about the potential of smart materials to generate vitality in static objects almost twelve years ago (Saburi 1998). While smart materials have been known to scientists for far longer, 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.

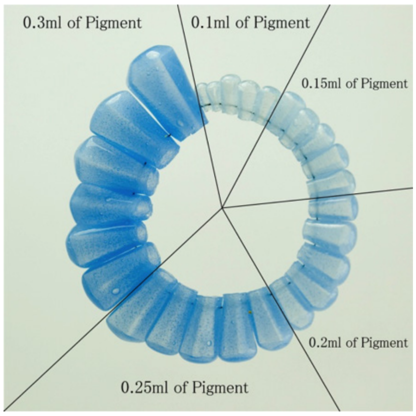
Taking David Rose's concept of the enchanted object (Rose 2014) and playful interactions as a starting point, my research addresses aesthetic considerations alongside functionality, thus developing material and technological solutions that constitute an integrated and functional yet unified part of the 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 Exploring the Future – Smart Materials

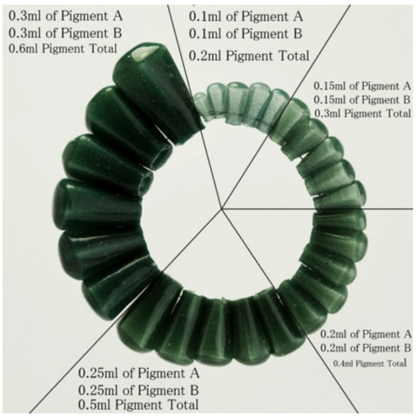
I initially became aware of a group of smart materials known as Thermochromics through a presentation given by Dr. Sara Robertson at the CIMTEC 2012 conference in Montecatini Terme, Italy, exploring the potential of temperature-sensitive thermochromic dyes and heat-profiling circuits in textile design (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 thermochromics. 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 thermochromic dye systems are available as reversible and irreversible types. However, as one of the definitive 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.

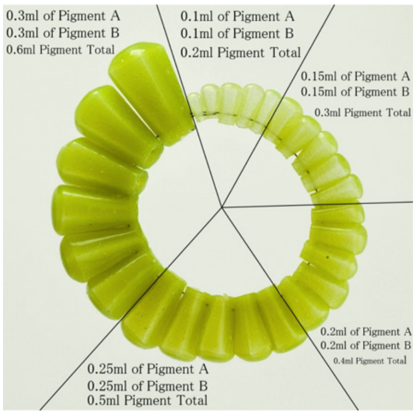
There are a variety of practical and industrial applications for thermochromic pigments, dyes and paints. One of the most well known is the inclusion of liquid crystal technology in forehead thermometers, where each degree of measured body temperature is assigned a corresponding colour. Similarly, Leuco dyes are widely used in fuel assemblies, to test combustion engines and as



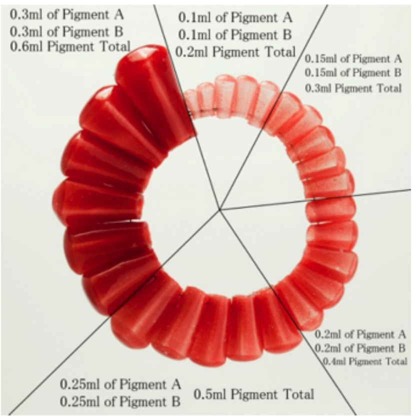


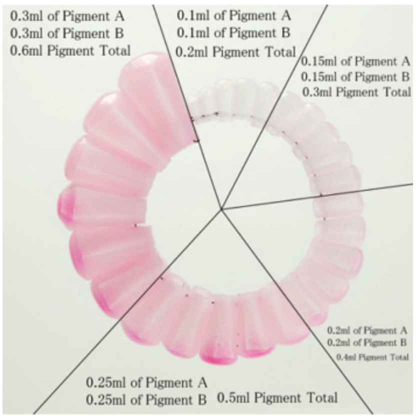
Figs. 1 & **2** Example of a Single Pigment Test: Blue 27˚C in its unchanged and changed state

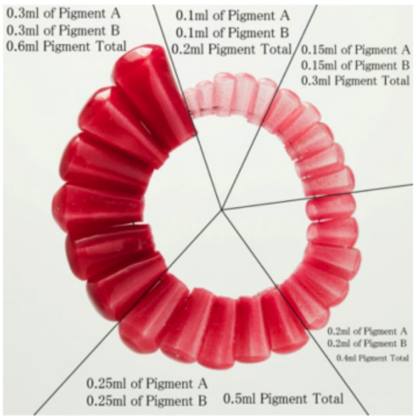




Figs. 3 & **4** Example of a Dual Pigment Test: Blue 27˚C and Yellow 38˚C in its unchanged and changed state







Figs. 5, 6 & **7** Example of the progressive stages of change in a dual pigment sample of Magenta 41˚C and Yellow 38˚C

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 base pigments in different colours and each with a different change temperature (Blue 27˚C, Yellow 38˚C, Magenta 41˚C, and Red 47˚C). Each batch of samples is made using the same process, requiring 16.5g 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 pigment and adding 0.05 ml of pigment per every five shapes (Figs. 1. & 2.).

Next, two pigments were combined in a single mix, starting with 0.1ml of each colour (a total of 0.2 ml) and adding 0.05 ml of each colour (a total of 0.1 ml) 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 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 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, others such as magenta and yellow displaying a more subtle outcome (Figs. 3. & 4.). If heated again the second pigment fades and reveals a milky base colour with the dominant pigment in evidence as a pastel shade (Figs. 5-7.). It is possible to further modify the colour response by introducing a permanent base shade consisting of artist or special effects pigments to the mixture, and I am currently conducting tests to exploit the aesthetic possibilities inherent in this suggestion. Two pieces in which this idea is explored are the *Xylaria* Brooch (Fig. 8.) and the *Cocoon* Necklace

Fig. 8 *Xylaria* Brooch in its changed state, Katharina Vones (2013)

Fig. 9 *Cocoon* Necklace in its changed state, Katharina Vones (2013)

(Fig. 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 *Cocoon* Necklace contains shapes that appear violet and then fade to light blue. The latter also has black 3D-printed components that have been treated with liquid crystal technology and change through a peacock spectrum of hues of green and blue from about 27˚C.

3 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*. 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. My research addresses these issues through 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.

3.1 Arduino – Accessible Electronics

The *Arduino* system of microelectronical 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 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 2014). 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.

Fig. 10 *Arduino Uno* RGB LED Colour Organ, Katharina Vones (2012)

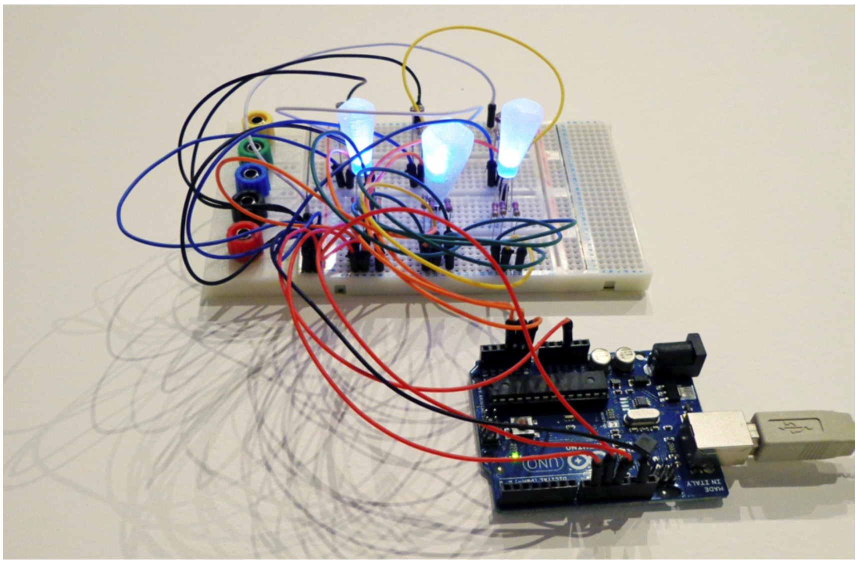


Fig. 11 *Geotronic* Brooch, Katharina Vones (2013)

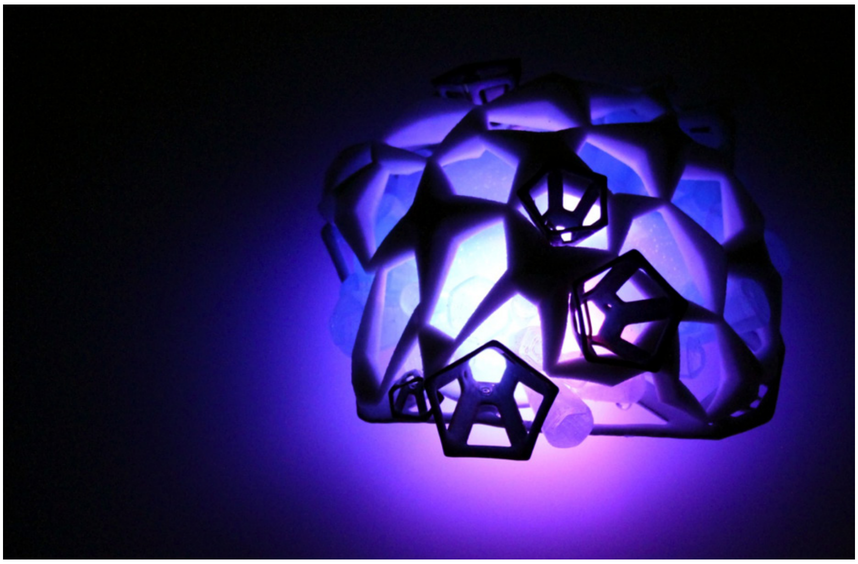


Fig. 12 Hyperhive Pendant (2 of 3), Katharina Vones (2014)

The first such circuit I created is a light sensitive colour organ (Fig.10.). Using an *Arduino 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 (Fig.11.) 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 (Fig.12.). 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.

3.2 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 2007), Sara Robertson (Robertson 2011) and Lynsey Calder (Calder 2014), 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 cycle of the Peltier element once current is removed, making rapid successive colour changes impossible.

4 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). 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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