Crafted Evolution - The creation of the *HyperHive* Series

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Abstract: The following paper describes the conception and creation of the *HyperHive* Series of interactive pendants. This practice-led research analyses how the recent emergence of terms such as 'craft technologist' and 'alchemical craft' suggests a paradigm shift in the field of contemporary jewellery, describing practices and practitioners using craft methodologies to work with novel materials and processes. A return to the idea of interdisciplinary knowledge exchange between the arts and sciences, has reintroduced the essence of alchemical practice to contemporary crafts practitioners. The processes of serendipitous discovery and material experimentation lie at the heart of this practice, and smart materials with their metamorphic qualities have yielded fertile ground for exploration. This body of research focuses on probing these materials' potential to create jewellery that comes alive on the body and responds to external stimuli by initiating a change in state, creating enchantment through playful interaction. Combining chromic smart materials with tactile silicone provides multifaceted colour transitions that react to the body and the environment in equal measures. Microelectronic elements imbue the jewellery with life, manifested through pulsating, breathing lights, and sensors that intimately connect object and wearer by measuring touch, light and movement.

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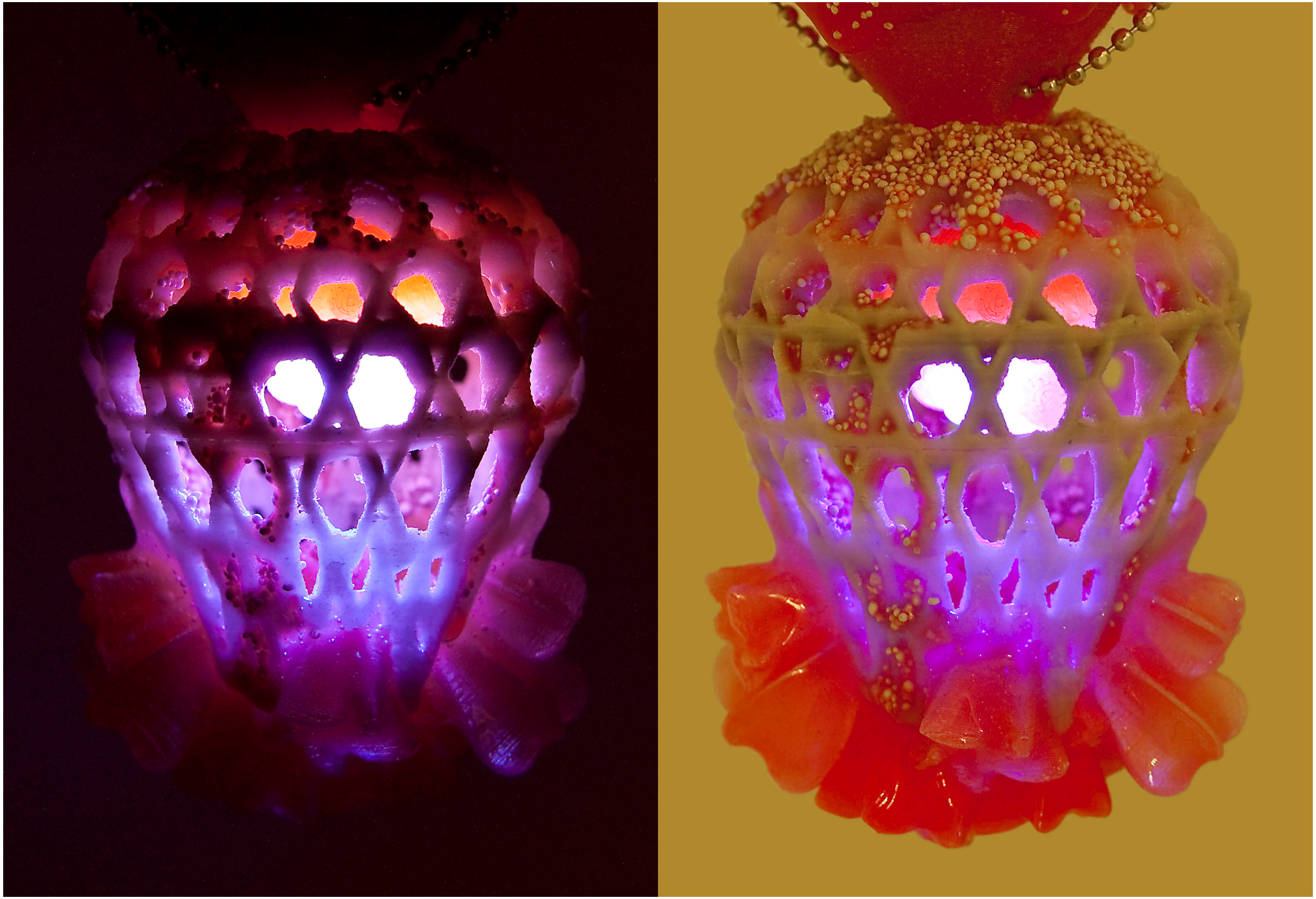


Vones | *HyperHive* Series: *HyperLight* - transitions

Introduction

The *HyperHive* series of pendants forms part of an exploration that began during my four years of doctoral research at the University of Dundee, into how a wearable jewellery object could harmoniously integrate miniaturised electronic components in conjunction with stimulus-reactive smart materials to create enchantment through playful interactions. Currently, the series consists of six pendants divided into four types, including one that reacts solely to environmental temperature, and three that use integrated microelectronic elements to trigger sensor-driven responses. Each of the latter pendants contains a different sensing mechanism, as well as a different combination of smart materials, thus exploring the potential of each arrangement. Sensors that measure the movement, proximity and touch of the wearer are integrated into 3D-printed structural elements and react to intimate contact by changing colour, and lighting up in combination with the colour change effected by chromic silicone. This generates a very dynamic and playful interaction between the object, its wearer and the environment, and testing these different interactions in a standardised format allows for direct comparison of processes and materials as well as ensuring repeatability. The following paper will lay out in detail how the *HyperHive* series was conceived, focusing on different aspects of their creation with a particular emphasis on the dichotomy that exists between employing a methodology of serendipitous material discovery and playful making with the more rigid procedures required in working with microelectronics and CAD. Finally, suggestions for future developments of the techniques and processes employed in the *HyperHive* series will be made, with particular reference to how they might be relevant to and ultimately enrich the fields of digital jewellery and human computer interaction.

Playful Interactions

Microelectronics and the Creative Making Process

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. The *Arduino* system of microelectronic components offers an accessible starting point for those less experienced at assembling electronic components and programming (Margolis, 2011). 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 this body of research, 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). Taking as a starting point the concept of engaging in the creative making process through play proposed throughout my body of research, it is hard to see how such a methodology can be applied to the linear, binary medium of microelectronics. In his seminal book on digital craft, McCullough states that:

> *"Play serves learning through experimentation without risk. Play often lacks any immediate obvious aim, other than the pursuit of stimulation, but functions almost instinctively to serve the process of development." (McCullough: 133, 1996)*

However, unless the craft practitioner who wants to engage with the practicalities of digital jewellery is already well-versed in electronic circuit design and programming, the process of developing microelectronic components can be a significant obstacle to employing this methodology. Beginner's kits and modular learning systems that emphasise playful experimentation, such as the *Crumble Controller* and the *Arduino* compatible *Grove System*, are useful aids for artists to get a first taste of prototyping circuits and designing interactions. But when it comes to creating wearable futures and digital jewellery, such systems lack the flexibility of scale and customisation necessary to develop a functionally and aesthetically coherent relationship with the jewellery object.

I initially started experimenting with a variety of LED components that respond in some way to their environment. The first such circuit I created was a light sensitive colour organ (Fig. 1). Using an *Arduino Uno*

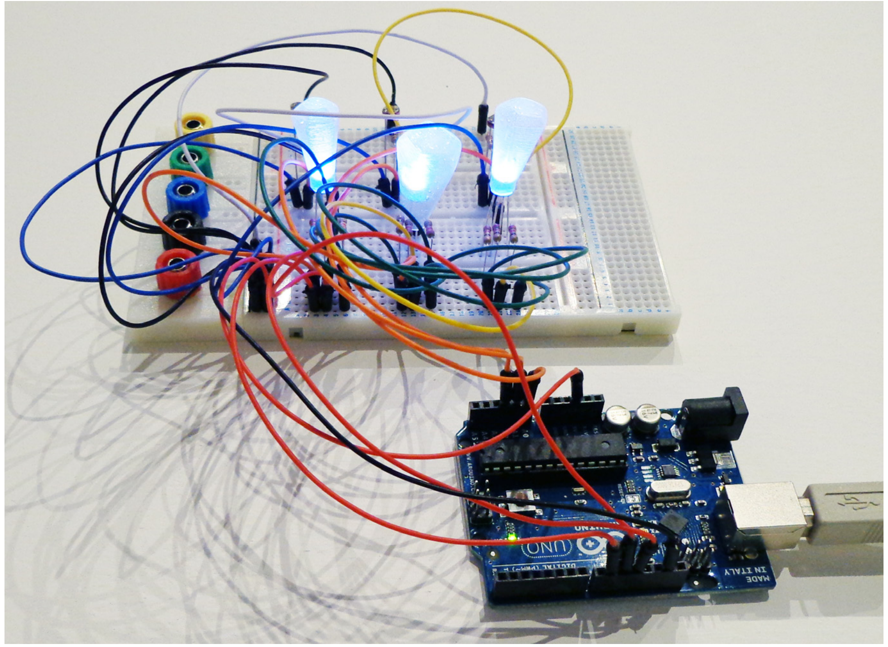
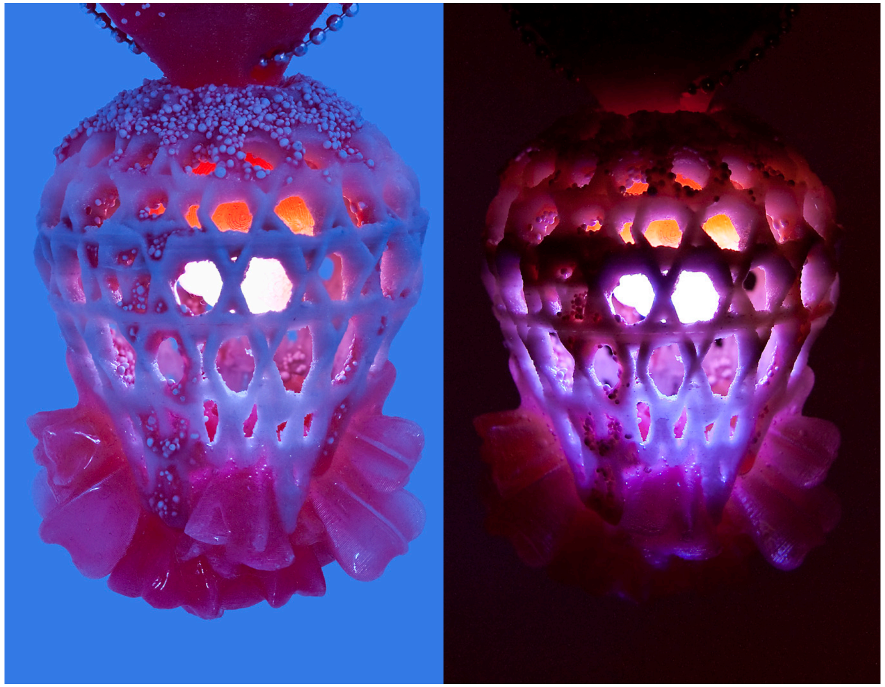


Figure 1. *Arduino Colour Organ*, Prototype stage (2013). Photo: Katharina Vones.

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 living organism might during the process of photosynthesis. The photocell also inadvertently acts as a proximity sensor, and thus a colour response can be triggered when a hand is passed over the sensor array. After initial prototyping on a breadboard, the circuit was then recreated on a custom made PCB with an *AVR ATTINY85* microcontroller and one light sensor to miniaturise the

Figures 2-3. *HyperHive* series: *HyperLight* Pendant (2016). Photos: Katharina Vones.



Figures 4-5. These images show how the RGB LED inside the *HyperLight* Pendant changes colour if exposed to different light levels. Photos: Katharina Vones.

assembly for integration into a wearable jewellery object, in this case the *HyperLight* pendant (Figs. 2 - 5).

The *AVR ATTINY85* microcontroller is suited to simple circuit designs, with only 8K of flash program memory, 512 bytes of RAM and fewer output pins than other full development boards in the *Arduino* series. However, for most simple sensor driven interactions this is more than sufficient. Limiting factors such as only two pins providing full analogue PWM outputs can be somewhat compensated for through programming, should this be required, for instance when connecting an RGB LED. Using an *AVR ATTINY85* microcontroller on a custom made PCB also offers a considerable cost advantage over using another Arduino-based full development board with an excess of functionality. Should additional functionality be required, the boards that are currently most suited to jewellery applications in terms of size are the *TinyLily* and *TinyDuino* by manufacturer *TinyCircuits*, offering the processing power of an *Arduino Uno* in a board the size of a small coin (TinyCircuits, 2016).

Touching and Sensing - The *HyperTouch* Pendant

In the following section I will dissect the creation of the *HyperTouch* pendant (Figs. 6&7) from the *HyperHive* series, in order to demonstrate the amount of component customisation and miniaturisation that is necessary in the creation of stimulus-reactive wearable futures on a jewellery scale. When considering the design of a piece of jewellery incorporating microelectronics, the artistic outcome plays an important role. Taking into account the finished aesthetic of the object whilst maintaining an element of spontaneity has played a considerable part in the development of the custom microelectronic components, making sure they do not interfere with the overall intention of the piece. While some digital jewellery, such as the work of Lisa Juen (Juen, 2010), does not disguise its use of electronic components, but indeed celebrates their mechanical aesthetic, this approach was not strived for in the case of the *HyperHive* series. An important aim of the *HyperHive* series is the harmonious integration of aesthetic and functional elements within the standardised and relatively confined space of the pendants' bodies. To achieve this objective to the fullest degree, the decision was taken to situate the electronics in the upper part of the pendant, as the 3D-printed element is supposed to be able to move freely around the central core. This also allowed for the lower central core to contain an LED or similar electronic component, with the wiring being guided around the hole for the chain attachment into the upper central core, where the microcontroller and battery are situated. Through this arrangement, the

Figure 6. *HyperHive* series: *HyperTouch* Pendant (inactive state). Photo: Katharina Vones.

Figure 7. *HyperHive* series: *HyperTouch* Pendant (active state). Photo: Katharina Vones.

piece maintains a maximum of kinetic freedom, and thus an element of playful interaction, whilst allowing the electronics to be completely self-contained. This was particularly important in the case of the *HyperTilt* pendant (Figs. 8&9), which requires the central element to be able to spin 360 degrees around the chain in order to enable a tilt switch to activate an LED in the lower central core.

The *HyperTouch* pendant on the other hand incorporates a capacitive touch microcontroller, allowing for two touch pads to be connected to a pre-programmed *AVR ATTINY85* in order to trigger two separate LEDs. A custom printed circuit board (PCB) to accommodate the *ATTINY85* microcontroller was designed and manufactured using the photoetching method (Fig. 10) because of its excellent potential for small detail reproduction and ability to manufacture several PCBs at once. It is also a process that can be easily executed in a small-scale workshop without specialist equipment, and thus lends itself to appropriation by individual designers interested in creating digital jewellery. After sketching and checking the basic circuits in a freeware PCB design application, I proceeded to refine the tracks in *Adobe Illustrator*. This workflow offers particularly interesting design possibilities for miniaturising PCBs where space is at a premium, or for creating aesthetically integrated PCBs that are intended to be fully visible within a piece of jewellery (Williams, 2009). The finished PCBs were pierced out with a jeweller’s saw, and populated with space saving surface mount components. One challenge

Figure 8. *HyperHive* series: *HyperTilt* Pendant (inactive state). Photo: Katharina Vones.

Figure 9. *HyperHive* series: *HyperTilt* Pendant (active state). Photo: Katharina Vones.

when manufacturing one-sided PCBs in this fashion is the lack of through-hole connections, necessitating all components to be attached from the same side. Drawing on the craft skills of the jeweller, this problem was solved by creating small through-hole connections using simple copper tube rivets where required (Fig. 11). This enabled the PCB to be integrated into the jewellery object in the most space-saving orientation, and minimise internal wire connections (Fig. 12). When soldering components to these connectors, the solder flows through the tube and creates a solid connection between both the tube and the PCB as well as the component. After manufacturing the first batch of the finished PCBs, closer analysis revealed that further miniaturisation is possible in future PCB designs by putting the tracks closer together and cutting away as much excess substrate as possible.

After populating the PCB and placing it inside the jewellery object, the electronic elements of the design were encased in silicone, a process also known as ‘potting’. This serves as a protection against moisture and movement, strengthening the solder connections through immobilising individual wires. For future assemblies of this kind, using a fully embedded LiPo battery with a charge circuit connected to a micro USB port would provide a space advantage, as only the port itself needs to be accessible in order to refresh the battery charge. A future consideration would also be to integrate a QI charging module in order to enable wireless charging on an appropriate base station.

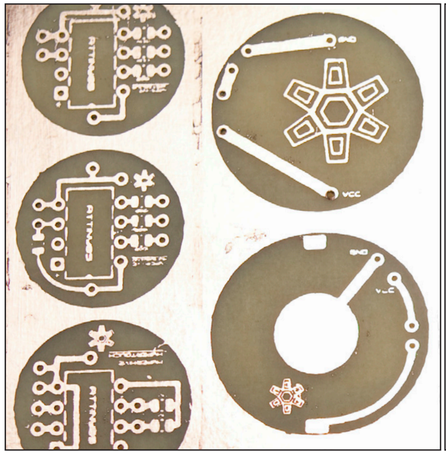


Figure 10. Etched *HyperHive* Components before population. Photo: Katharina Vones.

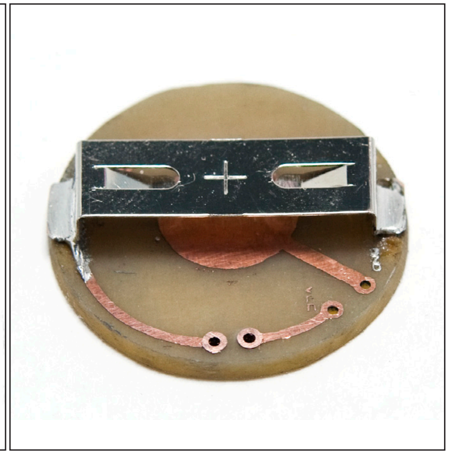


Figure 11. *HyperHive* battery holder fully populated with crafted vias. Photo: Katharina Vones.

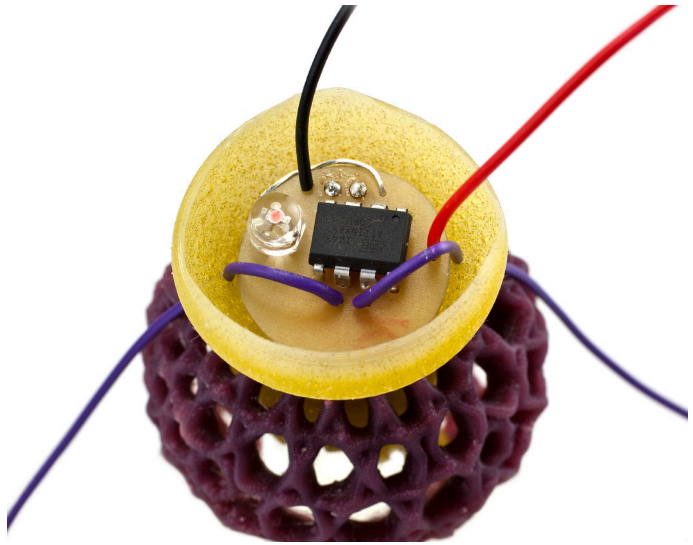


Figure 12. The *HyperTouch* Pendant with integrated components ready for the ‘potting’ process. Photo: Katharina Vones.

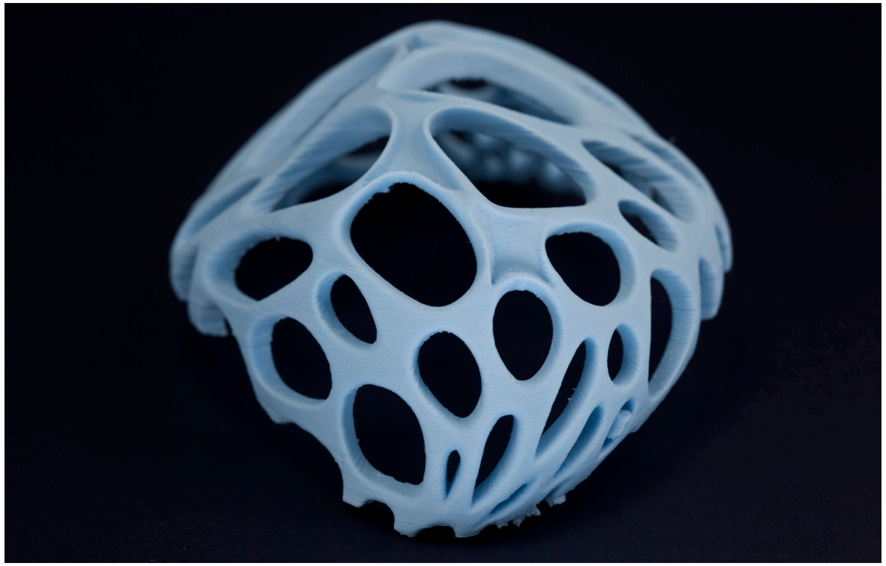


Figure 13. *HyperHive* Series: *Ovum* Brooch - Prototype model with integrated touchpad channels. Photo: Katharina Vones.

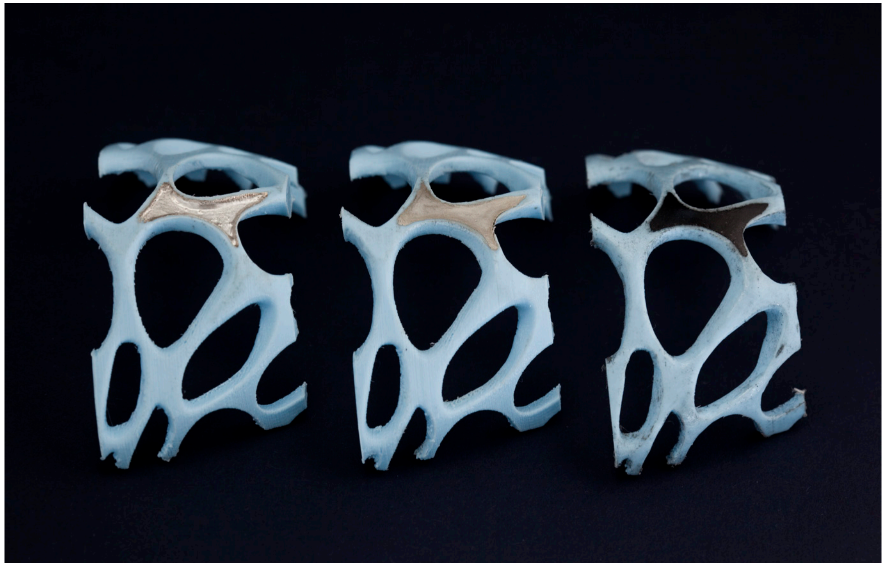


Figure 14. Three sections of the *Ovum* Brooch Prototype model testing different types of conductive inks. Photo: Katharina Vones.

To trigger the playful interaction of the *HyperTouch* pendant, the fabrication and incorporation of two conductive touch pads into the design was required. Several different methods of fabricating such a touch pad were explored, particularly focusing on the possibility of using flexible conductive material, such as self-adhesive copper foil and different types of conductive inks in conjunction with thermochromic silicone. While all of these compounds proved to be suitable for fabricating working touch pads, the conductive material has to be fully exposed in order to detect a touch input. This precludes the full aesthetic integration of the conductive material into the silicone shape by covering it with a thin 'glaze' layer of silicone. The poor adhesion between the tested materials and the silicone meant that without a final 'glaze' layer, this method of fabricating a touch pad was ruled out on grounds of a lack of long term durability. Another method that was tested but ruled out was the fabrication of a 3D-printed touch pad with integrated channels that were subsequently filled with different types of conductive ink (Williams, 2009). This method is particularly interesting for use in wearables, as it allows for the creation of aesthetically integrated channels and through-hole 'vias', enabling them to be situated partially on the reverse of the model and hidden from view. A large model file was adapted in the *Z-Brush* software package, and a section printed in PLA for testing with the different types of conductive ink (Figs. 13&14). Three different types were selected for testing, factoring in conductivity, cost and general availability. While the method of fabricating 3D-printed touchpads proposed by Williams is very effective from both and aesthetic and functional point of view, for the *Hyperhive* pendant in its current form this mechanism is unsuitable, as the main 3D-printed cocoon structure is not connected to the central silicone shape which contains the electronics to allow full freedom of movement. The final touchpads were therefore made from photoetched copper shapes which were soldered onto wires embedded into the main silicone shape. The copper shapes provide superior conductivity as well as aesthetically pleasing visual integration. Although this technique was not used in this instance, copper can be coloured through oxidisation and patination techniques, thus offering further aesthetic possibilities. Two different shapes were chosen to denote the different functionality of the switches, with each activating a different LED inside the pendant.

Conclusion

As this paper demonstrates, the playful exploration of microelectronics through the application of craft methodologies is an area that warrants further investigation, particularly in relation to digital jewellery. Some previous research in this area, such as the body of work created by Michael Shorter (2015) that explores the fabrication of paper electronics and circuits through the use of conductive ink, has opened up new avenues for those craft practitioners who for one reason or another shy away from the more traditional component-based approach. Others, such as Amit Zoran et al. (2013, 2015), Saegusa et al. (2016), Kathryn Hinton (2010) and Ann Marie Shillito (2013) have discovered alternative ways to engage with digital fabrication technologies by designing devices that allow for playful interaction with the user, thus allowing for the making process to be imbued with an element of serendipitous discovery and restoring Pye's notion of the "workmanship of risk" (Pye, 1968) to n otherwise mechanical and predictable interaction. While these are interesting developments, they do not yet offer a viable alternative to the widespread WIMP or GUI interfaces commonly used for 3D modelling, with only Shillito's haptic feedback modelling system *Cloud9* being a fully realised commercial product. Additionally, these alternative systems of digital fabrication rarely focus on the materiality of the final object. Investigating these different ways to fabricate and integrate digital objects and microelectronic components for use in digital jewellery highlights the challenges as well as the almost endless possibilities now facing the multidisciplinary maker. To fully integrate microelectronics in a way that is sensitive to the aesthetic and conceptual meanings of contemporary jewellery requires traditional craft skills as well as an intimate knowledge of digital fabrication processes, material properties and the physical laws of electronic circuit design. Once a maker has unlocked the secrets of all four, the current availability of what was once considered cutting-edge equipment for use in the small workshop enables makers to freely explore each technology directly through playful interaction with materials and processes.

Digital Enchantment and the Knowledge Object

A key concept in the endeavour of creating engaging and conceptually refined digital jewellery objects is the creation of an elusive characteristic defined by the term digital enchantment (McCarthy et al., 2005, Wallace, 2007, Rose, 2014). Within the context of my research, I diverge from both McCarthy et al.'s and Rose's definitions of enchantment by including 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 as essential criteria, while exploring the deeper personal meanings that can be created by the tactile qualities of a wearable object through its materiality. Even though Rose presupposes a natural place for the enchanted object within the recently established concept of the *Internet of Things*, this paper argues that a different type of enchanted object exists - one that is not necessarily connected to a function or purpose – but that has the capability to engage its wearer in a more playful, intuitive type of interaction. 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. These types of objects belong firmly into a category of artefact described by anthropologist James Leach as being *"…objective and non-personal objects of science" (Leach: 157, 2011).* This means that unlike artefacts and works of art created to primarily express the artist's unique creative response to their environment, material or subjective perception of reality, these kinds of 'knowledge objects' express measureable functionality, and therefore an objective potential utility. Leach equates this difference to the profoundly different ways in which the self is perceived and expressed within artistic and scientific practice. Those who create wearable 'knowledge objects' are content for them to possess a perceived potential utility, based on the transmission and recording of measurable data and objective information, whereas the artistic creator of the wearable 'enchanted object' is:

> *"…concerned with the integrity and aesthetic quality of their output because these things reflect back directly on an internal quality of the subject – unique creativity – that can be definitional of the self and its labours in a way that the discovery of a scientific truth apparently cannot be […] This particular creation of a self must be achieved through artifice, not through merely describing what is there or through its potential utility" (Leach: 156-157, 2011).*

Examples of commercially available wearable 'knowledge objects' are numerous and include a number of smart watches such as the *Samsung Gear* and the *Apple Watch*, as well as the now defunct *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 confined within established parameters by simply imbuing familiar types of body adornment with novel technological content. The 'enchanted object' is the antithesis of this - its functionality has no utilitarian context such as data collection or mediation, but instead exists only to provoke a creative and delightful interaction with its wearer. As such, they become part of a narrative of mediation, that places the wearable object in a purely functional role as a vessel for the remediation and delivery of data and other media plucked from the rich tapestry of cyberspace. The creation of stimulus-reactive, digital jewellery as a multi-layered construct, seen through the eyes of the cross-disciplinary alchemical maker pushes the boundaries of what is possible and thus moves beyond mere notions of gadgetry. 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.

Future Development of the *HyperHive* Series

The works presented in this article represent the first incarnation of the *HyperHive* series, exploring how microelectronics can be adapted to suit a pre-defined small-scale jewellery format. The insights derived from this process now enable the creation of further works based on the techniques discussed in this article. The first such object is the *Ovum* Brooch, touched upon in the last section of the article, and to be presented as a prototype at the *Research Through Design 2017 Conference*. The *Ovum* Brooch follows its own imaginary developmental lifecycle, and this is supported by using a novel silicone in its creation that expands when exposed to a source of heat during the curing process, setting in organic and unpredictable ways. After the initial growth phase, the piece remains dynamic in its responses to the external environment through the inclusion of photochromic pigments and microelectronic elements that can be activated through touch interactions by the wearer. A short film documents the various stages of the making process, creating a narrative of serendipitous creation and crafted evolution. Bridging the gap between the natural, the artificial and the imaginary is a key outcome of this body of research and aims to manifest a future ecology, in which nature has been supplemented by semi-organic forms of life, and the human body has been altered to accept permanent modifications to become Posthuman.

References

Amadeo, R. 2013. DOA: The Galaxy Gear reportedly has a 30 percent return rate at Best Buy. Ars Technica, 26/10/2013.

Fried, L. 2015. Adafruit Industries Homepage [Online]. Available: http://www.adafruit.com/ [Accessed January 28th, 2015].

Hedgecock, S. 2015. Google Glass Startups Claim: Not Dead Yet. Forbes, 23/01/2015.

Hinton, K. 2010. The Craft of Digital Tooling. MPhil, The Royal College of Art.

Johnson, B. D. 2011. Science Fiction for Prototyping: Designing the Future with Science Fiction, San Francisco, Morgan & Claypool Publishers.

Juen, L. 2010. Globalores.

Leach, J. 2011. The Self of the Scientist, Material for the Artist. Social Analysis, 55, 143-163.

Margolis, M. 2011. Arduino Cookbook, Cambridge, O'Reilly Media.

McCullough, M. 1996. Abstracting Craft - The Practiced Digital Hand, Cambridge, Massachusetts & London, England, The MIT Press.

Pye, D. 1968. The Nature and Art of Workmanship, Cambridge, Cambridge University Press.

Rose, D. 2014. Enchanted Objects: Design, Human Desire, and the Internet of Things, New York, Scribner Book Company.

Saegusa, H., Tran, T. & Rosner, D. K. Mimetic Machines: Collaborative Interventions in Digital Fabrication with Arc. Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, 2016. ACM, 6008-6013.

Shillito, A. M. 2013. Digital Craft - Industrial Technologies for Applied Artists and Designer Makers, London, Bloomsbury Visual Arts.

Shorter, M. A. 2015. The Craft Technologist. Studies in Material Thinking, 13, Paper 04.

Tinycircuits. 2016. TinyCircuits Homepage [Online]. Available: https://tinycircuits.com/ [Accessed June, 2nd 2016].

Williams, L. 2009. The Development of Digital Technologies for Use in Jewellery with Medical Applications. Doctor of Philosophy, The Royal College of Art.

Zoran, A. Hybrid craft: showcase of physical and digital integration of design and craft skills. ACM SIGGRAPH Art Gallery, 2015. ACM, 384-398.

Zoran, A. & Paradiso, J. A. FreeD: a freehand digital sculpting tool. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 2013. ACM, 2613-2616.