RTD

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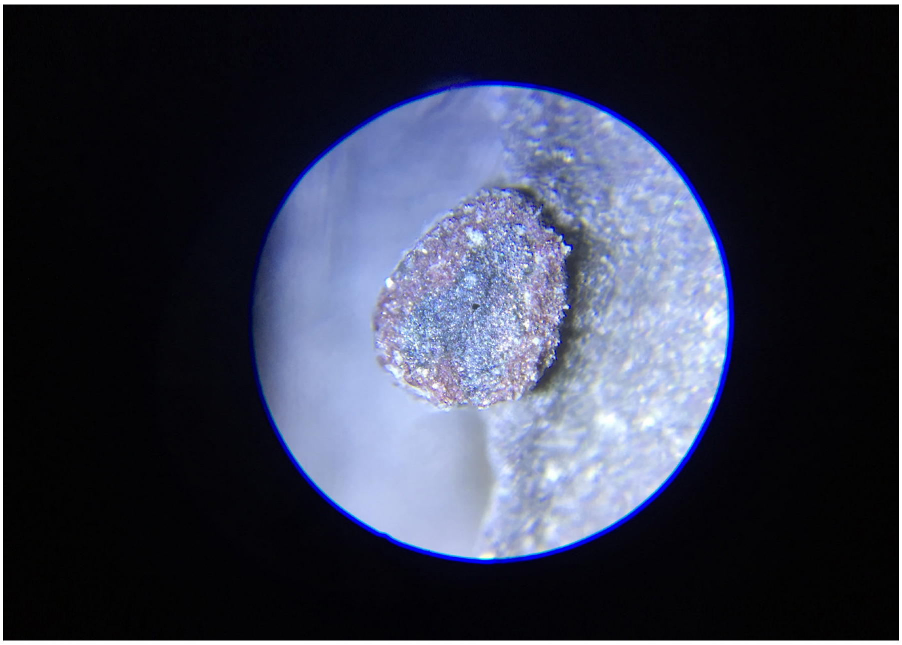

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Method& Critique *Frictions and Shifts in RTD*

Crafting Material Innovation and Knowledge Through Interdisciplinary Approaches

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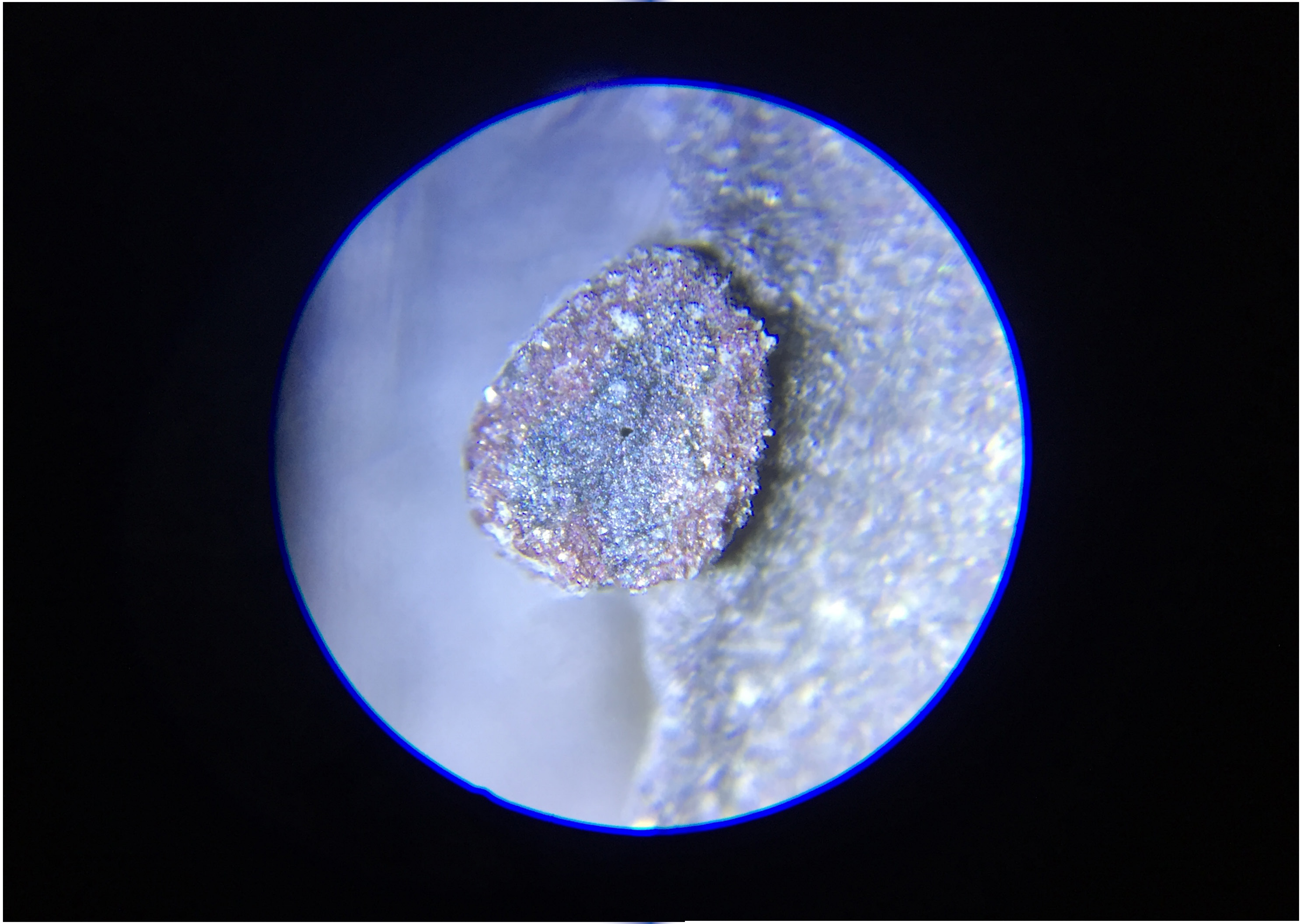
Abstract: This paper presents material artifacts created at the early stages of a practice-based PhD—the focus of which is to highlight, through practice, a third space that emerges as disciplines intersect—specifically textile design and material science. Ceramic fibres (high temperature insulators), anti-static stainless steel fibres (conductive materials) and carbon nanotubes (1d carbon nano materials) were chosen as departure points for exploration. This paper presents images alongside their written explainations to draw attention to the processes and approaches that have been used in the material developments. A 'soft' approach, driven by curiosity, intuition and playfulness, is taken to engage with these materials and is explored alongside a 'hard' approach, as a means to uncover this third space. Engineered materials, which have been synthesized and manufactured using systematic and scientific approaches are considered to be from this 'hard' domain— such as ceramic fibres, that although can be woven or knitted are not in current material palettes used by textile designers. New methods and ways of working were developed to take forward into the PhD enabled by the textile designer working tacitly with unfamiliar materials and understanding how insights from one sphere, might, when used in another, potentially reveal new knowledge and material innovations.

Keywords: material innovation; material exploration;= smart textiles; interdisciplinary; textile design thinking



Miller| Magnified rigidified anti-static steel based yarns encased in silver

Introduction

A series of three material experiments which have been conducted at the early stages of PhD research, are presented through image and text throughout this paper. The material experiments sought to analyse an emerging interdisciplinary design space between traditional textile practice and material science, focused on the fields of e-textiles and advanced materials for extreme condition environments.

Electronic textiles, or smart textiles, describe the combination of electronics and textiles into fabrics which are able to sense, compute, communicate and actuate. These fabrics have both electronics and interconnections woven directly into the fabric, allowing for both flexibility and size that are unachievable using other methods of construction (Stoppa and Chiolerio, 2014).

New conductive materials, alongside metallic based materials, are being developed for use within both these areas of e-textiles and advanced textiles for extreme environments. These include graphene and carbon based nanomaterials.

Overall, the 'wearable technology literature testifies to the enormous and growing field, with designers from several generations working around the world on wearable devices strapped onto, or inserted and woven into, garments and accessories. The makers have backgrounds in science or technology, interface design, fashion, or art; or they work in teams with diverse skills and backgrounds, since wearable technology is multidisciplinary in the extreme' (Ryan, 2014, p.5).

As wearable technology is increasingly 'inserted and woven into' clothing and fabrics, all those involved will continue to find necessity in developing effective ways to work together. For example, how do those with a tacit understanding of the perceptual qualities of textiles and materiality bring their knowledge to this area of smart and advanced textiles for extreme conditions? Interdisciplinarity is key. To take advantage of the potential and opportunity that comes about as a result of the convergence of material science and engineering with textile design, new ways of thinking are required. This is the premise of a paper 'Design Drives Material Innovation' by Oliver and Toomey (2010). The authors suggest that for successful material innovation, engineers and designers need to work together from the very early stages of material development.'Visionaries', says Quinn (2015, p.7), 'know that the cutting edge of technology is not sharp but sensuous and soft'.

Textile Design Thinking

Igoe, (2010, 2013); Philpott, (2012); Philpott and Kane (2016); Winters (2016) and others, seek to illuminate the methods and methodologies born out of the tacit and embodied knowledge that rests within the textile design discipline. Igoe (2010) tells us that, traditionally textile designers have 'tacitly synthesised' this knowledge and that in order to unravel and better understand the specifics of textile design thinking and the distinct methodologies that come about as a result of textile design thinking, we must work to solve the difficulties in making tacit knowledge explicit. That is to talk about the impetus behind why work is created, who it's being made with and for, as well as the steps being taken during the process of material creation.

Morrow (2014, p.461) in 'Drifting walls: learning from a hybrid design practice', and whose work sits between the fields of architecture and textile design, notes the criticality of 'building an explanation', stating that 'the aesthetic coherence or 'beauty' of an artifact can sometimes belie its cleverness, masking the complexities of the processes from which they result, making it seem somewhat indulgent'.

Textile Design is an intrinsically collaborative discipline and as such, textile designers may have unique skills, learnt through practice, that they can bring to the table in the development of e-textiles. 'Textiles are a site where creative and scientific disciplines find a natural meeting point, providing a unique platform for interdisciplinary dialogue and innovation. As an interdisciplinary site, textiles encompass aspects of design, art, craft and technology, indicating that those involved with textiles possess a specific blend of knowledge (Igoe 2010 in Philpott and Kane, 2016, p.4).

New methodologies and processes blending science, electronics and material engineering with traditional textile design are rich for exploration and this expansion of the discipline of textile design is happening in multiple arenas. Winters (2016, p.405) in 'Building a soft machine: new modes of expressive surfaces' argues that new opportunities within HCI (human computer interaction), soft robotics and wearable technology are possible by employing methodologies developed within the textile design discipline that focus on 'subjective, visceral engagement with material and physical computing using tacit textiles expertise.' Therefore, analysing 'how' a textile designer may begin to work within the domain of e-textiles could be beneficial for both the design research community and for multiple sectors of industry.

Hard and soft

The motifs of 'hard' and 'soft' are used throughout the PhD as conceptual pillars that frame the research. These are not seen as oppositional but rather as resting on a circle, together forming its entirety when brought holistically to balance. Recurring throughout the PhD, the motifs of 'hard' and 'soft' perform different roles, highlighting either technological concerns, intellectual concerns or operational concerns. For example, they exist in both metaphor and in the actuality of their subjective material properties.

Textile design is considered 'soft'. It largely rests in the values and archetypal qualities of the feminine, such as being rooted in emotional, intuitive and aesthetic responses. Igoe (2013), Morrow (2014) and Winters (2016) highlight that textile design has been omitted from critical discourses in design theory, due, Igoe argues, to 'the feminine engendered nature of the craft.' Materials science on the other hand is considered 'hard' — framed in the masculine and the measured, aligned to the rigorous, analytic and non shifting nature of fact, to which the sciences aspire.

'I believe that there is box- thought, the thought we call rigorous, like rigid, inflexible boxes, and sack thought, like systems of fabrics' (Barnett, 1999, p.26).

Building on Serres' notion of 'soft logic', Barnett (ibid.) presents 'cloth as a poetic language' and proposes to us, what if the poetics of cloth were 'composed of 'soft logic', modes of thought that twist and turn and stretch and fold?' This idea, that links the flexible and pliable qualities of textiles with the cognitive processes of those who practice it, forms the foundations of textile design thinking, pioneered by Igoe (2013).

Donald Schon (1983, viii) talks about the 'familiar dichotomy of the 'hard' knowledge of science and scholarship and the 'soft' knowledge of artistry and unvarnished opinion.' Philpott (2013) suggests that 'hard' and 'soft' knowledge domains are increasingly evidenced in textile design practice— illustrating through her PhD work both an effective combination and articulation of these. Philpott's developed a mixed method approach to foster original material innovation by combining the creative freedom and scientific rigour that she deemed integral to the development of new and otherwise impossible material results.

There is recent and growing recognition by those trained in textile design and material science alike of the potential that exists as these two disciplines come together in new ways. 'The Power of Soft' demonstrates recent research from an interdisciplinary team representing figures from both fields and suggests that if Applied Materials Science and Engineering are combined with the tacit knowledge of materials developed through craft processes and hands on making, 'a new paradigm shift for human-centered, purposeful technologies will be possible' as well as 'new approaches to soft technology.' (Morehead et al. 2016, p.79). As such, we are presented with the hypothesis: embracing a 'soft' approach will become of increasing value to 'remain at the leading edge.'

Developing practice and material tests

My fascination with 'hard' and 'soft' materials began in 2012 when I sought to challenge an 'optic-haptic' relationship by producing a series of bronze castings that looked like soft and crumpled fabric. My curiosity lay not only in the hard and soft fabrics themselves but in all the stages or states between these two extremes. When I worked in material innovation for performance sport (2014-2017) concepts of 'hard' and 'soft' knowledge domains and their distinct yet different approaches became uppermost in my mind. For example, during a project working with product designers, engineers and yarn developers to produce material innovations to help athletes reach their potential (for e.g to improve the fit and comfort of a trainer while simultaneously working on the aesthetic). Questions I asked were how were textile design enquiries different to material innovation enquiries? What were the unique qualities those trained in textile design could offer this area of material innovation and what were the challenges for textile designers in the area of material innovation?

The introduction presents literature which suggests an opportunity to explore the intersection between textile design and material science to reveal 'soft' approaches to 'hard' challenges. One challenge being addressed is to make explicit the methods and approaches for traversing between disciplines for developing material properties applicable to e-textiles and advanced textiles.The material experiments were developed to explore the intersection between soft and hard/textile design and material science. The materials were chosen due to their properties, functionality and their applicability to e-textiles and advanced materials for extreme environments, ceramic fibres (advanced materials); anti-static stainless steel fibres (conductive materials) and carbon nanotubes (carbon based nanotechnology). The processes and ways of handling the materials are approached through playful, inquisitive and interdisciplinary means.

Craft is blended with the scientific and the physical properties of hardness and conductivity are explored in each of the material artifacts either by working with the inherent material qualities or through lost wax silver casting techniques and a carbon nanotube growth method with controlled morphology, with the aim to create innovations that combine knowledge sets. It is important to note here that within material science the term hardness has a very technical and specific meaning that refers to a material's ability to withstand deformation, for example, through bending or scratching. Whereas, my own use of the term is more subjective and refers to flexibility and rigidity. The experiments are presented in the following section.

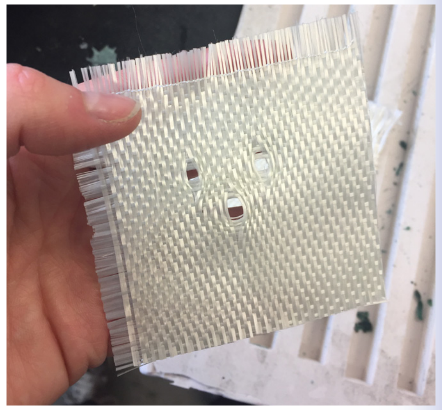
Experiments for material artifacts

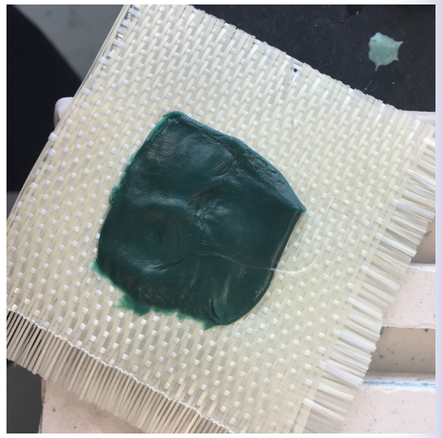
Ceramic fibres and silver
Experiment 1

Aims:
One of the key aims of this experiment was to consider how I might increase the functionality of woven ceramic fibres. Specifically, the properties of conductivity and hardness, through explorative means. To create a material with smart capability (conductivity), through an additional process, resulting in a material that contains both rigid and flexible elements, without compromising the flexible, 'soft' material.

Another key aim was to explore the inherent material properties of ceramic fibres, such as their high temperature tolerance and the processes that they could be exposed to as a result of this attribute. I was interested in what a textile designer could bring to these extreme materials, distinct from the context in which they have been developed as well as furthering my own knowledge and understanding of the material. Ceramic textiles are used in extreme condition environments due to their extremely high temperature tolerance (claiming to maintain excellent flexibility after continued exposure to 1370 °c). I sought to examine if ceramic textiles could withstand lost wax silver casting, a hands on craft process. The exploration began with the knowledge that the working temperature range of ceramic fibres is up to 1370°C and that the silver melt temperature is lower than that and up to 961°C, alongside the fact that most textile fibres disintegrate at around 100°C.

Process:
The process used in this experiment was the lost wax silver casting method. In this method a wax model is created, see figures 1— 4 and then 'sprues', also made of wax are attached creating channels running away from the model. The model and the sprues are suspended into a silica based, plaster-like material, called investment. This investment is then fired at a high temperature, burning out the wax, creating voided channels that the silver can be poured into. Later, the shell of investment is broken off and the sprues cut off the model, leaving a silver replica in the place of the former wax model.





Figures 1-4 (Above). Ceramic material preparation process. Photo: Claire Felicity Miller. The ceramic materials used for as high temperature insulation are prepared for the lost wax silver casting methods by making holes in the woven fabric and melting and pressing the wax into place on the fabric.

I received a selection of samples from the nextel ceramic fibres range, and I began my explorations with two woven samples, one was woven with twisted fibres and the other with flat and untextured fibres but both had the same material composition. These samples were cut and prepared for the lost wax silver casting trials (figures 1 — 4). Small holes were created within the weave— allowing the wax and therefore the silver to flow through the fabric. The silver replaces the portion of green wax seen in the images. The samples — after having been fired and the surrounding investment broken off— can be seen in figure 7, still attached by their sprues to the tree. Later, the samples were cut off these sprues and worked on further. Methods such as buffing, changed the appearance of the silver from a dull grey to a high shine.

Outcome:
We can see the process and the results of this experiment, documented through photography as seen in figures 1— 7. Within these images our attention is drawn to a rough looking cooking pot (figure 1), that has been used to melt down wax for the lost wax silver casting process and the close up of fingerprints pressed into the malleable material highlighting the hands on process and results of the experiment as well as the visible presence of the researcher. The lost wax silver casting method requires a high level of expertise, with knowledge, such as where to place the sprues and how many of them being integral to the final results. Highlighting the collaborative aspect of this work and my reliance on the specialist skill of the jewellery technicians.

The fact that the materials did not completely disintegrate was encouraging and something I had hoped for. They had stood up to and 'survived' the lost wax silver casting process. The textile constructed with the twisted yarn had more resilience to the process, remaining 'together'. While the material constructed with the flat, untextured yarn, did not stand up to the process, highlighting the role that 'twist' may have played in protecting the fibres from prolonged exposure to high heat during the casting process.

The ceramic material remained sandwiched between the solid silver sections on either side — creating a new material that contained zonal changes in hardness. As evident in figures 5-6.

Anti-static stainless steel fibres and silver
Experiment 2

Aims:
One of the key aims of this experiment was to explore, similarly to the previous experiment, the inherent material properties of anti-static stainless steel fibres. These properties include their high temperature tolerance (the material claims to have working temperature resistance up to 1400 —1400°C) and high conductivity, alongside others. Through combining these unfamiliar materials— developed for a wide range of uses within the field of smart textiles— with a hands-on, craft process, I sought to not only explore them using a curiosity-driven approach developed within my textile design practice, but also to gain a better understanding of these materials and their properties. I wanted to understand the ways in which they could be worked with; the processes that they could be exposed to as well as their subsequent 'breaking points'.

Figures 5-6 (Above). Post lost wax silver casting. Photo: Claire Felicity Miller. Artifacts cut from sprues, sanded and silver buffed to shine. In both images we can see the impressions within the silver, left by finger prints and the fabric beneath.

Figure 7 (Left). On the spruce. Photo: Claire Felicity Miller. This figure shows the ceramic materials that are sandwiched between the silver while still attached to the spruce. The silver is a black-grey colour prior to it having been buffed to a shine.

Figures 8-11 (Opposite Page). Preparation and magnification. Photo: Claire Felicity Miller. Figure 8 and 9 show preparing the wax. Pink sheet wax in 0.60mm was bought to ensure consistency of thickness on either side. Figure 10 shows the impression that the anti-static stainless steel yarn is tracing below the surface of the silver. Figure 11 shows the magnification of a sectional view highlighting where the anti static steel based yarn has broken off during the lost wax silver casting process. We can see that the yarn has solidified.

Because the working temperature of these continuous stainless filament yarns is above that of the silver melting temperature, a hypothesis was developed; these fibres may also be suitable materials to expose to the lost wax silver casting method.

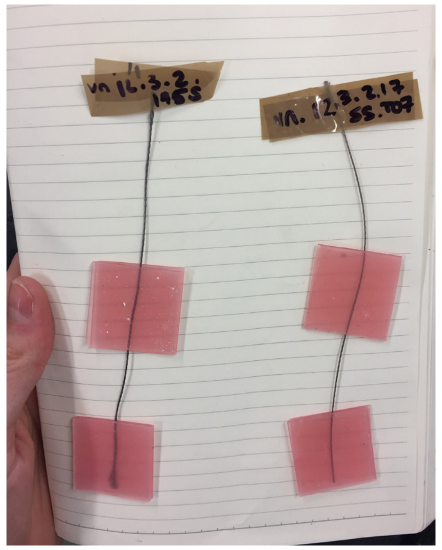
I considered whether or not these fibres may withstand the temperatures involved and if so whether or not the resulting material would remain intact, resulting in a material that might be made up of both rigid and flexible elements— the flexible anti-static stainless steel fibres acting as a web between the added silver elements. Could they be created in such a way that the flexible 'soft' material was not compromised? Could I increase the capacity for conductivity of the fibres once integrated into this new design?

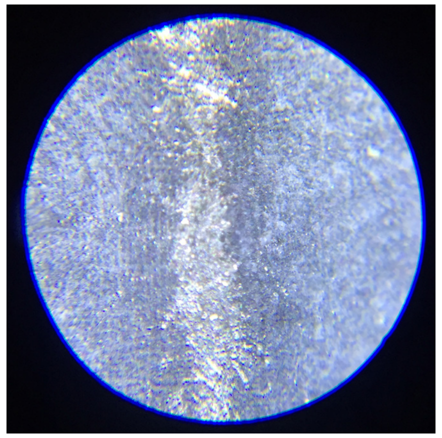
Process:
Anti-static stainless steel fibres were sourced from Bekaert in a range of weights and four of them were cut to the same length and prepared for the lost wax silver casting process. Pre-cut sheet wax was sourced to allow for consistency of the materials thickness within the experiments (see figures 8— 9), allowing for the only changeable variable to be the thickness of each fibre tested. Similarly to the above experiment, wax sprues were attached and placed onto a tree. This tree was then suspended into the investment prior to the wax being burnt out— making space for the silver in the voids that had been created during the process.

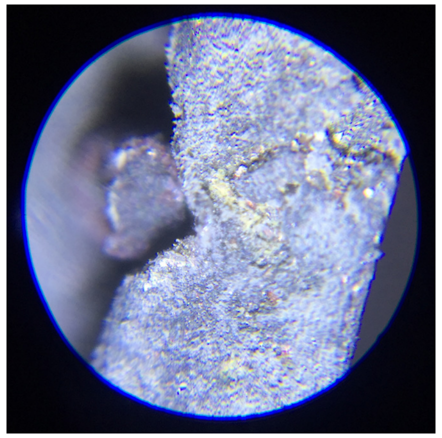
Outcome:
This experiment sought to add hardness through the lost wax casting process at designed intervals on highly conductive anti-static stainless steel fibres. However, the fibres used in this experiment did not stand up to the lost wax silver casting process. In both figures 10 and 11 we see a sectional view where the anti-static stainless steel yarn had rigidified and become trapped between the silver panels on either side. The sections of the yarn that had been external to the wax model prior to processing (see figure 12) had been blasted away and just the silver remained. In the images taken under the microscope we are able to see (figure 10) a trace of the fibre that remains, running inside the layers of silver beneath the surface. This is evidenced by the impression the sandwiched yarn left on the wax, and subsequently onto the silver that replaced it. Rather than be disappointed and the results considered unsuccessful, I had learned something about the fibres: Although their melting temperature was higher than that of silver, in fibre form they were perhaps too vulnerable to withstand the process.

Ceramic fibres and carbon nanotubes
Experiment 3

Aims:
The objective of this experiment was to explore an additional way in which I might increase the functionality of insulating ceramic fibres, specifically by adding the property of electrical conductivity to them through carbon nanotube deposition method. This method has been also performed on glass fibres (Turgut et al. 2018) which have lower decomposition temperature than ceramic fibres, at ITU (Istanbul Technical University), within their Aerospace Research Centre (ARC), with whom I collaborated. This led to the hypothesis that ceramic fibres may also be a good growth substrate for carbon nanotube







synthesis. Carbon nanotubes (CNTs) are 'tubular structures made of carbon atoms, having the diameter of a nanometer order but length in micrometres.' Theoretically they are able to carry a current that is '1000 times higher than that of copper' and they 'can be metallic or semiconducting, depending on their diameter and chirality' (Purohit et al. 2014, p.717). Three various widths and compositions of ceramic fibres were sent to ITU to test 'proof of concept', seeking to add electrical conductivity to the ceramic fibres at the nanoscale.

Process:
While two of the samples sent were the same fibre as used in experiment 1, all three were sent to ITU in fibre form (4 cm in length), rather than as a constructed or woven textile. Firat Turgut at ARC ITU performed the experiments by immersing the fibres in an iron nitrate catalyst solution, after which the strands were dried and put in a furnace at 40°C overnight. These fibres were then placed in a quartz tube and were placed back in the furnace for the carbon nanotube growth to take place (Turgut et al. 2018). The fibres were wrapped in little packages, (see figure 14) and sent back to London—where they were later assessed under a fume hood in a resin workshop. With gloved hands (see figures 13— 14), I inspected CNTs for the first time, gently manipulating the fibres between my fingers to see if the handle of the ceramic fibres had been affected—I worried whether or not I would rub the CNTs off the surface.

Outcome:
All three ceramic fibres sent exhibited successful carbon nanotube growth on the surface of the fibre. While two of the fibres showed short, irregular growth, one was very successful, showing a clear mohawk growth in the scanning electron microscope (SEM) images, see figure 15. This mohawk structure is consistent with successful conformal growth in the literature (Yamamoto, 2009). It was also some of the best growth of carbon nanotubes the research team at ARC ITU had seen– where delicate fibrous CNTs were grown on top of the hard ceramic fibres.

Figure 12 (Above). Impression. Photo: Claire Felicity Miller. Figure 12 shows two material artifacts after the anti-static stainless steel fibre that held them together as a single artefact did not withstand the lost wax silver casting process. Instead we see just an impression of the remaining fibre below the surface.

Figure 13- 14 (Below). Carbon nano tube anchored ceramic fibres. Photo: Claire Felicity Miller. Figure 13 shows successful growth of the carbon nanotubes on the ceramic fibres held within the palm of my gloved hands. Figure 14 shows another set of tests where the carbon fibre growth on the ceramic fibres was not as successful, we can see there is more of a grey colour than a black one.

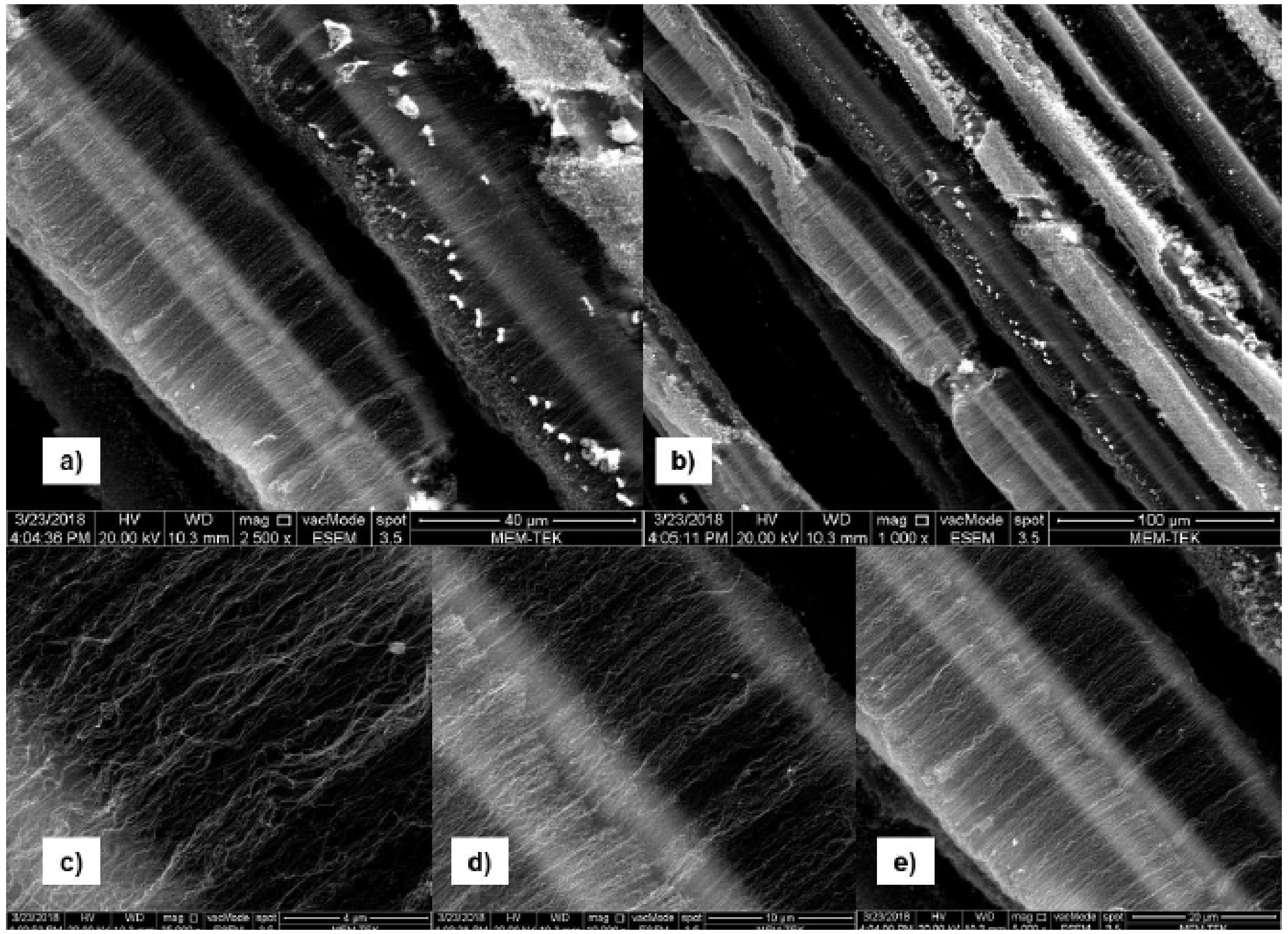
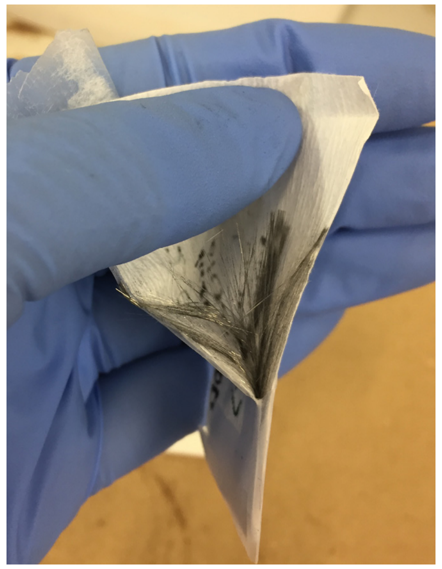


Figure 15 (Above) Figure 15. SEM (scanning electron microscope images) images. Photo: ITU ARC a) 2500x magnification, b) 1000x magnification, c) 25000x magnification, d) 10000x magnification, and e) 5000x magnification. These SEM images show effective conformal growth in line with images from within the literature.



Synthesised outcomes:
When considered as a group, we can see that the material artefacts shown in the experiments above explore changes in physical properties of conductivity and hardness, across a variety of scales (i.e down to the nanoscale).

Within the images, we see the diversity of approaches taken in working across both 'hard' and 'soft' domains. From the wax covered cooking pot (figure 1), to the SEM images, redolent of modern material science and the magnified images of anti-static stainless fibre enveloped within the silver (figures 10 and 11). In figures 1-4, we see a craft studio with the bare hands of the researcher and designer evident. Our attention is drawn to the dual approach that has been taken and rests now within the physical artefacts, emblematic of these 'hard' and 'soft' domains, highlighting the required dexterity in moving between workshops and processes. Through a combination of craft processes and through textile thinking, new functionalities or processes have been brought to the materials through playful, inquisitive and interdisciplinary means.

The images and the descriptions focus is placed on process — the material properties have been altered or adapted through 'craft'. The 'application' or 'output' of these material artefacts at this stage were not considered.

Experiment 2 built on experiment 1, in that it also used the lost wax silver casting process, although in the second experiment it was hardness that was added at designed intervals to an already highly conductive material (anti-static stainless steel fibres). While the ceramic material in experiment 1 was able to withstand the process the anti-static stainless steel fibres in experiment 2 did not, perhaps it was that they were not woven into a textile construction? Therefore, could I, in future experiments, design the material in such a way to find the point at which it no longer disintegrated and was able to withstand the process, by perhaps constructing a woven textile or 'twisting' (observed in the previous experiment with ceramic textiles and as seen in images 5 and 6) fibres together to form a new conductive material that could withstand this process?

'an object that gives in is actually stronger than one that resists, because it also permits the opportunity to be oneself in a new way' (Kozloff in Barnett, 1999, p.26).

In these experiments we see different types of collaborative relationships, for example, the artefacts in experiments 1 and 2 were created in cross-workshop environments, such as seen between textile design and jewellery. In experiment 3, a successful cross-continent collaboration took place between London and Istanbul. In addition, this was a collaboration between myself with a background in textile design, with a research team at an Aerospace Research Centre at ITU. Figure 15 shows SEM images taken by ITU of the successful conformal growth of CNT on ceramic fibres. The results could be used in highly technical and functional end uses such as in measuring strain and stress in aerospace structures.

I would have been unable to produce any of these artefacts alone. Marr and Hoyes (2016, p.7) tell us that 'over the last few years textiles has rapidly expanded into an interdisciplinary practice' — all of the experiments for material artefacts here were made in interdisciplinary contexts. Throughout the experiments I engaged with others as I explored the potentials and possibilities within the inherent material properties. From working with the technicians in the jewellery department, to sending ceramic fibres to Istanbul and discussing carbon based material properties with my supervisor who has a background in materials science, collaboration was key. The relevant skill sets I required were around me — highlighting the importance of the network and the environments that surround and are available to textile designers seeking to explore unfamiliar materials in unknown environments. Access to such physical environments, therefore becomes crucial, as well supportive relationships, where collaborators are willing to 'take a leap of faith' with you in material explorations.

Perlata (2017, p.52) states that 'teams need to develop mutual trust to operate effectively' and Baille (2015) says that developing effective co-design relationships is key to the continued development of textile design as an evolving discipline. Creating new avenues for exploration as well as encouraging more sustainable practices. Cross and Cross (1996, p.316 in Morrow, 2014, p.455) note that design processes that involve teamwork are also social processes and the importance of social interactions and relationships in such instances cannot be underestimated and Valentine et al. (2017, p.966) tell us 'that within the discipline of textiles, collaborative practice...has shown to be advantageous for pushing the boundaries of creative practice.' Therefore a responsibility that rests with designers such as myself who seek to continue working in hybrid and exploratory ways could benefit from developing methods that will support them in 'listening to' and in 'understanding' the other, so that skill sets and knowledge can be respected. This in turn will contribute to developing opportunities for those who may wish to explore the space further in the future.

Additionally, the experiments present us with a shifting and non-static notion of 'hard' and 'soft'. At the outset the materials developed and systemised within scientific domains, such as ceramic fibres and carbon nanotubes were considered hard, yet through the individual experiments we can see 'hard' and 'soft' qualities shifting. For example, in experiment 1 the ceramic fibres are considered 'soft' and the cast silver is considered 'hard', based on their respective flexible and rigid physical properties. In experiment 3, the CNTs have been considered 'soft' because of their delicate and soft fibrous nature and the ceramic fibres considered a 'hard' foundation on which they were able to grow. In experiment 2, the pliable anti-static stainless steel yarns, developed within the fields of material science, are considered physically 'soft' in contrast to the rigid quality of the 'hard' cast silver. These observations highlight how the use of the descriptions of 'hard' and 'soft' are interchangeable and interconnected when describing different processes across textile design and material science. These shifting metaphors are no longer bound by context demonstrating that a binary approach of either/ or is not an effective lens through which to analyse the intersection between the fields of textile design and material science.

'The binaries offers two possibilities, 'either/ or'; 'soft logics' offer multiple possibilities. They are the realm of the and/and' where anything can happen. Binaries exclude; 'soft logics' are to think without excluding— yet one is not set against the other, (that would be to miss the point)' (Barnett, 1999: 26).

Therefore we can consider 'hard' and 'soft' not as oppositional but as resting on a circle, together forming its entirety when holistically brought to balance.

Insights

E-textiles and advanced textiles

Through both active and intuitive means I sought to explore the concepts of 'hard' and 'soft' through textile based materials used typically, and developed within, material science and engineering knowledge frameworks; ceramic fibres; anti static steel based yarns and carbon nanotube anchored ceramic fibres. Although these can be woven, knit and embroidered, these materials have specific processing and engagement methods attached to their use. They have not, as yet, been applied using a 'soft approach' — where the materials inherent 'hard' technical properties are explored using a 'soft' and curiosity-led approach. Through direct material engagement, textile design could offer new perspectives and opportunities, for example by unlocking new material qualities, aesthetic and additional properties.

The functionalities of these materials, that could be utilised within smart textiles were at this stage not as important as the processes of participation of a textile designer developing material knowledge through interdisciplinary and 'soft' approaches. This challenges the notion of application and output at the early stages of materials engagement , development and innovation for textile designers working in the fields of e-textiles and advanced textiles.

Marr and Hoyes (2014) in their project 'Boundaries' introduced the idea of a playtype, distinct from a prototype. The playtype enabled thorough exploration of material properties during open-ended and process-led textile research, without consideration of a product or an end user in mind. However, Morrow (2014) tells us that exploratory design work done at the outset of a project, even before a brief, is often considered a chaotic approach to design research.

'To challenge [this] dominance is not necessarily to introduce alternate paradigms that displace it. Rather, it is to enable spaces in which to ask different questions, that concern other worldviews...' Akama (2017, p.80)

Therefore, a different way of contextualising experiments for material artefacts, independent of their end use may be necessary, particularly at the early stages of developments. Therefore, the outcomes at this stage were material artefacts that serve as representational and metaphoric examples working to address the question of how textile design thinking and material science might come together.

Textile Design Thinking

(Igoe, 2010) says that the majority of academic scholarship in textile design to date has been driven by scientific research rather than coming from a place of creativity. However, the specifics of textile design thinking with its distinct methodologies will be illuminated by analysing how textile design comes into contact with the sciences. Therefore, academic textile design research steered by solely a challenge based agenda will not serve to highlight the intricacies of textile design practice. Nor will research in textile design rooted in curiosity based investigations alone. Rather, it will be work that oscillates between the two fields that drives the development of further insights into textile design thinking. Kane et al. (2015, p.3) tell us that increasingly 'textile designers are undertaking research into technical areas with creative intentions, utilising artistic modes of inquiry. In response to an increased confidence in both the embodied and articulated knowledge utilised and generated by textile practice.'

The material artefacts presented document the process of a textile designer engaging with unfamiliar materials, developed within the hard domain of material science. However, the experiments for material artefacts also contribute to a much larger conversation that considers the necessity of externalising tacit textiles expertise and approaches. Additionally, the work goes some way in revealing the methods that exist within the textile design discipline. Suggesting, for example, that creating space for open-ended material engagement at the early stages of a design project utilising e-textiles or advanced textiles for extreme conditions is of value.

Hard and Soft

The material artefacts document a synergy between the concepts of 'soft' and 'hard'. These concepts have been explored both intellectually and physically and highlight the thinking-through making that has taken place in the development of the experiments for material artefacts. By weaving the metaphors of 'soft' and 'hard' between operational concerns and intellectual concerns I have been able to put a stake in the ground as to where it is that my research sits— between these two domains of textile design and material science, allowing for a strong foundation that underpins my work going forward. Kimbell (2012, p. 129) in 'Rethinking Design Thinking: Part 2' suggests that through 'understanding design expertise and activity as constituted materiality and discursivity in practice', we can better understand the work of designers and the practices that surround their disciplines. As such the representation of textile designers within the design research community offers an opportunity for textile designers to contribute to a changing understanding of design thinking— one that begins to place increased awareness on the role of materiality and thinking through-practice, recognising that currently, 'design thinking' fails to represent the diversities within different design practices. (Kimbell, 2012, p.129)

Additionally, going forward, both the concepts and properties of 'soft' and 'hard' are recognised as no longer being bound by context and are seen as interchangable and interconnected. Their meaning dependent on the lens of the viewer. This can be evidenced in for example the properties of silver. At the early stages of the experiments silver was seen as 'hard', it's presence in the material artefacts bringing rigid elements to both the ceramic and anti-static stainless steel fibres. However, considered from a different point of view, a metallurgist would view silver as a 'soft' metal. Additionally, during the process of lost wax silver casting in the experiments for material artefacts, silver went from a rigid material to molten metal and back to a rigid metal again. This reversability of material states highlighting the fluidity and metaphor of the motifs that I have used to frame my research.

Summary and next steps

Through these material artefacts I have gained increased understanding as to ways in which these two areas of material science and textile thinking might come together— offering examples of a pliable and adaptive 'soft' approach to materials developed within the 'hard' domain of material science and engineering.

These experiments have illuminated how the process taken in their development might feed into how other projects within the PhD are approached. For example, in an interdisciplinary project that engages with industry integrating sensors into textiles to monitor the health of operators in extreme condition environments. Priority is focused on developing relationships and early open-ended material exploration seen as integral.

Collaborative relationships will be integral to the success of my work going forward. Workshop formats like those seen developed by Light Touch Matters (2018) and Burchill (2018), aiming to aid both designers and materials scientists alike in understanding the key differences of language and how materials are talked about within the two disciplines offer a foundation upon which I can build. Developing workshop formats alongside a new series of experiments for material artefacts that build upon those presented here will be pursued. Particularly, those that straddle both challenge based and curiosity based research.

The challenge [in such interdisciplinary efforts] is to move together to unexplored territories even though initially there is little common language and without knowing exactly the final destination. Success comes through doing things closely together, trusting in each other's competence and opening the mind to joint adventure' (Ketoja in Kaariainen and Tervinen, 2018, p.91).

Additionally, maintaining and developing an adaptive and open minded approach to support moving comfortably between various disciplines and domains will remain a key focus going forward. Flexibility and pliability in 'expectations' of outcomes will be continually considered. Indeed, Philpott (2012) says that one must have an open mind necessary to create the new knowledge found within a PhD.

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