RESURFACED: Using Laser Technology To Create Innovative Surface Finishes For Recyclable, Synthetic Textiles.

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Figure 1: ReSurfaced samples shown at Green SCin; the materials experiment, March 2009
Abstract

Monomateriality is a crucial component of lifecycle design, enabling high value recycling to occur at the point of disposal. If polyester textile products are preserved as monomaterials during their production they can be returned for reprocessing into virgin quality material over several cycles through chemical repolymerisation.

However, current textile production and finishing processes often mix materials from different ‘metabolisms’ irreversibly in one product, creating complex hybrids. These products, designed in the ever-increasing drive for performance and functionality, leave a legacy of waste and prevent inclusion in future fabrications (Allwood et al 2006).

Emerging technologies are presenting new opportunities for textile finishing, in particular with synthetic thermoplastic materials such as polyester (Wang, 2006) which represents as much as 60% of global fibre production (Morley, 2009). This practice based research project set out to explore these new technologies, which could be employed to preserve monomateriality in order to make polyester textile products more easily recyclable.

It concludes that there is potential for ‘design for upcycling’, enabled through a new toolbox of technological processes which facilitate production of complex, functional yet fully monomaterial (and therefore recyclable) textile products.
Cradle-to-Cradle Design [C2C]

Over the course of the last decade, the fashion and textile design industry has been evolving to meet the fast-changing demands of consumers newly alert to the environmental impacts of their purchases. Recycling, once a niche, craft activity has become a more common response, embedded in many company strategies alongside attempts to reduce waste, carbon emissions and toxic chemicals from all elements in a product's lifecycle. However the eventual result, no matter the intention, is often products that are unrecyclable or unable to be reused, eventually ending up in landfill.

During recent years, designers have been addressing this often disconnected strategy and seeking to produce better, more sustainable ways of working. Cradle-to-Cradle (C2C) is a set of design principles based on natural systems that eliminates the very concept of waste. All materials are viewed as continuously valuable, circulating in closed loops of production, use and recycling. It is a movement that has the potential to move recycling systems from a limited ‘extended life technique’ for materials to that of truly perpetual material flows which retain value through each reincarnation.

First coined in the 1970’s by Swiss Architect Walter R. Sahel, the term C2C was refined at the beginning of the new millennium by German chemist Michael Braungart and architect and designer Michael McDonough, who promised a new way of thinking about “making things” in their collaborative publication the Hannover Principles, which they followed up with Cradle to Cradle: Remaking the Way We Make Things in 2002. A book that has undergone many reprints and is now a cult read.

This is a dialogue that celebrates new design and creativity. It is a methodology which, rather than focussing on logistics and technology to solve
our resource problems, places the designer at the centre of the solution (Goldsworthy & Lang, 2010). Designers working to this end can adopt many different routes to get there, but there are two main strategies which need to be integrated into the very start of the design process, setting a brief which ensures all materials involved in a product’s construction can be either:

- returned to the earth where they harmlessly decompose and become food for plants and animals while rebuilding nutrients in the soil.
- returned to industrial cycles when no longer useful, thereby supplying high quality raw materials for new products.

For textile designers this means two very different approaches for working with either natural or synthetic materials at all stages of the production cycle. In the case of biological (natural) fibres the key concern is to prevent use of any chemicals, which would cause harm if they were leached into natural systems as material is returned to the earth through biodegredation. For synthetic materials the priority is to design products, which can be effectively recycled in perpetuity without loss of quality.

**Designing For A Closed Loop Polyester Economy**

Polyester is aligned to the industrial cycle and as such needs to be preserved as a recyclable resource. In a 2003 report, US based furnishing supplier Designtex identified this problem and described their vision of a closed-cycle polyester economy, where all polyester fabrics are recycled perpertually;

*Recycling by itself, only postpones the arrival of the discarded material at the landfill, where it may never biodegrade, may biodegrade very*
slowly, or may add harmful materials to the environment as it breaks down. A genuinely sustainable future depends on creating closed loops, or cycles, for all industrial commodities, including polyester. In a closed loop, materials would never lose their value and would recycle indefinitely (Livingston, 2003).

At that time, it was possible to create mechanically recycled polyester fabric from packaging waste, but not possible to recycle polyester fabrics. Repolymerisation had been successfully trialled but was not yet commercially available. However, this changed in 2005 when Teijin launched their EcoCircle system in collaboration with pioneering sportswear brand Patagonia and the polyester economy became a viable scenario.

Desigtex had identified that this future vision may be hampered, by some commonly used processes. Furniture manufacturers often apply their own specifications for finishing fabrics before they are installed on seating and architectural products. The processes used in finishing the fabrics often include chemical backings, which are contaminants, most of which in use today are incompatible with breaking down polyester and repolymerising it.
This is also true of many finishes used in the garment industries, including trimmings and fixings. But these finishes have been at the core of many innovative textile products during the last decade. For example, coating and lamination offer methods of improving and modifying the physical properties and appearance of fabrics and also the development of entirely new products by combining the benefits of fabrics, polymers and films.

“The finishing of a fabric, the final stage in its making, is fast becoming as important as it’s construction: it is also where the look, texture and performance can be dramatically altered. Treatments include holographic laminates, silicone coatings and chemical finishes which devour surfaces they come in contact with.” (Braddock-Clarke, 1998)

However these treatments, although innovative and effective during the life of the material’s useful life, often create barriers at the point when a material needs to be taken back to the melting pot for recycling. This project set out to find an alternative to these processes, which might suggest a way forward for recyclable finishing. As William McDonough writes in Cradle to Cradle, our products should be ‘gifts for the future’ not materials destined for landfill. Many textile processes, nonwoven constructions, chemical finishing processes, coating, lamination and composite materials render products unsuitable for recycling and destined for landfill (Horrocks and Anand, 2000).

Most environmentalists agree that recycling must increase, and that there may well come a time when coated and laminated materials will come under scrutiny. (Fung, 2002)

B. Gulich (Wang, 2006, p27) suggests ‘designers should keep in mind how a product, meant to be sold tomorrow, can be recycled or disposed of the day after tomorrow.’ He discusses the advantages of single polymer design or single material systems. Products consisting of only one material are ‘pure’
and easy to re-use. It is not generally necessary to deconstruct the product prior to reprocessing.

**Laser Tools For Monomaterial Techniques**

I have been searching for ways of manipulating the surface of polyester, a thermoplastic material, which could dramatically alter the surface aesthetic without the need for toxic chemicals or adhesives, thus preserving recyclability.

![Figure 3: Laser finishing of synthetic materials developed during PhD study](image-url)

Lasers create heat and when used with thermoplastic materials cause melting. This creates the potential for various surface effects to be achieved without the adding of any other materials – simply by controlling the way the laser interacts with the material. During this project I explored the potential for a new series of finishing techniques using the laser with 100% recycled polyester. Lasers are certainly not new in the textile industry: Other designers have explored the potential of innovative laser finishing with regards to environmental benefit.
Janet Stoyel was one of the first designers to establish the laser as a finishing tool for textiles with her company ‘Cloth Clinic’ started in 1994. In particular her work to explore the devore process through laser fin, uses no dyes, no chemicals, no wet finishes and no stitch. Devore is a particularly renowned pollutant, generating chemical and colour waste and also generating large quantities of fibrous sludge. Of her innovative work in textiles Janet has written:

*By inventing futuristic processes and harnessing the latent design potential of Photon Laser and Ultrasound technology, I realise permanent effects on materials in an environmentally holistic manner, without dyes, chemicals or wet applications, challenging conventional material concepts through the ultimate marriage of engineered materials and technology. I exploit the characteristics inherent within a material, changing molecular structures, alchemically transforming surfaces (Stoyel, 2009)*

Anne Smith’s Altered States project (1998-2000) also explored the potential of laser cutting and etching technology, as a method for environmentally low impact methods for producing decorative effects on fabrics. The project focused on the exploration of the aesthetic and commercial viability of the application of laser cutting and marking technologies to interior, furnishing, fashion and accessories materials, and resulted in a patent on the ‘application of laser cutting and marking technologies to generic flooring materials’.

Savithri Bartlett’s doctoral research project, completed in 2006, at Loughborough University School of Art and Design (LUSAD), accepted the challenge to archaic fabric printing technology by suggesting an innovative route of dye uptake and surface design of textiles. The use of lasers as a means of controlling dye uptake at the surface of textiles was achieved by changing the quality of the material surface, thereby controlling colour intensity achieved during dyeing.
For my own doctoral research I have been concentrating on the area of ‘laser welding’ as a process for investigation. Laser welding was identified as an area of potential innovation for textile finishing and explored through a collaborative investigation with TWI, an engineering research facility based in Cambridge. The resulting material samples illustrated many new finishing and resurfacing techniques. Some were replacements for traditional methods and others, were completely new processes, which would be unattainable with conventional tools. Recyclability is preserved, while aesthetic, function and innovation retain priority in the design process.

One of the key advantages of this technology over the more commonly used CO2 lasers is that they work with a much lower energy consumption and are more controllable which enables complex effects to be designed into a single process. The potential for the use of laser welding to increase the productivity and quality of welded seaming of fabrics for garment production has been previously explored, but my focus was on the surface finishing of the fabric. A successful application for funding from the Materials KTN enabled me to work with the technology provider (TWI) to explore the potential for laser welding to be used as a finishing tool.

Designing The Study: A Craft Approach

The practice based research was designed very much as a ‘design’ process. Working closely with a technical specialist, Jo Lewis, also trained as a designer, enabled a hands-on, craft approach to be used with experimentation based on action and reflection throughout the study.
Traditional makers form an in depth understanding of the materials and tools that they work with, through various combinations of hands on experience, and technical/scientific understanding. Through this dialogue with materials and processes they are able to develop an individual aesthetic, a personal visual vocabulary. (Masterton, 2005)

There were several stages to the experiments:

- finding ways to overcome the limitations of the available equipment
- optimising settings for mark making and welding with the chosen materials
- identifying and exploring finishing techniques which could be achieved through this process

I used many different constructions of polyester materials in the tests; knitted, woven, nonwoven, yarn, monofilament, sheet and fibre.
Because the material, polyester, was a familiar material, I spent very little time testing the parameters of power and speed for the material I was exploring. I did look closely at the type of effect or mark that could be achieved with various fabric constructions and weight. These ranged from a single layer transparency effect to a much more complex construction on multiple layers bonded without any surface marks – and a variety of effects between the two.

**Identifying Potential Finishes**

After initial testing I designed the study to investigate 3 main approaches.

- Multi Layer Composite Experiments
- Single Layer Embellishments
- Nonwoven Construction Experiments

As this technology had been previously employed mainly as a stitch substitute, that is to create seam bonds for garment construction, I began by experimenting with multi-layer composites. A previous body of work for the
'Ever and Again’ project had looked into the use of CO2 laser welding as a tool to resurface low grade recycled felts in order to ‘upcycle’ them to a higher value material product (Earley, 2007). The CO2 technique had not always produced controllable or successful results and I wanted to test this new technology as an alternative. I quickly discovered that laser welding could produce much more controllable results, bonding layers together with minimum disruption to the surface of the materials joined.

Sampling explored stitch replacement (for quilting, sashiko, 3D constructions), and resurfacing techniques (emulating embossing, double faced laminations, jaquard effects). In some cases at certain power settings I observed that the top surface was affected. Where in the exploration of seaming this would be considered undesirable, in the exploration of finishing techniques this opened up a new area for investigation.

When the laser was applied to single layer materials 2 main characteristics could be achieved. Transparency was the result in certain material substrates, such as fine satin weaves, and emulated a devore finish. This surface effect has been explored previously by other designers using the CO2 laser. However, the use of the laser welder gave more easily controlled results with less destruction to the surface of the material treated.

More dense textile constructions and materials resulted in a melted surface effect akin to spot lamination or coatings. This led to a further group of experiments which explored surface embellishments beading, sequins, embroidery, flocking and foiling – all achieved without the use of adhesives or stitch.
The final experiments leading on from observation of the bonds created between yarns in the experiments to emulate embroidery, were based on the replication of web formation, perhaps alternatives to lace or nonwoven constructions.

Figure 6: Selection of final samples developed during PhD project 2009

In all over 20 existing textile processes were emulated and explored successfully resulting in materials not only created from recycled polyester materials, but also suitable for full chemical recycling into high value polymer of virgin quality.
Conclusions & Future Work

During this project laser welding was found to be a potential alternative to many existing finishing processes and some innovative techniques not attributable to existing processes were also identified. The resulting materials retained 100% monomateriality and were successfully preserved as recyclable resources.

In order for this technology to be available for full scale production there are several developments of the equipment and process required and it is hoped that collaboration with a suitable industrial partner can be achieved in order to fully resolve the potential for a highly responsive, integrated manufacturing and recycling system which can sit within a vision for a closed loop polyester economy in the future.

Note

The Clearweld ® process was invented and patented by TWI. It is being commercialised by Gentex Corporation. The process uses lasers and infrared absorbing materials for precise joining of coloured or clear synthetics. It offers superior engineering advantages compared to today’s adhesive and solvent bonding, and ultrasonic, vibration and hot-plate welding methods.
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