SMART.idea Award Report

“Electronic Circuit Construction for Thermochromic Materials”

Problem Provider

Company Name: B & H Liquid Crystal Resources Ltd

Address: Riverside Buildings, Dock Road, Connah’s Quay, Deeside, Flintshire CH5 4DS

Contact Name: Russell Booth **Position:** Managing Director

Telephone No: 01244 817101 **E-mail:** Russell@liquid-crystal.com **Fax No:** 01244 818502

Solution Provider

Organisation Name: School of Textiles & Design, Heriot-Watt University
Address: Netherdale, Galashiels, Selkirkshire, TD1 3HF
Contact Name: Sarah Taylor **Position:** Reader in Textile Design
Telephone No: 01896 892148 **E-mail:** s.e.taylor@hw.ac.uk

Project Team: Sarah Taylor, Dr Robert Christie, Dr John Fletcher, Sara Robertson and Luca Rossini.

Issue 3 January 2007

Project Summary

The intention of the project was to evaluate aesthetic and technical performance of thermochromic dyes in conjunction with integrated heating mechanisms. Thermochromic dyes change colour with temperature, leuco dye types undergoing a change between two single colours and liquid crystal types changing through a spectrum of colours. We proposed to develop electronic systems that could locally change the temperature of textiles to which thermochromic dyes have been applied and to observe the colour change response to this localised heating. By using a combination of different colour changing thermochromics combined with permanent colour pigments, the potential to produce dynamic, progressively changing multi-coloured textiles and related materials would be explored. With support and expertise from B&H Liquid Crystal Resources, the intention was to enhance the positive and minimise the negative features of the thermochromic dyes through exploratory application. We anticipated that this investigation might prompt the need to establish improved temperature changing thermochromic dyes to allow wider scope for multi-colour change effects to be achieved. The project set out to investigate creative and intelligent applications of these materials within the textile market, moving away from previous applications which have been most commonly used for novelty effects. It aimed to develop concept-designed controllable heating mechanisms that would use temperature sensing in combination with pulse-width modulated and hysteresis controllers. It also aimed to examine and record colour-change effects using both temperature responsive microencapsulated leuco dye thermochromic systems and liquid crystal dyes on textiles and a variety of other related materials, applied using special printing techniques, in order to engineer the desired controlled progressive, multi-colour change.

Key objectives were to:

- Devise and develop electronic heating mechanisms to exploit the effective resistance of copper;
- Create simple circuits to determine design parameters for further testing;
- Monitor the effectiveness of colour change on various thermochromic substrates using simple circuit designs.

Summary of methodology

The availability of small electronic elements enabled the development of low relief circuit designs allowing unobtrusive integration with flexible substrates. Two different techniques were used to design a range of heating elements. *Copper heat-sinks* were used in combination with surface mount devices (SMD technology) which act as resistors; the resistors were used to enable heat transfer to the copper. The second technique used *Track resistors,* consisting of distributed elements: long and narrow metal tracks deposited on both rigid and flexible substrate. Using these techniques a series of circuits were designed for optimum heating capability. The circuits were controlled using a variable power supply. This mechanism offered flexibility for monitoring and evaluating voltage, temperature, timing and colour change effects. Simple switch mechanisms were used to control individual heating elements. A wide range of thermochromic fabrics and other related materials were prepared using a screen-printed process. The fabrics were systematically tested in combination with each circuit design to establish optimum voltage and the required conditions in order to achieve clear image resolution as well as image disappearance. Various factors were taken into consideration such as ambient temperature and the effect of colour change and colour loss at temperatures over given intervals. Photographs and videos were used to record and analyse these transitional effects.

Project Achievements

Microencapsulated leuco dye thermochromic systems with different temperature-induced colour change thresholds (31°C and 47°C) and liquid crystal thermochromics of both cholesteric and chiral nematic type that exhibit ‘colour-play’ just above ambient temperatures were tested. Materials for the application of thermochromics were chosen if they featured one or more of the following qualities: white/black, functional and technological for example, phase change material. The following materials were printed with both types of thermochromics: medium weight furnishing cotton; woven merino wool; Outlast phase change material: black wool felt: wax coated cotton: Fothergill engineered carbon fabric (black): linen black (furnishing weight): viscose/acetate, textured cotton: vinyl: polyester film and textured polyester film.

Different mixtures of microencapsulated leuco dye thermochromic systems with different temperature change thresholds were tested in combination with permanent base pigments. Interesting ‘colour play’ was achieved using the variable colour change thresholds within individual samples. Various binders were tested to establish the best formulation to strengthen colour change of the liquid crystal dyes. A binder was discovered that significantly improved this effect as opposed to the recommended traditional pigment binders for liquid crystal dyes. The results of this testing highlighted the importance of experimentation. Further testing was conducted on site at B&H Liquid Crystal Resources. This provided essential access to knowledge and support for printing textiles and other related materials such as plastics with thermochromics.

Heat-sink technology in combination with surface mount resistors offered flexibility in sizing and the design of block shapes. Copper has good thermal conductivity and was exploited using a series of rigid printed circuit board (PCB) designs and a system that allowed the development to apply the heat-sink directly onto a thermochromic fabric. Resistors were soldered onto the copper shapes in order to allow internally-generated heat flow into the metal surface, creating the “heat-sink”. The design of the first circuit was used to determine the boundaries of this technology and to monitor variables associated with the heat profiles across simple block shapes. To keep continuity throughout experiments and for recording colour change, a star shape circuit was designed in order to observe the heating behaviour of a complex shape and to allow maximum design potential. The circuit was composed of connecting heating elements. To optimise the thermal behaviour, smaller sized heat-sinks were used. This resulted in faster, more effective colour change. A simple series of switches was used to power each heating element. This method was quick and easy to produce making it suitable for fast prototype development. The method of mounting electronic circuitry and heat-sink arrangements on rigid boards proved effective in creating colour-changes on thermochromic textiles and related materials. Testing showed that within a range of voltages between 4.00 and 7.00, thermochromic materials with different responses generated different colour change qualities. It was found that microencapsulated leuco dye thermochromic systems that change at 31°C were affected by variations in ambient temperature, and therefore the resolution of shape was not clear. Due to the temperature threshold of these particular thermochromic dyes they also stayed in their changed state for longer, making the clarity of the image visually static. Higher temperature change threshold microencapsulated leuco dye thermochromic systems (47°C) were more effective, as they are less affected by ambient temperature. The fabric quickly reverted to its original colour state after removal of the heat source, as the ambient temperature acted as a cooling factor on the thermochromic material. There was no significant variation of colour change results within the range of thermochromic fabrics within the higher colour change threshold. Further development of the heat-sink system was conducted combining a digital mix (DMX) system to successfully activate individual heating elements in the circuit design. There was no difference in colour change between the rigid heat-sink on to the circuit board and the heat-sink directly applied to fabric. Each system offered potential design applications.

Track resistor designs were another mechanism for creating localised heating. The resistance properties of stainless steel were exploited for the tracks of this flexible circuit design produced on a thin film. This technique allowed the development of linear designs as well as block shapes in contrast with the heat-sink technology. The board was designed with several test shapes including a star shape for continuity. The design was outsourced and produced by a company who specialise in flexible circuit technology. The resistance of tracks was predetermined and therefore optimum size and length of tracks were addressed in the circuit design. Once in contact with thermochromic materials this method proved visually effective in creating a smoother colour change transition and a higher resolution of the image. Resolution was clearer due to the thermal behaviour of the base film, which made dispersion of heat very effective. The resistance of the stainless steel tracks optimised heat transfer to the thermochromic fabrics. When combined with a thermochromic fabric the thermal response of the track design gives a clear, gradual colour change transition which was in contrast to the staggered stages of colour change of the heat-sink circuit design. Flexible track technology is more expensive and has to be outsourced, but has proved to be a better heating mechanism for effective colour change response. As previously stated, voltages were recorded between 4.00 and 7.00 to assess the effect of power control. Improvements to this design could be explored for example using flexible connections, in future testing. The design of the circuit was limited due to production timescales and cost.

Heating mechanisms that use temperature sensing in combination with pulse-width modulated and hysteresis controllers were designed. Technical drawings were informed by the results using the other heating mechanisms**.**

Project Conclusion

The research project culminated in a knowledge base for predicting the heat profiling effects on printed thermochromic textiles and other related materials and has enabled us to design a series of controllable electronic circuits that have been optimised for heat transfer. Techniques have been developed which further amalgamate these technologies creating novel colour change phenomena. Heat-sink technology in combination with a DMX system has allowed us to engineer almost unlimited colour change sequences. As this project has demonstrated, colour change as pattern is possible through the arrangement of circuit board design. The collaboration with B&H Liquid Crystal Resources was vital in that it allowed experimentation with a wider range of both leuco and liquid crystal thermochromic dyes. We have achieved improvements in the understanding of printing thermochromic dyes onto textiles and related materials as both single and multi-colour change thermochromic samples. New formulas for multi-colour change through the use of combining different temperature threshold dyes have been realised. The results gained from the multi-colour change thermochromic samples highlight the possibilities of working with different temperature change thresholds. This shows potential for commercial opportunity which would allow the development of unique colour-change effects when used in combination with temperature sensing controlled electronic systems.

The project has formed an integral part of a three year PhD project and it is anticipated that these results will be realised in the creation of conceptual design-led pieces. The project will be disseminated for educational purposes; widening the use and understanding of these specialist dyes when used with integrated heating mechanisms. We intend to use these results to form the basis of a paper that has been accepted for oral presentation at the 3rd International Conference, “Smart Materials, Structures and Systems” organised by the International Conference of Materials and Technologies (CIMTEC). We intend to secure further funding for future development of this research to pursue more complex electronic circuit construction informed by the results of this project. Examples of selected colour change effects are appended in this report and samples can be made available for demonstration purposes.

Appendix

1.

2.

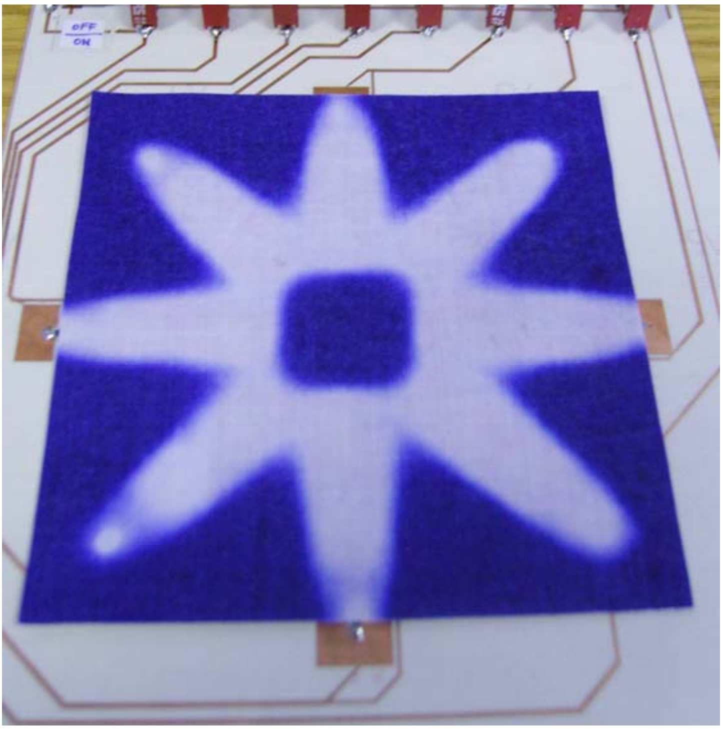


Image 1 shows a microencapsulated leuco dye thermochromic sample printed on cotton with a temperature change threshold of 47°C in combination with heat - sink circuit design with switch control mechanism.

Image 2 shows the same fabric sample on an improved circuit design which demonstrates clearer resolution of the final appearing shape.

3.

4.

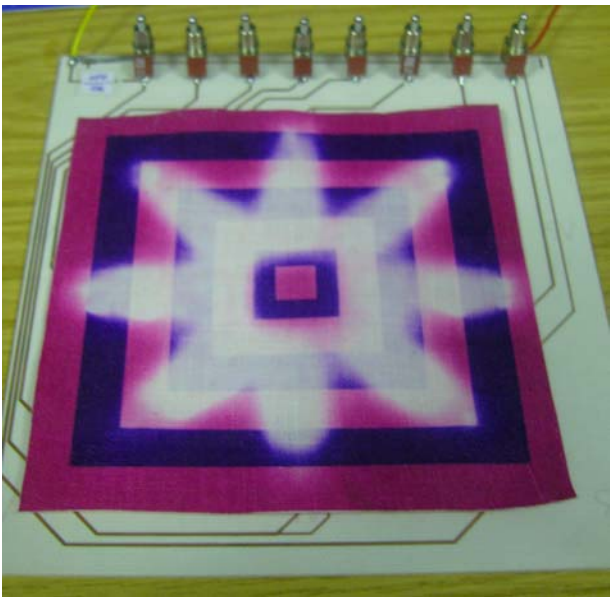


Image 3 shows a phase change fabric printed with a blue (31%) and a red (47%) leuco thermochromic dye. The blue is responding to the heat source more rapidly than the red.

Image 4 shows a linen sample printed with the higher temperature leuco dyes which have been layered onto other leuco dyes to create interesting “colour play”.

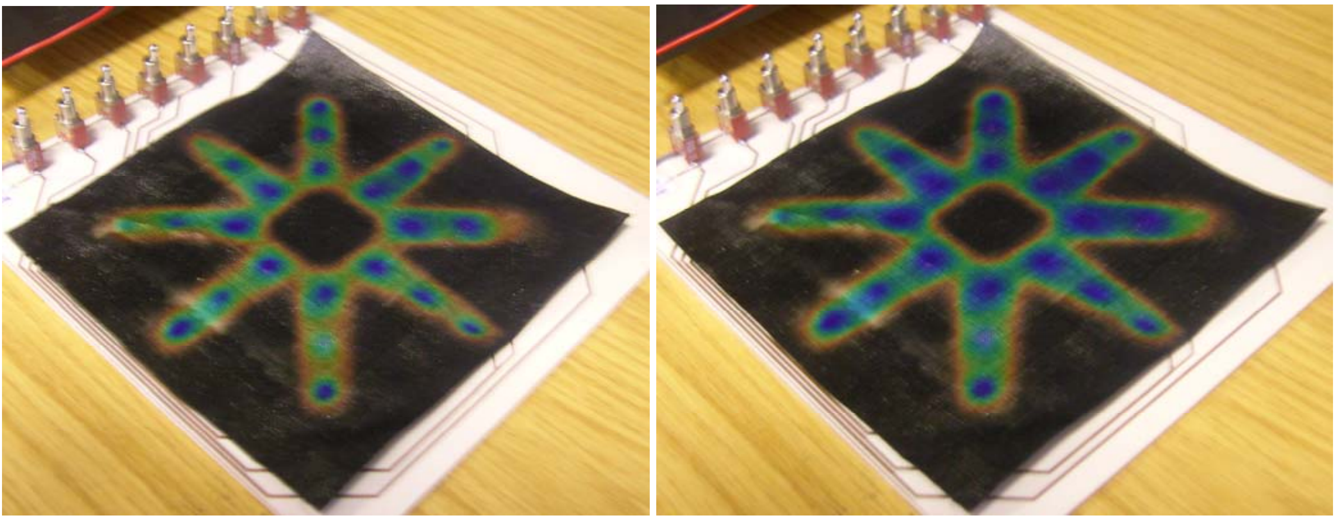

5.

Image 5 shows black linen fabric printed with cholesteric liquid crystals in combination with the improved heat-sink circuit board. The image highlights transitional colour of the image which creates interesting “colour-play”.

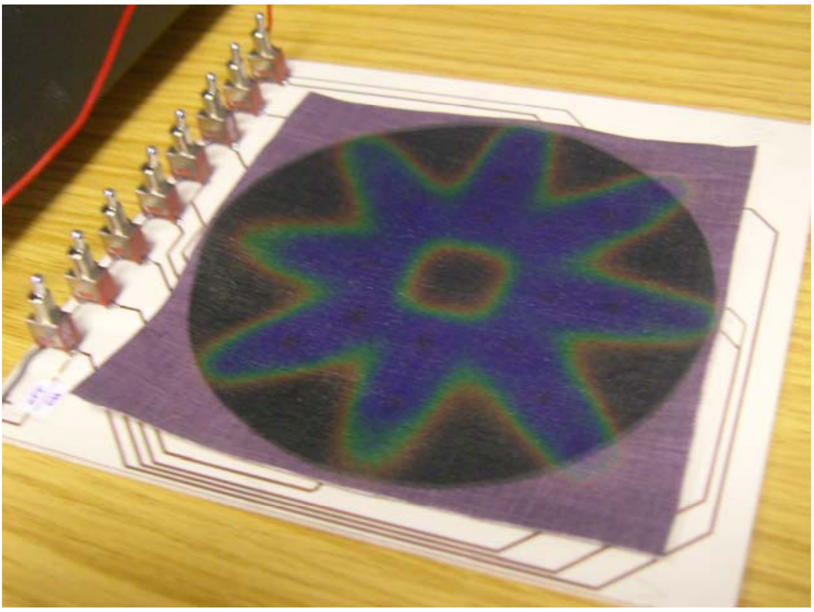
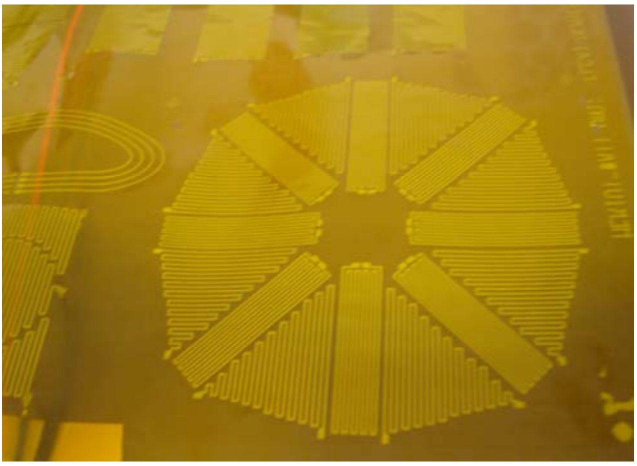
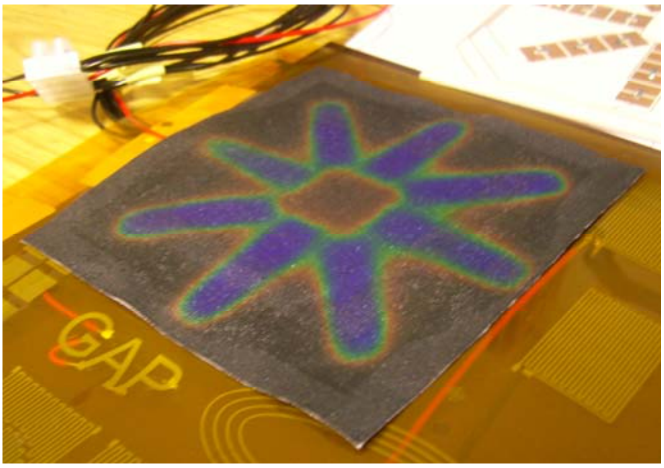

6.

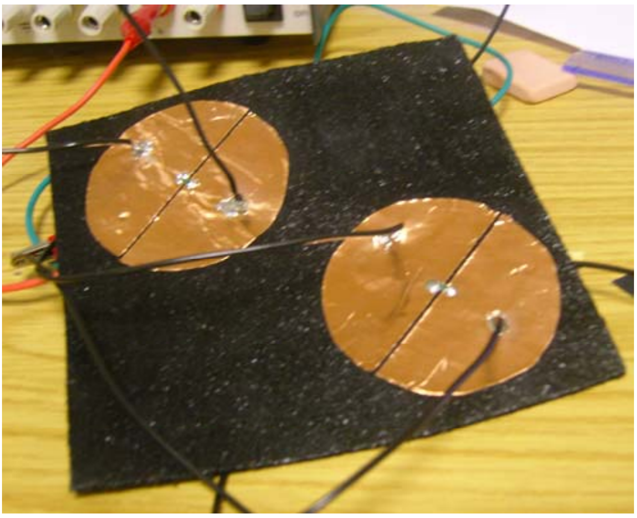
Image 6 shows pattern effects in combination with liquid crystal dyes with controlled localised heating of a heat-sink circuit. The liquid crystal is printed as a circle over a pigment dye base.


7.



8.

Image 7 shows the flexible track of the circuit design. Image 8 shows the developed liquid crystal image in combination with the heated flexible track design.

9. 

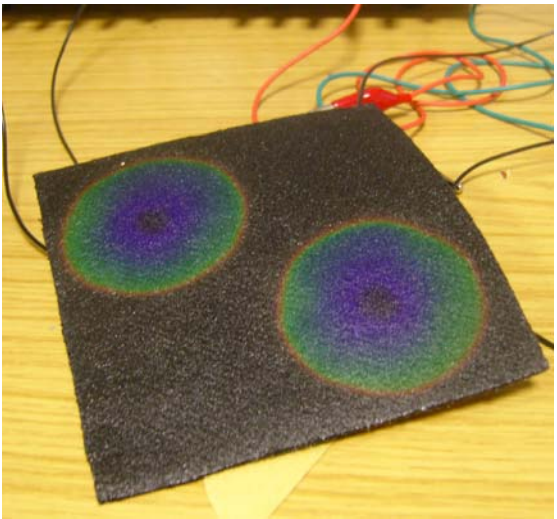
10. 

Image 9 shows heat-sink technology applied directly onto a printed liquid crystal fabric. Image 10 shows the liquid crystal image when heated.

11. 

Image 11 shows the effect of “colour-play” when using a combination of both cholesteric and chiral nematic liquid crystal dyes printed on black wool felt. A hair-dryer has been used to create heat transition across the fabric and highlights new colour effects.