Fray, H and Pereda, J

Conductive Circuits

Printmaking with conductive ink

Hannah Fray and Javier Pereda
Printeractive, Design Lab, Liverpool John Moores School of Art and Design
Liverpool John Moores University
www.printeractive.co.uk

This article discusses the role of interactive materials such as conductive and thermochromic inks and how the creation of printed objects can interact with the audience. These technologies push the boundaries of traditional printmaking, taking the print beyond the page, inviting the audience to engage (interact) with the piece. As part of the Design Lab and Print Lab at Liverpool John Moores University School of Art and Design we have been running a series of experiments and workshops with a wide range of artists, printmakers, designers and makers. We began exploring from an interdisciplinary perspective, using printmaking and interaction design to explore how different interactive inks such as conductive and thermochromic inks could change the role of what a print means and how it can be used.

There are a wide range of interactive inks such as thermochromics (heat), photochromic (light) and conductive (electric) inks, among others. Thermochromic inks are water-based inks where opacity can change based on the temperature they are exposed to. For example, some inks can be full black when exposed to cold temperatures below 15˚C, and heat-based ones react when exposed to temperature above 27˚. Other interactive inks have the property of conducting electricity. These type of inks blend a conductive material such as carbon or silver with water. For example, Bare Conductive uses carbon, water and natural resin. Conductive inks are common in circuit boards (e.g. gold, silver), fare tickets and RFID tags without the hassle of etching the printed substrate to print conductive traces on relevant substrates and is typically created by infusing graphite or other conductive materials which can conduct electricity.

A Background in Interactive Materials

Interactive materials such as conductive inks facilitate the introduction of printmaking into digital media, electronics and interaction design. On one hand, artists have explored multi-sensory immersion through touch. *Haecceity* by Tracy Hill (Figure 1) invites visitors to touch the print to activate the piece's sound. For this, conductive ink was screenprinted onto a laminated board, which increased the conductivity of the material and connected to hidden wires in the back of the board, which received the signal from the printed ink. Dalziel & Pow (Dalziel & Pow, 2014) created the *Sound Poster*, a screen panel with characters that, when touched, produces a series of sounds. Gallery visitors are able to print a 'receipt' using a thermal printer. Interacting with materials can also reflect directly on the object itself. Tania Bruguera's 2018–19 installation at Tate Modern uses thermochromic material that changes colour when exposed to people's body heat, revealing a hidden portrait.
On the other hand, conductive materials have also been used to build visual and physical responses as part of interactive systems. Michael Shorter (Figure 2) from Uniform presented in our Printeractive workshop a series of printed circuits on posters that the audience could play music from. --Figure 2-- Finally, Bare Conductive (Bare Conductive, 2018) show how printed ink can be used to conduct electricity to low powered electronics such as LEDs.

These examples highlight the merge of printmaking with digital and analogue technologies, whilst changing the way in which people view, share and engage with printed artwork.

Figure 1. Haecceity by Tracy Hill at Warrington Museum (Hill, 2018)

Figure 2. Michael Shorter presenting an integrated printed circuit on paper at LJMU Printeractive Workshop

Our approach with conductive materials

We developed some experiments using conductive ink produced by Bare Conductive, who developed a business to business (B2B) platform after winning Innovate UK funding in 2010 (Innovate UK, 2016). The ink is a water-based carbon pigment that can be applied to paper, plastic, metal or fabric. We trialled this ink using three printmaking processes: etching, relief and screenprinting. We quickly learnt that the ink viscosity did not lend itself well to processes that required greater consideration and time for inking. For etching, we found that adding the conductive paint to existing ink worked but the dilution lowered the conductivity. The ink responded well to being rolled onto a relief plate but the most successful process was screenprinting.

For our experiments we tested the conductivity of the materials by using a multitester, a device used for measuring voltage, current and resistance. The values that we tested were the resistance levels as seen in Figure 5. This is measured in ohm, which will depend on the used material, as well as size and shape of the object. For example, thin carbon based screenprinted curved lines show a value of 45ohm just after 10 cm, whilst a thicker straight line will have just 0.4ohm at the same distance (Figure 5). The higher the ohm value, the less conductive it is. Knowledge gathered from our initial screenprinting experiments revealed that electronics such as LEDs benefit from continuous lines instead of halftones. We ran other experiments with CircuitScribe pen, which uses a composition of silver, water and resin in a ballpoint pen. We combined this conductive thread and realised that such materials were highly conductive, thus enabling us to power a series of LEDs with a 9V battery (Figure 3 left). Comparing both conductive inks, we found that silver will conduct much more electricity than carbon-based ones. Nevertheless, carbon-based inks can still be used for conducting enough electricity from the human body to the (micro)computer where the interaction is programmed (Figure 3 right).

Figure 3. (Left) Silver ink and conductive thread can power a series of LEDs. (Right) Screenprinted carbon Ink on paper reacts well when activated by touch

We started screenprinting using both a 71T and 90T screen mesh, the ink became incredibly viscous and oxidised quickly. Firstly, we mixed the ink in a cup – something which is second nature when mixing ink for screenprinting – but this seemed too slow in relation to this material as it coagulates quickly when printing. One of the best solutions was diluting the ink directly on the screen using a pipette filled with water, using around a 90:10 ink to water ratio, adding more water liberally when the ink started to coagulate on the screen. This worked well for small edition numbers, producing roughly five prints before the screen started to dry and become unprintable. Different papers absorbed the ink at different rates, we tested medium weight cartridge, Fabriano Rosapina, Arches and Southbank Smooth. We discovered that the less absorbent the paper, the better the conductivity and found Southbank Smooth the most successful (Figure 5).

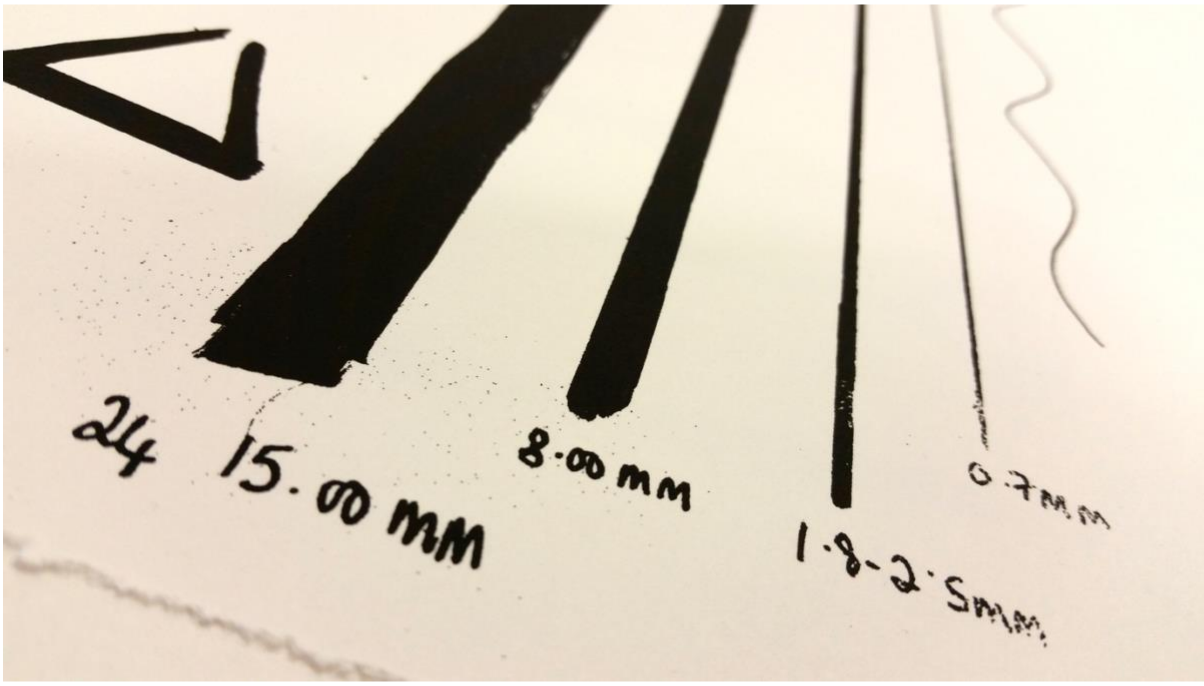

Figure 4. Screenprinted lines for conductive ink resistance testing

Figure 5. Screenprinted conductive ink evaluation of resistance readings

Final thoughts

To conduct electricity effectively with this ink required a heavy layer, with four passes of the squeegee. Nevertheless, silver-based ink provided a better ohm reading. It can be suggested that carbon pigments will work better with human touch connected to self-powered controllers such as the MakeyMakey, Raspberry Pi or Arduino. Such devices can be connected to computers and engage directly with interactive systems by sending electronic currents that can be transformed to keyboard inputs. Finally, such inks can be combined with other reactive, water-based inks to augment the diverse interactions and affordances. What remains is to further understand how printed objects can engage with humans and computers alike. We are now trying to further this research by experimenting with Art and Heritage collections through a series of workshops at museums, galleries and institutions. The current research that we are carrying out at Printeractive in the Design Lab at Liverpool John Moores University is exploring how these interactive materials can be used to trigger a wide range of actions with sensors and microcontrollers. Printmaking becomes central within this approach, whilst changing the creative processes, outputs and ways in which printmaking can be used to produce such artefacts. We are currently trying to change the paradigm of what is a print, this to say an object that goes beyond the page.

Figure 6. Testing the viscosity of Bare Conductive ink through screenprinting.

References

BARE CONDUCTIVE. 2018. *What's Happening at Bare Conductive* [Online]. Available: https://www.bareconductive.com/news/ [Accessed September 12 2018].
DALZIEL & POW. 2014. *Zippy Digital Installations: The making of* [Online]. Available: http://www.dalziel-pow.com/zippy-digital-installations-making/ [Accessed November 29 2018].
GRIFFITHS, A. 1996. *Prints and Printmaking: An Introduction to the History and Techniques*, University of California Press.
HILL, T. 2018. Haecceity. Warrington Museum.
INNOVATE UK. 2016. *Bare Conductive: original paint technology opens a digital world* [Online]. Available: https://www.gov.uk/government/case-studies/bare-

conductive-original-paint-technology-opens-a-digital-world [Accessed November 29 2018].

NORMAN, D. A. 2002. *The design of everyday things,* New York, Basic Books.

THOMAS, P. 2013. *How Uniform created a device that plays music printed on postcards* [Online]. Available: https://www.digitalartsonline.co.uk/features/hacking-maker/how-uniform-created-device-that-plays-music-printed-on-postcards/ [Accessed November 29 2018].