

Bridging the Gap

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Abstract

This paper illustrates some of the outcomes from research carried out by the main author as art jeweller in the Laser Processing Research Centre (LPRC) in the School of Mechanical, Aerospace and Civil Engineering at The University of Manchester. The work shows examples of surface marking of titanium using a 60 W CO₂ 10.6 µm laser for the production of jewellery and observes the effects caused by heat delivered to the titanium substrate. Points are addressed such as the distance created between artist and technology, allowing 'accidents' to happen in a necessarily precise and safe environment and the need for closer communication between disciplines in order to understand the potential of emerging technologies for art and design.

Keywords:

Jewellery, laser, titanium oxide, science

Introduction

"It is up to the engineers and scientists who create these technologies to explain what they have done in a language that can be understood by non experts" (Broers, 2005)

This work described in this paper illustrates a unique journey taken from art practice into engineering research using laser processing for the production of four groups of art jewellery: *Medals, ID Cards, Ocular Series 1-6* and *Fortuny*.

It engages scientific and art cultures into dialogue using both methodologies that contribute to bridging the gap between them, bringing into focus the importance of interdisciplinary collaboration.

Lasers in the studio

Lasers are no longer new technology. It has taken since the 1960s, when they were invented, for the technology to be sufficiently adapted for use in art and design departments. One of the first lasers to be commercialised enough for artists to use was the Nd:YAG welding system. This system was designed to allow the operator to work in direct contact with the material by inserting the hands as well as the work piece into a chamber where all parameters can be altered. A stereomicroscope and crosshair facilitate the positioning of the work piece to the precise location where the laser pulse will strike. The total welding energy can be controlled by adjusting the intensity of individual laser pulses, pulse length and pulse frequency. Operating the laser by foot control means that the operator is free to handle the work piece.

This system revolutionised fine soldering (Rucker, 2009) and opened new opportunities for welding dissimilar metals and for welding close to organic and fragile materials. This is due to the unique properties of light produced by laser (laser radiation) outlined below:

- Monochromacity (radiation that has only one wavelength)
- Coherence (photons travelling in phase)
- Collimation (very narrow, low diffracted beam)
- High brightness
- Short time duration (capability of producing very short light pulses)

In this respect the laser welding system is a triumph for jewellers as it also allows for direct material manipulation, a fundamental part of creative process. Some schools of jewellery have resolved the problem of access and experimentation by installing such a system in the workshops along with the other equipment. In addition many secondary schools and art and design departments are now equipped with CO₂ lasers that will cut a wide variety of

sheet materials. Artists and designers have always looked for new methods of creation to develop their work. Production by laser generates new potential for designs that could not be manufactured by any other means.

The work explained in this paper demonstrates how laser controlled oxide growth on titanium can be used as an artistic tool for contemporary jewellery by producing defined colours (O'Hana et al, 2008). This is mainly carried out on a 60 W CO₂ 10.6 µm laser on a base material of commercial Ti-6Al-4V alloy plate.

The titanium work piece is placed on a honeycombed bed in ambient air and a Universal X-660 Laser Platform fitted with a pulsed 60 W CO₂ laser is used to treat the surface. This freestanding unit comprises the laser, an X-Y beam positioning system with 0.81 × 0.46 m work area, interchangeable focusing optics, extraction and computer interface. The laser beam was focused by a 50mm focal length lens in an enclosed lens cartridge to a spot of diameter 0.15 mm at the work piece.

Titanium colour

Titanium was introduced to jewellery departments in the UK in the 1960s, coincidentally at the time when lasers were first being demonstrated. Its unyielding qualities make it hard to work with for jewellers but as Bartlett (2006) has shown, those that persist do so mainly because of its colouring potential. This is not an application of pigments but an oxide layer caused by the application of heat or by anodising. The colour that can be observed on anodised titanium is an optical phenomenon known as interference (Walton, 1984) where the metal surface and its microscopic film of oxide (caused by applying heat or anodising) reflect light. As white light rays enter the oxide film it is broken up and refracted from the metal surface back through the oxide layer as multiple reflections into the eye. It is the different thicknesses of oxide that cause the film to appear as different colours. Heat from a laser beam can also be used to create oxides on the titanium surface. This has been demonstrated both from an artistic perspective (Carey, Steen and Watkins, 1998) as well as from a scientific one (Pérez del Pino et al, 2004).

Medals

The titanium was first sandblasted and tilted on the laser bed as a method of avoiding back reflection of the laser beam back into the system and sprayed with graphite for increased conductivity of energy to the substrate. Some of the graphite was removed from the surface to reveal part of the underlying titanium substrate prior to marking with an average parameter of 42 W at 530 mm/s. The colour variation seen in Figure 1 is caused by the tilt of the titanium and consequently of the beam going out of focus as it traverses the metal substrate.

The medals are marked with readily available, digital graphic symbols and housed in a frame of acrylic cut on the same system. Symbols rank amongst our oldest and most basic inventions but effectively conveying a precise, instant message is very much a demand of the digital age. The interdisciplinary team carrying out the work observed how at the point of contact through the graphite layer the titanium became heavily corroded. Far from considering the visible erosion a problem, the effect was welcomed as an unexpected result and became a potential marking method for future work. This curious exchange of culture methodology and reaction became critical for the development of work throughout the research and the message it became concerned with.



Figure 1. *Medal*. 2005. Titanium, acrylic, security clip. 50 mm x 105 mm

'ID' Cards

The *Identity Cards* are a result of the discussions and, often transient, conversations of this research. The importance of drawing is often overlooked during the necessary programming that lasers require. The very technology that this research aims to understand for the benefit of art and design cultures steers the hand away from the sketchbook or, more precisely, away from the pencil, creating a worrying redundancy for the hand. "Hands get shaped", wrote McCullough, "They may get callused or stained. They pick up experience." (McCullough, 1998). Without this experience, this handling, how can we understand material behaviour? This applies in equal measure to drawing. The *Identity Cards* are marked with details of the author's current drawings to focus on the expression that a simple gesture captured from a multitude of other marks can have. It also attempts to replicate the subtle and gradually fading nature of the hand made mark which, in contrast to the digital environment, can be anywhere between 'on' and 'off'.

Figure 2 shows how the *ID Cards* were cut to credit card proportions to purposefully fit the plastic holder typically used for security passes. The colour variations obtained on the titanium are partly due to the tilt applied at one end, but mainly to the concentration of points appearing on the image after conversion to Bitmap (BMP). Signals from the BMP file are received by the laser that mark each individual 'bit' in the image with an average parameter of 57 W at 132 mm/s and repeating the process three times. Heat generated by the laser beam is increased in proportion to the concentration of 'bits' in the image. This causes the colour to change accordingly from pale straw colours, where the points are spread thinly, to pale blue where the points are densely packed and where more heat is accumulated from the laser as a result.

Different cultures may identify with different aesthetic values. The *ID Cards* explore details of drawings taken from sketchbooks on one side and, on the other, numerical data taken from other work. They are designed to allow the bearer right of entry to both art and science communities. For this reason they

are two sided and reversible, being wearable by either culture as a 'pass' into the other.



Figure 2. *ID Card*. 2005. Titanium, security card holder. 85 mm x 55 mm

Ocular Series 1-6

This series encapsulates the collaboration of this research in six pieces, of which one is shown in Figure 3 (b). It illustrates the positive aspect of working with the technology and its software alongside the hand made, it opens new levels of materials understanding through the use of microscopy and it further engages with scientific and engineering cultures by the dissemination of artistic applications to scientific audiences (Pinkerton, O'Hana and Shoba, 2007). Transfer of images taken from drawings, hand writing and fingerprints are used in this series as well as programmed geometric patterns making full use of parameters that enable the colour spectrum of titanium to be visible. Figure 3(b) shows a sample of original handwriting converted to BMP that is transferred to the titanium surface using average parameters of 57 W at 132 mm/s.

The *Ocular Series* makes use of reclaimed lenses and is modelled on the notion of eyesight correction and the essential use of both eyes needed for stereopsis. The objects invite the viewer to peer through, to examine in detail, to inspect further - actions associated with the scientific activity and the

laboratory environment where the research took place. They also aim to clarify vision, encourage discovery, alter perceptions or simply appeal to the wonder of magnification.

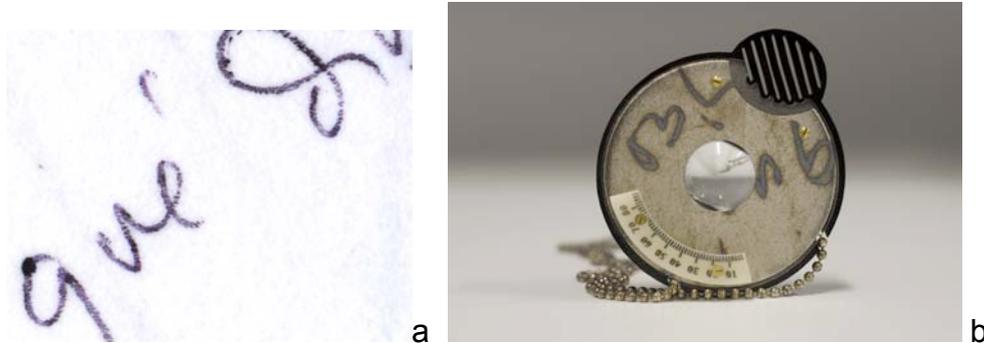


Figure 3 (a) Detail of handwriting; (b) Transfer of handwriting by laser to front of *Ocular 3*. 2006.
Titanium, acrylic, recovered lens, silver.

The series includes the use of acrylic, a material that responds particularly well to cutting and marking by CO₂ laser. It is used extensively in the applied arts and contemporary jewellery industries as the laser offers a precise, clean cut, instantly dispensing with the need for post-production polishing.

The acrylic offers a frame by which to handle the work without having to necessarily touch the metal. The design for all of the pieces relies on a casing of acrylic that is cut and rastered (removal by vaporisation of material over a given area), using the same laser. The rastered area, illustrated in Figure 4, allows the titanium to sit level within the casing.



Figure 4 2006. Acrylic casing for *Ocular Series 1-6*

Two specifically shaped channels were cut into the acrylic ensuring the safe anchoring of silver ball chain needed to complete the item as a pendant.

Fortuny

These pieces are based on the work of textile designer Mariano Fortuny (Bottomley, 2007) and attempt to replicate not just the colours used in Fortuny's original textile prints but also to convey the evidence of hand printing and the aged textured surfaces of the designer's fabrics. Could the hand-drawn characteristics of Fortuny's templates be represented on the titanium, yet retain the illusion of being digitally perfect? As with all technologies it is important to understand the properties of laser. It is difficult to realise this unless the artist is in direct contact with either the machine or with an experienced and sympathetic operator. There has been a continuous attempt to retain some imperfection in the objects created by this study, mainly to counterbalance a technology that is programmed for digital perfection. Consider this statement by art jeweller Sebastian Buescher:

"Imperfection Please is a state of mind, a concept, and not just a theme for a collection of work. Its core consists of experimentation, venturing into new territory, focusing on the process and not getting disappointed because an expected goal is not achieved. And while perfection aims to be perfect, a dangerous game that is destined to fail, imperfection is freedom, completely and totally, unique and unexpected. It is about doing things differently and not conforming to existing standards. Each jewel becomes a fragile reminder that sometimes we can break, that sometimes we cannot pull ourselves together and that sometimes we feel utterly flawed, totally imperfect, in a world that bombards us with images of perfection." (Buescher, 2008)

The *Fortuny* series is a good example of how the hand made process can be programmed, in the same way that fingerprints can be left in a cast object to make the process appear entirely hand made. Getting to know any machine

or process can bring the operator and their work closer together – rather like driving a car. Understanding how an engine works is likely to make the driver use the gears more efficiently. For example, if the designer knows that the heat affected zone (HAZ) on acrylic is likely to happen on a specific part of the design, it is possible to program the laser to process the material in a different order to that which it would automatically do, thus reducing potential heat damage.

In the case of Figure 5, a rare example of a mistake has been ‘allowed’ as a welcome change from the predictable outcome of a pre-designed, carefully programmed file. The shift in pattern, due to moving the titanium plate in between file delivery of the laser, has created apparent shadows around each shape giving the pattern a three-dimensional appearance.

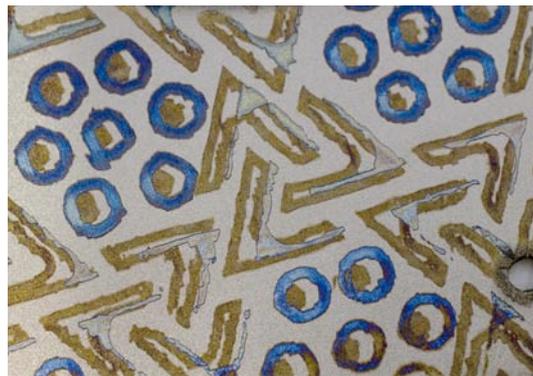


Figure 5 *Fortuny 3* (detail), 2007. Titanium.

Beneath the visible surface

Analysis of the titanium and the oxides created on its surface was carried out from particular colours on a marked test piece, shown in Figure 6 (a). Examination of these oxides under a scanning electron microscope (SEM) showed that the surface topography had been significantly altered by the laser treatment. Whereas there is little change in the original surface geometry seen in samples processed at the lowest line energy (defined as mean laser power divided by traverse speed), a significant change is seen at higher line energies where some surface cracks can be seen.

Figure 6 (b) shows the untreated titanium substrate in area 1 of the image, a band corresponding to the dark outer circle (using parameters of 60 W, 166 mm/s) in area 2, and area 3 with visible cracking corresponding to the colour within the circle (using parameters of 60 W 20 mm/s 1000 ppi). The series of 'craters' that mark the edge of the coloured circle are caused by the initial power surge of the laser beam.

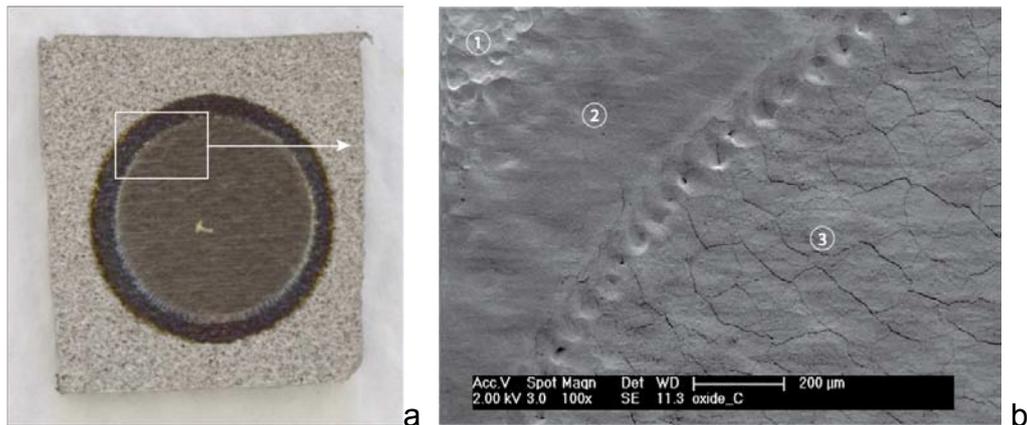


Figure 6 (a) Marked section from sample oxide;
(b) SEM image of marked section

The cracks can be attributed to the tension induced by the constraining effect of the underlying layer during surface thermal contraction. Higher line energies and consequent initial expansion at lower traverse speeds and higher laser powers thus leads to more final contraction and damage.

Final thoughts

Laser processing allows for speed and repetition in cutting and marking materials that cannot be equalled by hand. However these are not always advantages for its use in one-off artwork production. *Fortuny 3*, detailed in Figure 5, a bracelet of 135 mm in diameter, took two and a half hours to mark – and infinitely more to program – so that speed is not always a guiding factor. Heat delivered to the titanium bracelet was sufficient to warp it causing the beam to defocus. In addition, cutting the titanium with the available laser systems was problematic so that some work was cut by water jet. Access, also continues to be difficult - unless the artist is based in an institution with available laser systems - as their expense prohibits time for the necessary

'free' testing essential in the creative process.

The most important quality delivered by laser for this research is precision and control. The sensibility of a final piece lies in the artists' ability to control the process. In the same way that a typewriter does not create an author out of its owner, a laser requires imagination by its user in order to take ownership of the process rather than be led by it. The technology should be invisible through imagination, ingenuity and originality.

This research demonstrates how laser controlled oxide growth on Ti-6Al-4V alloy under ambient conditions can be used as an artistic tool by producing precisely defined colours but underlying this work is a call for interdisciplinary collaboration. A closer interaction between arts and sciences would enable a greater understanding of emerging materials (Conreen, Laughlin and Miodownik, 2007) as well as an increased value placed on the creative process. This research continues to address concerns of art / science communication, believing that an exciting pool of creativity and problem solving for both cultures can be found at this interface.

“Artists are passionate about materials and, like scientists, are expert in asking interesting questions. That makes them excellent collaborators in any project to keep materials science departments vibrant and creative places”

(Miodownik, 2003)

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