Digital Mapping of Differential Oxidation Arising from Fingerprint Sweat Deposits on α-Phase Brass

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Abstract: Visualization of differential oxidation on phase brass, subject to heating to temperatures of up to 600°C, is shown to be enhanced by selective digital mapping of colors reflected from the surface of the brass using Adobe® Photoshop®. Enhancement is optimal when the brass is heated to ~250°C with areas of oxidation having a mirror like appearance. The use of this enhancement method to visualize fingerprint sweat deposits on brass cartridge cases is demonstrated.
Keywords: latent fingerprint, print visualization, metal corrosion, digital mapping, forensic science

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Introduction

That human sweat can corrode metal has been known for some time [1] and, in a forensic context, has been alluded to recently by Champod et al. [2] when discussing fingerprint detection on brass cartridge cases. Champod et al. state that "latent marks on brass cartridge cases may sometimes spontaneously develop over time due to a process of differential tarnishing." What is being described is surface corrosion of the brass by the fingerprint sweat deposit. This leaves a thin (on the order of tens of nanometres) layer of oxide that follows the outline of the finger ridge pattern originally deposited in sweat.

Whilst human sweat can corrode a variety of metal elements and alloys [3], the example cited by Champod et al. (a cartridge case) has attracted much attention in recent years as visualizing latent fingerprints on discharged cartridge cases is problematic, due to a variety of reasons. Given [4] found that latent fingerprint degradation on cartridge cases was not uniform over the entire surface and was most prominent in a small area that had been subject to gaseous blowback. According to Given, gaseous blowback can occur on a small area of the external surface of the case not completely sealed against the chamber wall and therefore exposed (in the gun chamber) to the products of combustion from the firing process. Further, Given stated that the case will expand due to increased pressure during firing, which will increase the abrasive friction during the extraction process of the case from the chamber.

Clearly, the difficulty that conventional techniques have in enabling visualization of fingerprints on discharged cartridge cases would alone provide sufficient grounds to warrant researching fingerprint corrosion of metal.

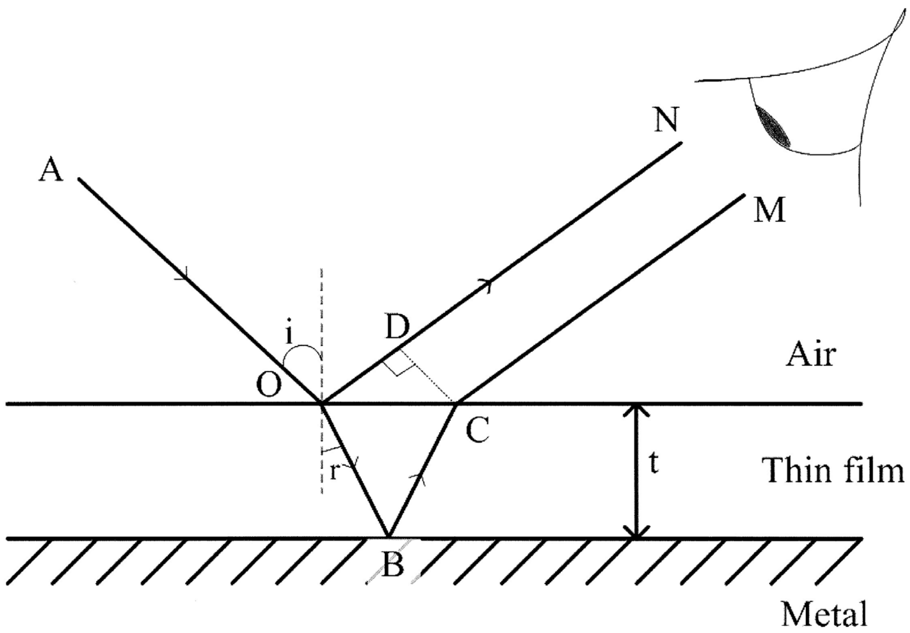

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Figure 1: Optical interference in a thin film caused by an optical path difference between rays reflected and refracted at the air-thin film surface.

Lately, Wightman and O'Connor [5] have investigated the visualization of fingerprints deposited on planar brass, aluminium and stainless steel disks that were heated subsequently to temperatures between 200°C and 900°C. They confirmed results from earlier work related to fingerprint visualization on heated metals [6]with, frequently, no additional enhancement being necessary in order to visualize the fingerprint ridge characteristics. They postulated that visualization occurred due to differential oxidation, that is, the fingerprint sweat acted as a barrier to oxidation on those parts of the metal surface covered by the sweat. Wightman and O'Connor believed that visualization was enhanced by interference colors resulting from a thin oxide film on the metal surface not covered by the sweat.

Enhancement through optical interference has been observed previously for fingerprints deposited on brass disks in Iraq [7], where, relative to the UK, the higher air temperature (UK = 18 ± 5°C, Iraq = 32 ± 7°C) and lower relative humidity (UK = 68 10%, Iraq = 17 6%) resulted in a zinc oxide layer that produced optical interference as the viewing angle of the disk was adjusted in natural daylight.

Such optical interference occurs in thin films when, for a given wavelength, the optical path difference between rays reflected and refracted at the air-thin film surface differs by half a wavelength, as shown in Figure 1.

From Figure 1, it can be deduced that constructive interference occurs when [8]:

$$2nt\cos r = (m-1/2)\lambda \qquad \text{(Figure 1)}$$

where n is the refractive index of the thin film of thickness t, r the angle of refraction, m an integer, and λ the wavelength.

From an extended light source such as natural daylight, a thin film would produce the change in colour with viewing angle that was observed for fingerprints deposited on brass disks in Iraq [7]. Taking the refractive index of a thin film of zinc oxide to be 2 [9] and a range of viewing angles between 10° and 80°, for peak perceptive efficiency of the human eye (550 nm) t evaluates to 70 nm ≤ t ≤ 80 nm [7]. This range of t is consistent with values reported for the thickness of zinc oxide formed during the electrochemical corrosion of phase brass in an aqueous saline solution [10].

Optical interference and differential oxidation therefore present non-invasive methods of visualizing fingerprint deposits and fingerprint corrosion on metal, which can have benefits over techniques that require physical or chemical interaction with the fingerprint or substrate.

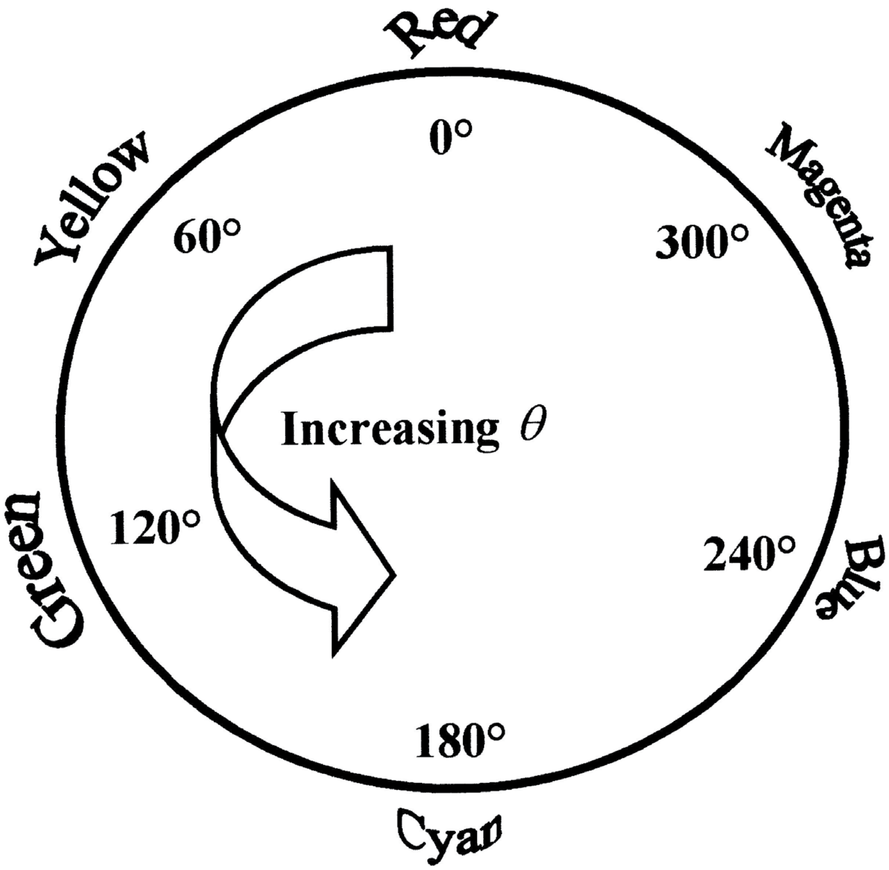
In this article, we examine how the visualization of differential oxidation on heated phase brass can be enhanced by digital mapping of colors reflected from the surface of the brass. We identify the temperature to which the brass needs to be heated to achieve an optimum enhancement in visualization by this method. Digital mapping of colors is then applied to brass disks subject to fingerprint deposition and subsequent heating and finally to brass cartridge cases where fingerprints were deposited pre-firing. Digital color mapping is shown to produce a faithful image of the fingerprint ridge characteristics on brass cartridge cases.

Mapping of colors is a process that may applied from a consideration of a color spectrum or wheel in which the three primary colors (red, green and blue) are separated at 120° intervals around a 360° wheel, Figure 2. In the color wheel, three secondary colors (yellow, cyan and magenta) are each spaced midway between two primary colors. Mapping can occur by moving a given color (or angle) to another color (or angle). In practice, this may be achieved by the use of an interactive color wheel computer program in which, for example, hue is based on a 360° color wheel [11].

Methods

Initially, differential oxidation was explored by heating 1mm thick 25mm diameter phase brass disks (68Cu-32Zn by percentage weight) onto which another brass disk had been partially overlaid. The additional (overlaying) brass disk provided an area that prevented oxygen from the air reaching the disk surface but which would reach the same temperature as the disk during heating. Disks were heated to a temperature (T) of between 50°C and 600°C in 50°C intervals. Each disk was held over a Bunsen flame until the required temperature had been reached (typically a few minutes). Each disk was then allowed to cool in air. The temperature was measured by means of a K-type thermocouple placed in contact with the disk (Hanna Instruments, Leighton Buzzard, UK). The experiments were then repeated with a fingerprint deposit replacing the overlaying disk, five donors each providing a fingerprint for each temperature which gave 60 samples in total (12 temperatures x five donors). In the month of June in the UK, fingerprints were deposited by pressing a finger onto the brass surface for 1-2 seconds with a light pressure sufficient to ensure contact between the finger and brass. Whilst no attempt was made to regulate the amount of pressure applied by individuals, this procedure was intended to produce reasonably uniform deposition. All fingerprint donors washed their hands with soap and water twenty minutes prior to depositing fingerprints.

Figure 2: 360° color spectrum or wheel.



Finally, 40 brass 9mm pistol cartridges were washed in distilled water followed by a wash in acetone and finally another wash in distilled water prior to drying with a paper towel. Each cartridge was handled by one of 40 donors in order to leave one or more fingerprints on the cartridges. The cartridges were then loaded into magazines, which were inserted into a pistol and discharged. When fired, each cartridge case was automatically extracted and ejected.

Digital color mapping was performed using Adobe® Photoshop® CS4, version 11.0.

Results

Overlaid disks showed varying visibility of the area beneath the overlay, which depended on the temperature reached by the disk. For disks where T > 300°C the area of overlay was clearly visible. For T <300°C, disks were photographed in natural daylight (but not direct sunlight) and the resulting images analyzed with the Hue/Saturation dialog box in Adobe® Photoshop®. Specifically, the overlaid and non-overlaid areas on each disk were color deconvoluted using the red, green and blue (RGB) color model [11]. With 32 bit mapping, the red, green and blue contributions to the reflected light showed little variation between the two areas for 50°C T 200°C. The largest variation occurred for T = 250°C where (on a scale of 0 to 1), R:G:B was 0.83:0.86:0.83 and 0.82:0.8:0.34 for the non-overlaid and overlaid areas respectively. Thus (with T = 250°C) the blue contribution was less for the overlaid area. This is what might be expected as the overlaid area would (through differential oxidation) exhibit less oxidation and therefore retain more of the natural yellow appearance of metallic brass with red and green giving the reflected yellow colour [5, 11]. The non-overlaid area appeared to have a mirror-like finish with a white appearance when viewed obliquely. Again, this white appearance would be expected as the R:G:B values were similar. Oxidized brass with this appearance was also observed by Wightman and O'Connor (5), which they referred to as the brass 'turning silver'. Wightman and O'Connor also found a decline in fingerprint visualization between 200°C and 280°C [5].

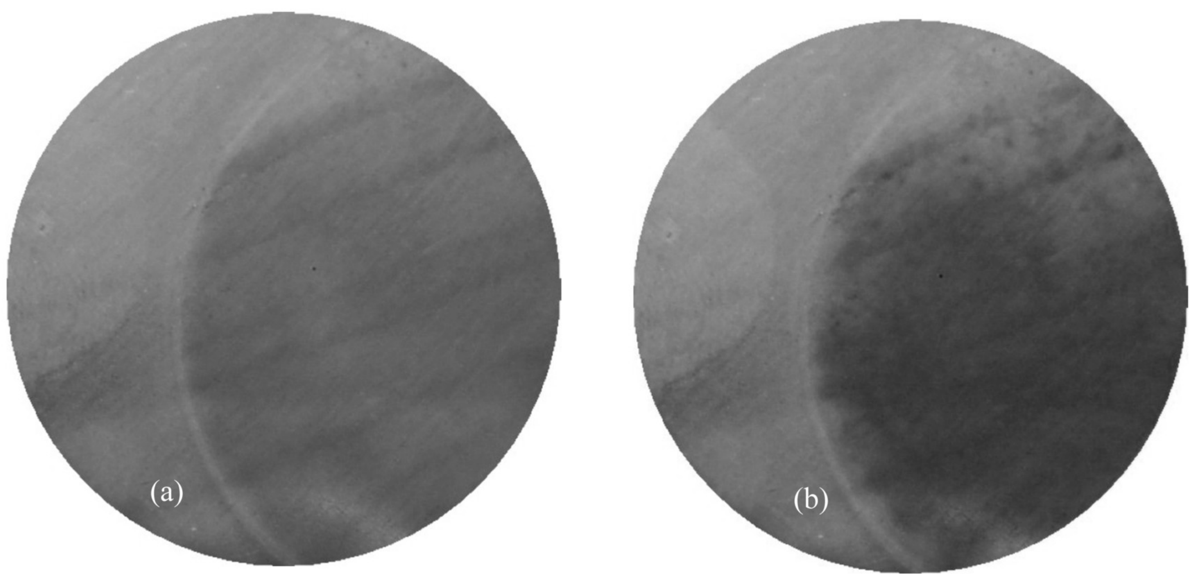


Figure 3: Brass disk heated to T = 250°C. The overlaying disk (removed) lay to the right of the disk. (a) shows the disk before and (b) after digital color mapping.

To seek to improve the visualization of the overlaid area, the yellow part of the spectrum was color mapped on the T = 250°C disk. As the Hue values in Adobe® Photoshop® are based on a 360° color wheel, mapping was undertaken for 45° 75° where is the color wheel angle (Figure 2). It was found that optimum enhancement in

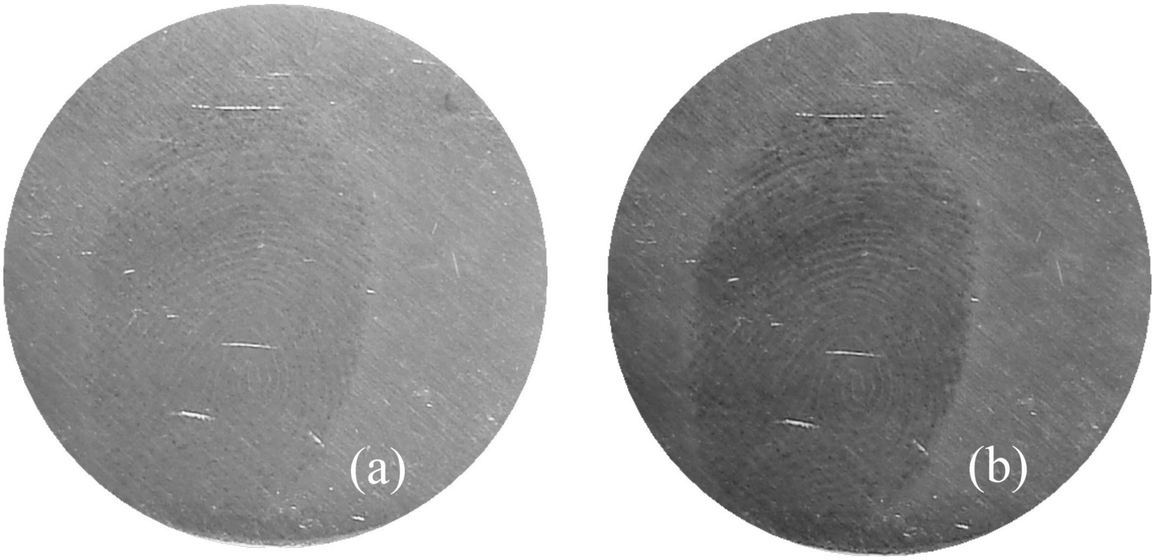


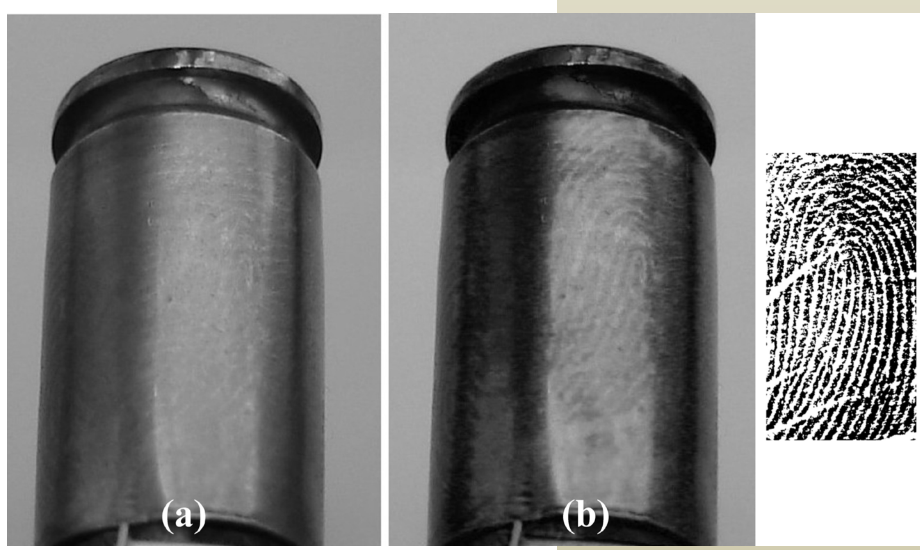
Figure 4: Fingerprint deposited on a brass disk heated subsequently to T = 250°C. (a) shows the disk before and (b) after digital color mapping.

visualization of the overlaid area occurred for a change of of –60°, that is mapping to the red part of the spectrum. Figure 3 shows the overlaid disk heated to 250°C (with the overlaying disk removed), before and after mapping. It can be seen that there has been some creeping of oxidation under the overlaying disk, which, clearly, would be a problem if this were to occur when seeking to enhance and identify fingerprint ridge characteristics by mapping. This is considered later.

Experiments with a fingerprint deposit replacing the overlaying disk gave similar results with all five disks heated to T = 250°C producing the most improved visualization, Figure 4 showing a typical disk for T = 250°C before and after color mapping of $45° \leq \theta \leq 75°$ by a change of θ of –60°. Here, there is no obvious creep of oxidation into areas of disk covered by the fingerprint sweat deposit (as was observed in Figure 3) and it is likely that the fingerprint sweat provides a better seal to the surface of the brass than an overlaying disk.

Of the 40 discharged cartridge cases, six showed signs of fingerprint ridges and, for four of these, the ridge detail appeared in an area that manifested the mirror like appearance described above. Observing fingerprints for this number of discharged cartridge cases is consistent with previous work [6]. All six cases were photographed in natural daylight (but not direct sunlight) and the color mapping referred to above applied. The four cases displaying the mirror like appearance all showed an improvement in fingerprint ridge visibility, Fig. 5 showing a typical example. It can be seen from Fig. 5 that the fingerprint covers an area that runs along the length of the case. Consistent with the fingerprints deposited on planar disks, there is no evidence of oxidation creeping into areas covered by the fingerprint sweat deposit. The inset in Fig. 5 is of an inked impression of the fingerprint in Fig. 5 with which a registered expert confirmed the commonality of ridge characteristics between the color mapped image and inked impression.

Figure 5: Fingerprint deposited on a brass cartridge casing pre-firing shown post firing. (a) shows the casing before and (b) after digital color mapping. Inset: an inked impression of the fingerprint.



Conclusions

We have shown how the visibility of differential oxidation on heated brass disks can be enhanced by selective digital color mapping of the yellow part of the visible spectrum. The enhancement obtained is optimal when the brass is heated to ~250°C with areas of oxidation having a mirror like appearance. The use of this enhancement method to visualize fingerprint ridge characteristics has been demonstrated. The success of this technique would seem to depend critically on the degree of oxidation of areas not covered by the fingerprint sweat deposit and the thickness of the resulting metal oxide thin film. Future work could usefully investigate whether this technique is likely to work with reloaded ammunition, in which the surface of the brass case is already oxidized and also whether there is any correlation between time of deposition and survivability of a fingerprint on a cartridge case. That is, is the fingerprint more likely to be visualized if deposited (say) one week before rather than immediately before discharging the weapon?

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