A preliminary study on vacuum metal deposition as a standalone method for enhancement of fingermarks on ballistic brass materials

ABSTRACT

In order to assess the efficacy of vacuum metal deposition as a technique to develop fingermarks on ballistic metallic surfaces, a preliminary study using 6 donors (3 male & 3 female) was conducted. Using a sequential metal deposition process, two metal combinations were studied – gold/zinc and silver/zinc. Results indicate the potential of this technique, by developing identifiable fingermarks on brass metal discs aged from a few days up to more than a month old. As the development of fingermarks on fired (brass) cartridge cases is an area of interest, a further study was conducted where a total of 20 fingermarks were deposited on cases. After firing, second level fingermark characteristics were successfully observed on cartridge cases highlighting its potential as a fingermark enhancement method for ballistic brass materials. Further work is required to fully evaluate the VMD process and its reliability as a fingermark enhancing method on ballistic surfaces.

KEYWORDS: Forensic science, vacuum metal deposition, fired cartridges, fingermarks, fingerprints, ballistics

Vacuum metal deposition (VMD) is a fingermark enhancement technique that is used in police casework (1), but is a relatively unexplored technique in relation to metallic surfaces. It is a thin-film deposition technique in which a source metal is vaporized in a vacuum, in order to coat a substrate. The technique has been long established in the industrial application of metal coatings for articles such as mirrors (1). The use of VMD as a tool for the forensic enhancement of latent fingermarks was first proposed in 1968 (1), however a substantial number of years passed before it would be considered as a viable enhancement technique. VMD was initially introduced in the forensic field to detect fingermarks on paper (2), and was then optimized to be fully operational in the late 1970's. The method involves placing the item to be treated inside the deposition chamber which is sealed/operated at a high vacuum, typically larger than 3 x 10^{-4} mbar. The chamber contains tungsten boats for the containment and heating of the selected metal to be deposited and a window to allow the operator to monitor and control the deposition process (1, 3). The most commonly used metals in the VMD treatment of latent fingermarks are gold/zinc, gold is applied first, followed by zinc (1). After the vaporization of gold, gold atoms cluster together forming agglomerates, which may penetrate some constituents of the fingermark residues (Fig. 1). Zinc is then vaporized, which preferentially deposits on the exposed gold agglomerates (4) rather than on areas where these are embedded in the latent fingermark deposit. The zinc is binding to the fingermark furrows and not the ridges of the print (Fig. 1). The fingermark developed is a negative one with the furrows covered by the gold and zinc appearing grey. Positive development of fingermarks can also occur. It is thought that positive development occurs in samples where the fingermarks are rich in fatty components or other contaminations (i.e. grease) (6, 7). Other metal sequential deposition protocols for VMD can also include silver/zinc, sterling silver, copper/zinc and copper. The metal combinations studied here, are considered to be most utilised (5,6,7,8).

One of the greatest advantages of VMD includes its versatility, including its suitability for a wide range of substrates, including wetted ones (2). VMD is also ideal to use as a sequential treatment, as it does not damage any DNA that may be present in fingermarks (8) (since it targets the metallic substrate and not the fingermark itself), and works well with other conventional fingermark enhancement techniques such as cyanoacrylate fuming (7, 8). Drawbacks of VMD include the cost of the equipment, and that the quality of enhancement relies upon the experience of the operator to determine the optimum time at which the process should be halted to prevent overdevelopment of fingermarks. The cost of the deposition metals is minimal due to the minute quantities needed for each process. Over recent years, studies have focused on using VMD on fabrics (5, 8, 9) with some success. The introduction of polymer banknotes in some countries has sparked a resurgence in VMD research, in an attempt to enhance fingermarks on this difficult surface (9).

The motivation behind this research stems from the lack of studies on employing VMD on metallic surfaces as a standalone technique, and also the scarcity of reliable techniques for the development of fingermarks on fired cartridge cases (10). A study by Fraser et al. (11) showcased the increased efficacy of VMD compared to cyanoacrylate fuming on smoother almost non-porous fabrics (such as nylon), however this finding might hold true for metallic surfaces also (which are non-porous surfaces). The only peer reviewed literature studies using VMD for metallic surfaces was by Dafydd et al.(12) and Tiwari et al.(13). In the former study they used Scanning Kelvin probe in conjunction with VMD for latent fingermark visualization, while in the latter the authors focused on optimizing the deposition protocols for fingermark enhancement on aluminium surfaces.

This preliminary study addresses utilisation of gold/zinc and silver/zinc protocols for the enhancement of latent natural fingermarks on brass metal discs, exploring the potential of the method for groomed fingermarks on fired brass ammunition, a topic of great interest for forensic examiners.

Materials and Methods

Fingermark deposition

Six donors were employed for the first part of this study (3 male, 3 female), and written consent was acquired after the purpose of this study was explained. Ethical approval was granted for this study by the Liverpool John Moores University ethics committee (17/PBS/002). The criteria for this preliminary study was achieving a balance between male and female donors since it has been debated that the gender of the donor can play a role in the composition of fingermarks (in some studies male donors tended to have higher concentration of fatty components in their fingermark residue) and consequently in their enhancement (14, 15). The age of the donors was between 25-30 years old, within this age limit there were no particular differences observed in fingermark composition (14). The donors were asked to wash their hands with soap and water and resume their normal daily routine for 30 minutes before depositing any fingermarks as it is the standard procedure for generating natural fingermarks (16, 17). The donors' daily normal routine revolved around desk based work using a computer. The deposition was performed by placing simultaneous fingermark impressions from the right thumb across two brass metal discs. This was done to ensure the same fingermark was examined with the two metal deposition protocols as proposed by Sears et al. (16). The discs (3cmx3cm) had been previously cleaned with 5% v/v Decon 90 solution, followed by ethanol and left to air dry. Each donor deposited 12 full fingermarks (which is an adequate number for a preliminary study (17)) which were divided into four even groups according to the number of days they were left to age before development (2, 7, 14, 35 days old), the aforementioned time ranges were chosen based on fingermark research and guidelines in the literature (16, 17). The discs were stored under dark and dry conditions, with temperatures ranging from 15-20°C and were only accessible to the authors. The simultaneous natural fingermark impressions were treated with two different vacuum metal deposition protocols, namely, Gold/Zinc and Silver/Zinc. Each run on the VMD lasted approximately 10 minutes, with the duration (of each run) varying slightly between samples due to inherent donor variability (although sample fingermark deposition and collection protocols for all donors was the same). The gold and silver wire used for each run was of length less than half a centimetre. The apparatus used for all experiments was a VMD900 Metal Deposition System from West Technology. Blank cleaned discs were run with VMD to assess any deposition artefacts on the brass surfaces which may affect any fingermark evaluation. No impact on the results was noted.

Brass cartridge cases (.38 Special) were cleaned with a 5% v/v Decon 90 solution and ethanol. Each donor (2 male, 2 female -male and female donors 1 and 2 from the initial brass discs study) deposited a single groomed fingermark on 5 cartridges (groomed procedure same as for natural marks including rubbing of forehead and nose areas as per IFRG guidelines) (17). The cartridges were fired using a .38 Smith and Wesson (S&W) revolver. This weapon was chosen due to the larger case surface area of the ammunition enabling full fingermark deposition, and discharged 5 days after the deposition of the fingermarks (the shooting time was based on the availability of the firearms services). The loading and collecting of the cartridges was completed whilst wearing gloves. In this instance groomed fingermarks on cleaned cartridge cases were employed to increase the chances of fingermark residue adhering on the cartridge after firing. The employment of groomed fingermarks is considered acceptable for pilot studies (17).

Ridge detail grading

Developed prints were graded according to the scheme given in Table 1 (18). All gradings were carried out by the first author initially (who was involved in the experimental part of the study), and done by examining the mark on the casings using a magnifying fingerprint glass. The photographs of all impressions were taken with a NIKON D7100: Camera mode: Manual, Shutter Speed: 1/250, Aperture: Wide open (f/1.4), ISO: 3200, White Balance: Auto WB, Autofocus: AI-Servo, Drive Mode: Continuous, Metering: N/A, Image Quality: raw were also used for this purpose. No enhancement photo software was used. Independent blind grading conducted by a second trained fingerprint examiner was undertaken (an author with 25+ years fingerprint casework experience, who was not involved in the experimental part of the project). Both were graded independently and both set of grades were in agreement. All fingermarks were labelled with an alphanumeric code to prevent potential bias, and to protect the donors' privacy. In all photos no scale was used due to the known dimensions of the objects, and due to the fact that the photos were not used to compare the size of the items.

Results

One male (male donor 1) donor -of the total 6 donors- (Fig. 2(a) &2(b)) produced fingermarks that were of identifiable quality throughout all of the different aging times time intervals. One female donor (female donor 1) (Fig. 2(c) &2(d)) failed to deposit any fingermarks that could be developed by either deposition protocol.

Fingermarks from male donor 2 were more receptive towards the Silver/Zinc metal deposition protocol (Fig. 3 (b)). Female donor 3 mostly produced ‘’empty ’’ fingermarks but in some cases ridge detail enhancement was achieved (Fig. 3(d)).

Male donor 3 mostly produced ‘’empty ’’ fingermarks but in some cases some ridge detail enhancement was possible (Fig. 4(b)). In these instances, it could be inferred that fingermarks from certain donors (female donor 1 and male donor 3) may not be ideal for the VMD.

Female donor 3 had not produced an identifiable fingermark on earlier time intervals, however at 35 days an identifiable fingermark (Fig. 5(d)) was developed. It seems that the effect of time on fingermarks might be complex, meaning that a fresh fingermark will not necessarily be developed any easier than an older fingermark when VMD is used.

Fingermarks which contained second level detail – ridge characteristics - were developed on fired cartridge cases (Fig. 6a, 6b, and 6c). The fingermarks were deposited 5 days prior to firing the cartridge. Out of 20 fingermarks only 3 (deposited from male donor 1, the same donor as in the brass discs experiment) displayed some sort of second level characteristics when enhanced. Although the sample size was small, it indicates that there is a possibility to enhance fingermarks that would be of a quality high enough to perform identification of a suspect.

Below (tables 2&3) the grading of the fingermark developed on brass metal discs using two different metal deposition protocols can be seen.

The fingermark grades data was checked for normality (using the Kolmogorov-Smirnov test) and it was found that it does not follow a normal distribution (as expected when using a non-linear scale), the grades of fingermarks developed with Gold/Zinc and Silver/Zinc were divided in to two groups and tested with a Mann-Whitney test. The result shows that there is no significant difference (p~0.4, confidence interval 95%) in the quality of developed fingermarks when using one of the two metal deposition protocols. Table 4 shows the grades of the fingermarks deposited on fired cartridge cases using Silver/Zinc, based on the results from the brass disc experiments.

Discussion

The work described here, indicates that successfully enhancing latent fingermarks on a flat brass surface with VMD depends on the donor of the fingermark. Out of 6 donors, only one male donor produced fingermarks that could be developed to an identifiable level throughout all the different time intervals. The overall quality of the fingermarks developed by male donors and by using the Gold/Zinc and Silver/Zinc protocol seems to be higher and statistically significant than the fingermarks from female donors (Mann-Whitney p~0, confidence interval 95%), but the lack of data due to low donor numbers limits the value. The statistical analysis of fingermarks developed by Gold/Zinc and Silver/Zinc show that overall, there is no significant difference in the quality of the enhanced fingermarks. However, it should be noted that certain donors responded better to one of the two metal deposition protocols, namely male donor 3 and female donor 3 produced identifiable fingermarks with the Silver/Zinc deposition protocol. Fingermarks that were aged up to 35 days were only identifiable when developed from male donor 1, and female donor 3. Further work is recommended to assess the aging process of fingermarks in relation to VMD enhancement.

The results on fired cartridge cases shot by a .38 S&W revolver demonstrate that VMD is capable of producing fingermarks that have second level characteristics (bifurcations, ridge endings etc.). When applied to casework, such detailed fingermark development may prove problematic due to the degradation of the fingermark residue on a cartridge case that would make the development of a clear ridge detail pattern more challenging. Moreover, the use of VMD processes impacting on other evidence types needs to be considered (e.g. case striation marks). This study has also shown that natural and groomed fingermarks from certain donors can be enhanced successfully using this technique. The authors are currently working to incorporate more donors as it is suggested by the IFRG guidelines (17), to take into account different weapon types, and to examine if the weapons themselves have an effect on the enhancement quality of the fingermarks. In terms of the compounds that are present in fingermarks and could be facilitating their enhancement when using VMD, both eccrine and sebaceous components are to be considered, especially since it has been reported (12) that eccrine prints of good quality can be developed with VMD.

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Tables

Table 1. Outline grading scheme used for assessment of developed marks (18), adapted from (7).

Grade	**Criteria**
0	No ridge detail developed
1	No clear pattern or ridge flow, with few or no characteristics disclosed. Cannot be used for identification purposes.
2	Pattern or ridge flow is disclosed; however, characteristics are not clear throughout the whole impression. May possibly be used for identification purposes.
3	Pattern and/or ridge flow is disclosed with clear characteristics throughout. Identifiable ridge detail.

Table 2. Evaluation of natural half fingermarks on brass metal discs developed with Gold/Zinc

Donors	Grades Day 2	Grades Day 7	Grades Day 14	Grades Day 35
Male donor #1	1,2,1	0,1,1	1,2,3	3,3,3
Male donor #2	1,2,1	1,1,0	1,0,1	0,0,0
Male donor #3	1,0,1	0,0,0	1,1,1	0,0,0
Female donor #1	0,0,0	0,0,0	0,0,0	0,0,0
Female donor #2	0,0,0	0,0,0	0,0,0	0,2,0
Female donor #3	0,1,0	0,1,0	0,0,0	1,0,0

Table 3. Evaluation of natural half fingermarks on brass metal discs developed with Silver/Zinc

Donors	Grades Day 2	Grades Day 7	Grades Day 14	Grades Day 35
Male donor #1	1,1,1	2,1,1	1,2,2	1,3,1
Male donor #2	1,1,1	0,0,0	2,0,1	0,0,0
Male donor #3	1,0,0	1,1,1	2,2,1	0,0,0
Female donor #1	0,0,0	0,0,0	0,0,0	1,0,0
Female donor #2	0,0,1	0,0,0	0,0,1	1,1,2
Female donor #3	0,0,0	0,1,0	0,1,0	3,0,0

Table 4. Evaluation of groomed fingermarks on fired brass cartridge cases

Donors	Grades
Male donor #1	1,2,1,1,0
Male donor #2	0,0,0,0,1
Female donor #1	0,0,0,0,0
Female donor #2	0,0,0,0,0

Figure legends

Figure 1. Visualisation of fingermarks and grab impressions on fabrics. (Part 1: Gold/zinc vacuum metal deposition) (5)

Figure 2. Simultaneous natural fingermarks on brass discs developed 2 days after deposition: Male donor 1 (a): Gold/Zinc (b): Silver/Zinc. Female donor 1 (c): Gold/Zinc (d): Silver/Zinc.

Figure 3. Simultaneous natural fingermarks on brass discs developed 7 days after deposition: Male donor 2 (a): Gold/Zinc (b): Silver/Zinc. Female donor 2 (c): Gold/Zinc (d): Silver/Zinc.

Figure 4. Simultaneous natural fingermarks developed 14 days after deposition: Male donor 3 (a): Gold/Zinc (b): Silver/Zinc Female donor 2 (c): Gold/Zinc (d): Silver/Zinc.

Figure 5. Simultaneous natural fingermarks developed 35 days after deposition. Male donor 1: (a): Gold/Zinc (b): Silver/Zinc Female donor 3: (c): Gold/Zinc (d): Silver/Zinc.

Figure 6. Groomed fingermark by a male donor (male donor 1) on 3 separate cartridge cases (a, b, c) developed with Silver/Zinc one day after firing.

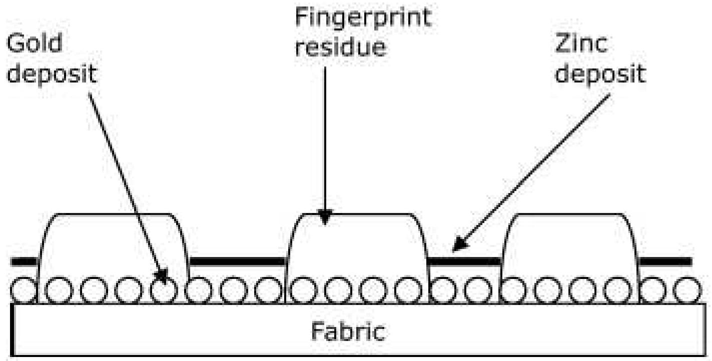

FIG. 1

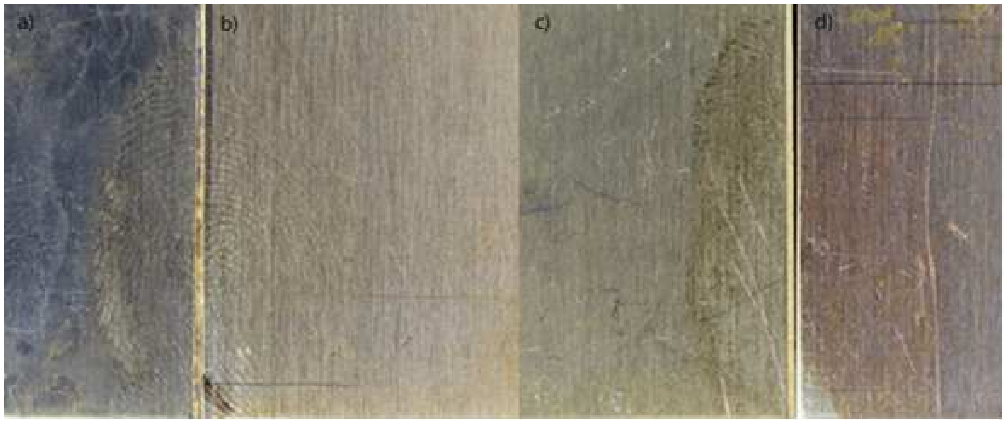

FIG. 2

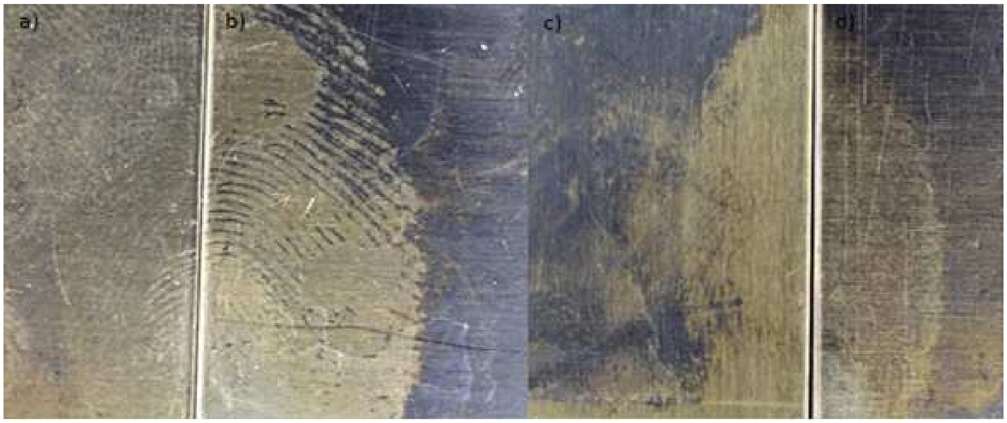

FIG. 3

FIG. 4

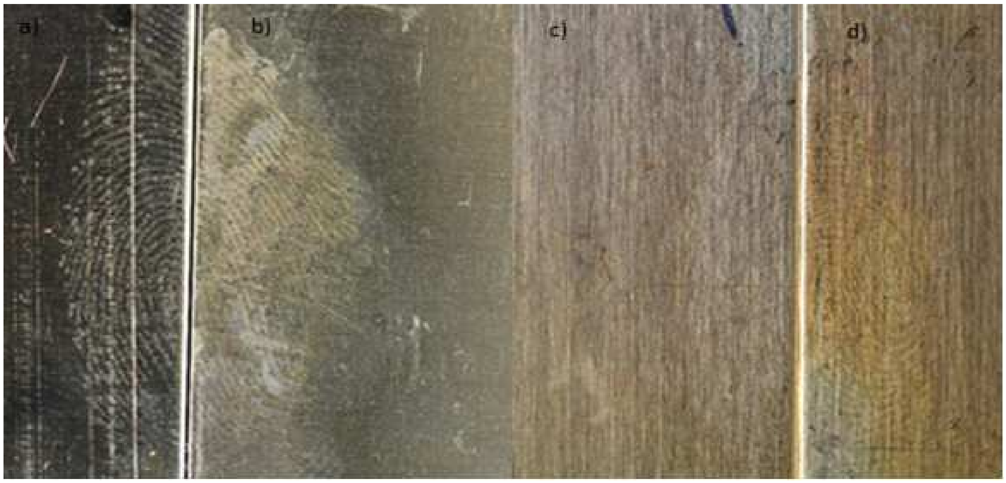

FIG. 5

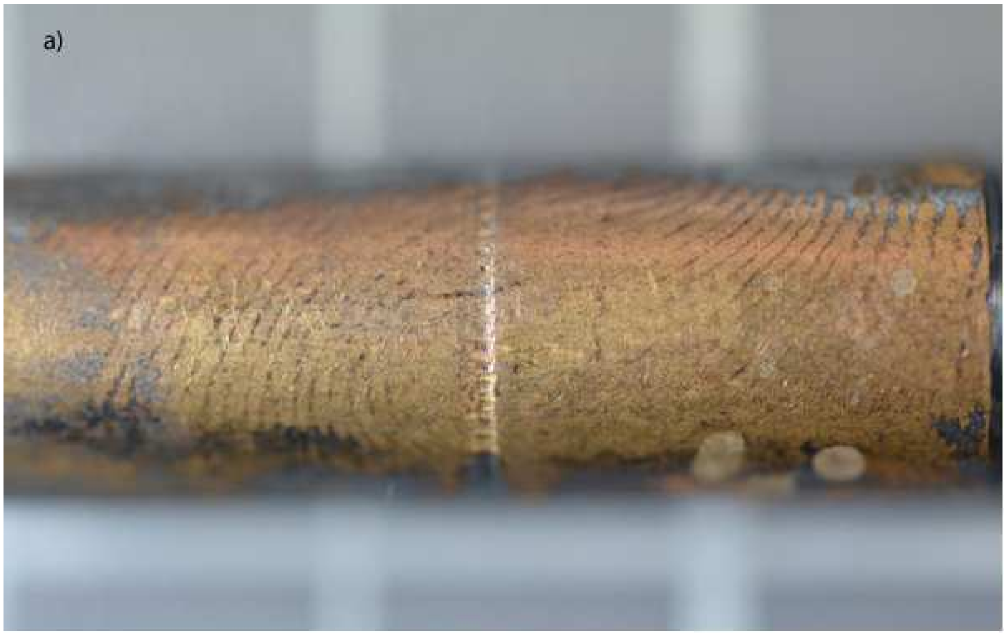

FIG. 6a

FIG. 6b

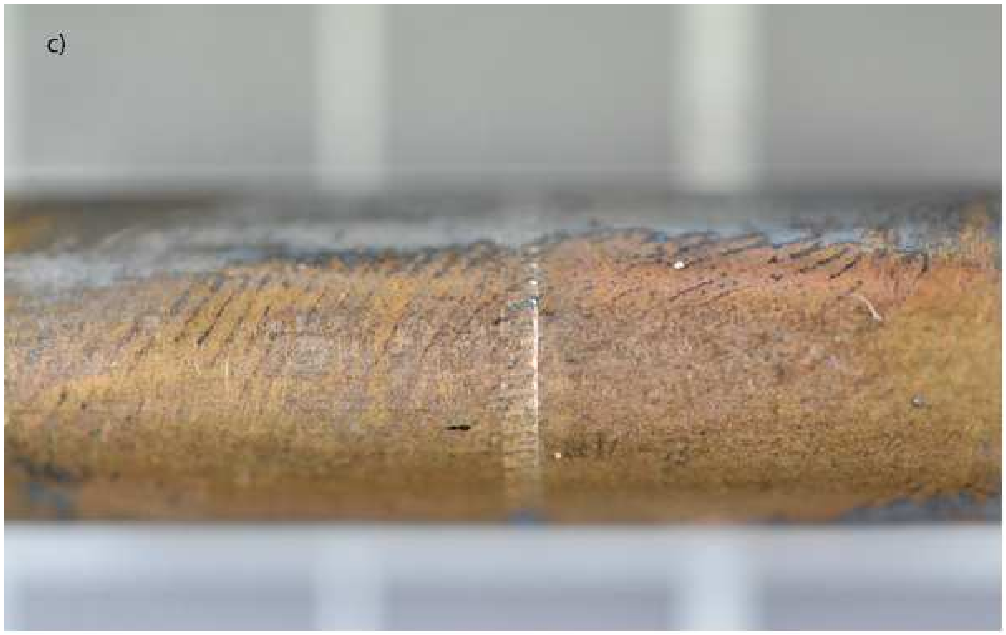

FIG. 6c