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Usability of Nickel Electrodeposition for Visualization of Latent Fingermarks on Brass Cartridge Cases

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***Abstract*— The development of latent fingermarks is very important for forensic investigations because they serve as key pieces of evidence. Our previous research has shown that this technique can be applied to the development of latent fingermarks on conductive substrates. This study aimed to find the optimal nickel electrodeposition process conditions for the visualization of latent fingermarks on brass cartridge cases. The optimal range of thicknesses of nickel films was determined and an excellent image contrast and development accuracy was achieved, which allowed the characteristics of fingermarks to be visualized.**

Keywords—latent fingermarks, nickel electrodeposition, brass cartridge, fingermarks visualization

I. Introduction

It has long been known and confirmed in practice that the patterns of friction ridges or papillary lines on the fingers, palms, and soles are an individual characteristic of each person and that their classification is relatively simple. For forensic practice, the fact that papillary line drawings can be transferred from person to object is of great importance [1,2].

Despite the development of various methods of identification of perpetrators of criminal acts, fingermark identification has retained its primacy in the recognition of individuals. Three main categories of fingermarks can be found at the crime scene: visible fingermarks, indented fingermarks, and the most important but problematic type, invisible or latent fingermarks. The type of fingermarks will depend on the physicochemical properties of the medium through which they are transferred to the substrate and the nature of the substrate on which the fingermarks have left. Latent fingermarks are formed by the deposition of secretions from eccrine and sebaceous glands and are barely visible to the human eye. The identification of fingermarks is most often done on metal, glass, ceramic, or plastic surfaces [3].

To enhance the visibility of the latent fingermarks various methods are developed and adopted in forensic practice such as physical, optical, physicochemical, and chemical methods [4,5,6]. The application of a particular method will depend on the different conditions under which fingermarks can be found.

A special place in forensic investigations can be given to the visualization of latent fingermarks on metal surfaces due to the frequency of occurrence of metal objects in criminal activities (weapons, cartridges, knives, jewelry). Metals are electrical conductors and fingermark residue usually contains substances that have dielectric properties. This fact led to the idea that electrochemical methods could be applied to the development and enhancement of fingermarks on metal surfaces [7,8,9,10].

Electrodeposition is a well-established process for obtaining single or multilayer metal coatings on conductive surfaces. It is a fast technique that can be well-controlled but requires the existence of a current source and the determination of optimal process parameters (electrolyte composition, pH value and temperature, current density, and deposition time).

For the application of electrodeposition in the development of latent fingerprints, it is important to know that the metal is deposited only on the valleys between the friction ridges and that with a properly selected color of the deposited metal, it is possible to achieve good results in terms of good contrast and resolution.

Building on our previous work on using nickel electrodeposition for the development of latent fingermarks, this research determines the possibility of using the same process on brass cartridge cases [11,12].

II. Experimental

A. Chemicals and materials

The four rectangular samples with 10 x 70 mm dimensions were cut from the brass foil (260 1/2H, thickness 125 μm), and ten fired cartridge cases were chosen for the experiments (Fig.1.). A thin copper wire is attached to the bottom of the case for easier manipulation in the electrolyte.

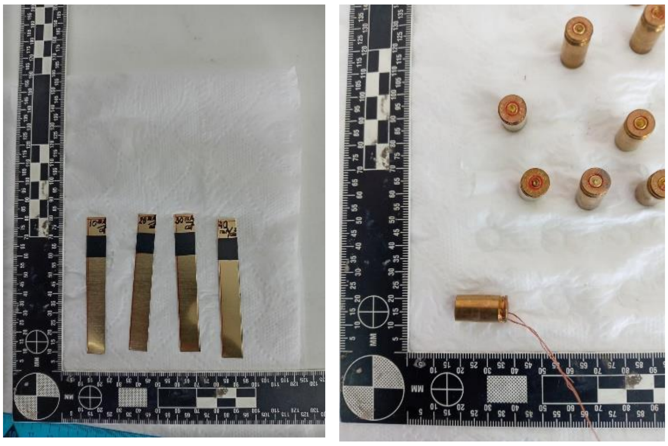

Fig.1. Brass samples to determine the rate of nickel electrodeposition (left) and samples of brass cartridge cases after cleaning, without fingermarks (right)

First, they were degreased and cleaned ultrasonically with a special detergent (Asonic-metal, general-purpose ultrasonic cleaning concentrate), then cleaned with ethanol and deionized water and dried by a flow of compressed air. The open side of the brass cases was closed with plasticine mass that could withstand a temperature of 50°C. All of the samples and cartridge cases will serve as the cathode in the electrodeposition process. The nickel anode was thoroughly prepared by polishing it with sandpaper, and then ethanol and water were used for rinsing.

The electrolyte for the electrodeposition was made in our laboratory and consisted of 300 g/l $Ni(NH_2SO_3)_2 \cdot 4H_2O$, 30 g/l H_3BO_3, 30 g/l $NiCl_2 \cdot 6H_2O$, and 1 g/l o-Benzoic sulfimide (saccharine). The pH value and the temperature of this electrolyte were maintained at 4 ± 0.05 and 50 ± 2°C, respectively. Electrodeposition was carried out using the direct current galvanostatic mode. The current source can provide currents of 50, 100, 150, and 200 mA.

Based on the measurement of the dimensions and the calculation of the cartridge case's surface, the brass foil samples' area was defined to determine the deposition rate. The area of the samples, and subsequently the cartridge cases defined for the electrodeposition of nickel, is enclosed by using insulating tape.

B. Experimental procedure

Electrodeposition rates were determined on samples of brass foil following the capabilities of the current source and the calculated surface of the case's shell, which was about 5 cm^2.

The deposition time was chosen based on the experimentally determined deposition rate and literature data that the typical thickness of the fingermark residue ranges from about 0.01 to 2 μm [9].

After each electrodeposition process, samples were carefully rinsed with deionized water and dried by compressed air. Before and after each experiment, the mass of the samples was measured on an analytical balance, to calculate and control the thickness of the deposited nickel film.

To ensure sufficient sweat on the friction ridges of the hands, the donor put on a silicone glove for 3 minutes. Fingermarks of the thumb of the right hand were left gently by the donor on the surface of the cartridge cases, in the direction normal to the basis of the case. The electrodes, the electrolyte, and the current source are connected in an electric circuit. The laboratory setup for the electrodeposition of nickel on brass surfaces is shown in Fig.2.

The sweat residue from the papillary lines prevented nickel electrodeposition and those surfaces have remained brassy. In the interpapillary space, nickel which is of a shiny silver color, was electrodeposited. Good contrast in brass and nickel colors is very helpful in detecting and defining papillary line features (minutiae), for person identification purposes.

After developing the fingermarks on the brass cartridge cases, visual analysis was performed under a desk magnifier with high illumination, and the samples were photographed with a camera (Samsung A50, 16MP resolution). The results of the application of the standard method of developing fingermarks with powder and the proposed electrochemical method were compared. Based on this comparison, an assessment of the quality of the fingermarks development and usability of the electrodeposition method was made.

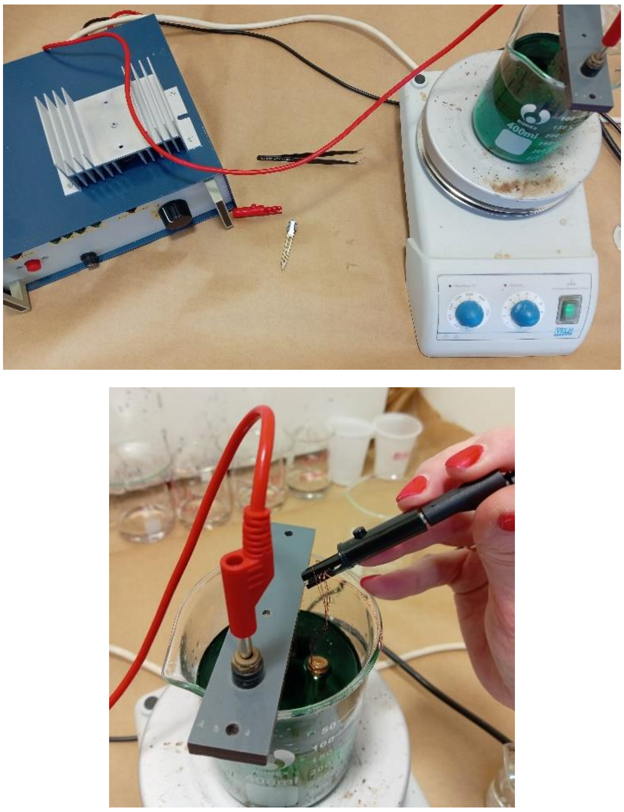

Fig.2. The laboratory setup for the nickel electrodeposition on a brass cartridge case.

III. Results and Discussion

A. Determination of the deposition rate

The most important parameters that determine the rate of electrodeposition and thus the fineness of the microstructure (grain size and shape) of the deposited metal films are the current density and the deposition time. By increasing the current density, nickel films with a fine-grained structure can be obtained [13,14].

Four brass samples were selected to determine the rate of nickel electrodeposition. The area selected for deposition was 10x50 mm, which corresponds to the surface area of the brass case intended for fingermarks analysis. The chosen deposition time was 1 minute, which is sufficient time to determine the deposition rate even when they are low.

With current values of 50, 100, 150, and 200 mA and a deposition area of 5 cm^2, current densities in the range of 10 ÷ 40 mA/cm^2 could be achieved. With the known values of the nickel density, the deposition area, and the measured difference in the mass of the samples before and after the process, it was possible to calculate the thickness of the deposited film and the deposition rate for each value of the current density. The measured rates of the nickel electrodeposition process at different current densities are given in Table 1:

TABLE 1. Deposition rates of nickel at different current densities

Current density (mA/cm^2)	10	20	30	40
Deposition rate (μm/min)	0,16	0,38	0,58	0,85

B. Visualization of latent fingermarks by electrodeposition of nickel films onto brass cartridge cases

Fine-grained columnar structure of nickel films is possible to obtain by electrodeposition, as shown in Fig.3. Due to the simultaneous release and adsorption of hydrogen during the process, intensive stirring of the electrolyte is required to prevent the formation of porous films [14,15].

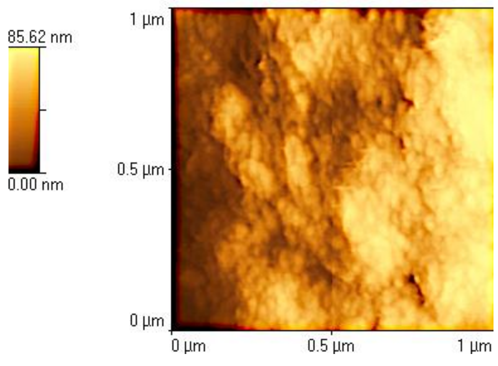

Fig.3. AFM topography of electrodeposited nickel film obtained at a current density of 10 mA/cm^2

In our previous research, it was established that the best results and compact microstructure of the nickel film were obtained when the current density did not exceed 50 mA/cm^2 [12].

As the current density increases, the grain size of the nickel film decreases and it acquires a better microstructure. Due to the possibility of a large difference in the height of the traces of papillary lines (0,01 to 2 μm), for successful visualization of fingermarks the thickness of the deposited film must be as small as possible, and the film as compact as possible.

According to the obtained optimal parameter values for the electrodeposition process of nickel on flat brass plates in our previous research, the initial test was performed with the maximum possible current density in this case, which is 40 mA/cm^2, over the entire surface of the case shell, for 1 minute. The film coverage of the case was good, but the film thickness was too large (about 0.8 μm) and the fingermarks were completely covered.

An experiment with a reduction of the deposition time to 10s at the same current density also did not give a satisfactory fingermark development, regardless of the reduced film thickness (0.15 μm). The nickel film was of non-uniform thickness across the case shell, which could be observed visually.

Decreasing the deposition rate to 0.16 μm / min by reducing the current density to 10 mA/cm^2, and depositing nickel for 1 minute, the same problem was observed. This led to the conclusion that the problem is the shape and mutual position of the electrodes.

The nickel anode was much larger compared to the brass cartridge case, but the cylindrical shape of the case affected the nonuniform distribution of the current density over the surface of the case.

This problem was solved by masking the part of the case shell that was not facing directly toward the anode, with non-conductive tape. The minimum necessary area to be left exposed for the electrodeposition was estimated from the size of a thumbprint on a flat ceramic plate and it was 1.65 cm^2, as shown in Fig.4. The reduction of the area for deposition required the use of higher current densities, due to the limitation of the current source.

Fig.4. Donor fingermarks on ceramic (black) and brass cartridge case (brown) surfaces were developed with black fingerprint powder and preserved on the dactyloscopic film.

When immersing in the electrolyte, attention was paid to the orientation of the anode and the unmasked part of the cathode (cartridge case). Their mutual distance was 3 cm. With the minimum possible current of 50 mA, a current density of 30 mA/cm^2 was achieved (deposition rate was 0,58 μm/min).

Experiments were performed with short deposition times of 5, 7, and 10 s, corresponding to nickel film thicknesses of 0.05, 0.07, and 0.1 μm, respectively. In all cases, satisfactory visualization results were obtained, as shown in Fig. 5.

Fig.5. Development of fingermarks on the brass cartridge cases by the electrodeposition of nickel with the 30 mA/cm^2 current density and a deposition time of 5s (left), 7s (center), and 10s (right).

The best contrast was achieved by nickel electrodeposition lasting 10s, as shown in Fig.6. Characteristic details of the fingermark are noticeable.

Fig.6. Development of a fingermark on the brass cartridge case by the electrodeposition of nickel with the 30 mA/cm^2 current density and a deposition time of 10s, after photo editing (the reflection from the surface that occurred during photography is reduced).

The amount of material from the papillary lines of the donor was minimal, because it mostly came only from the sweat glands (hands were well washed before leaving a mark), so the content of insulating, fatty material was reduced.

It can be considered that the mentioned process conditions are optimal for this analysis.

IV. Conclusion

The opportunity to apply well-known electrochemical methods in a new way in forensic practice is a constant challenge for scientists. This paper shows the research in which the development of latent fingermarks was attempted using the method of nickel electrodeposition on brass cartridge cases.

Selected parameters for the electrodeposition process of nickel on the brass cartridge case, i.e. current density and deposition time, were examined and defined.

After experiments were performed over the entire shell surface of the case, it was concluded that due to the shape of the electrodes, part of the cartridge case must be covered. Optimal results were achieved by masking the part of the case that is not exposed to the nickel anode, at a current density of 30 mA/cm^2 and a process duration of 10 s. Due to the difference in colors of brass and nickel, excellent contrast is achieved and the features of the papillary lines that are important for the identification of persons are visible.

Limitations for the application of the electrodeposition method may be the impossibility of its application at the crime scene or the size of the object for analysis, as well as the fact that it can only be applied to conductive surfaces.

Regardless of the existing standard methods (fingerprint dusting, ninhydrin reaction, cyanoacrylate fumes, etc.), which were also experimental at the beginning, testing and improving new methods and procedures is extremely important.

It can be concluded that the metal electrodeposition, in this analysis it is nickel electrodeposition, is a usable and useful method for visualizing latent fingermarks on brass cartridge cases.

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