Development of latent fingermarks by electrochemical deposition of nickel on brass surfaces

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Abstract:

Introduction/purpose of the research: Latent fingermarks can be found on the crime scene on various surfaces and made visible by different forensic methods. As this evidence can often be found on brass surfaces (ammunition casings, decorative items, etc.) the paper discusses the possibilities of applying electrochemical deposition of nickel on brass. The condition for the application of this technique is the existence of a conductive substrate. Fatty components of latent fingermarks have insulating properties and prevent the electrodeposition process.

Methods: Experimental thin rectangular pieces of brass foil were used as substrates for latent fingermarks. Samples were degreased in acetone and ethyl alcohol, rinsed in deionized water, and dried in a stream of compressed air before leaving the fingermarks. To enhance the presence of sweat on friction ridges, the hand was placed in the silicone glove for five minutes. A slight touch of the index finger was left on the tiles. Fingermarks were developed on brass samples by fingerprint powder and the electrochemical deposition of nickel on another brass surface simultaneously. In order to obtain the best possible evidence, the parameters affecting the deposition rate (current density, deposition time) were changed until a clear fingermark was obtained.

Results: The fingermarks were compared visually using a magnifying glass with illumination to observe the contrast between the papillary lines and the *interpapillary space and the characteristic details (minutiae). The optimal results were achieved with the current density (deposition rate) of 50mA/cm² for 10s.*

Conclusion: Electrochemical deposition of nickel on brass is an applicable technique for developing latent fingermarks with certain limitations.

Key words: latent fingermarks, interpapillary space, brass, fingermark development, electrochemical deposition.

Introduction

Fingermarks can be used for the identification of perpetrators of crimes and have a very high evidentiary potential in criminal justice (Tutulugdžija et al, 2017; Kesić et al, 2020). The standard to be reached to decide that there is sufficient agreement between a mark and a print is still a matter of debate, but in some countries as Poland, there is a numerical standard that defines the criteria of 10 to 12 minutiae as the minimum required to identify a person (Bécue & Champod, 2023). In the Republic of Serbia, the Baltazar criterion has been used for years, according to which it is sufficient to match 12 characteristic details (minutiae) on a fingermark and a fingerprint for the identification of a person.

Fingermarks can be found on various surfaces at the crime scene. Invisible or latent fingermarks are the most problematic type of fingermarks. The most common surfaces on which latent fingermarks are searched for are glass, ceramic, porcelain, plastic, and metal (Jasuja et al, 2011).

Latent fingermarks, left by the contact of fingers, palms, or soles with the touched surface, can be developed or made visible by the application of various methods in routine forensic practice. Applying fingerprint powder, in which there is no chemical reaction between sweat and the powder for development, is the most often used one. Various chemical reagents are also used, such as silver nitrate, ninhydrin, cyanoacrylate esters, DFO, amido-black, etc. These methods include chemical reactions between the reagent and sweat. Among physical methods, it is important to mention optical methods that are often used to search for latent fingermarks. The optical methods involve the application of light of different wavelengths (Bjelovuk, 2022, p.180). It is important to emphasize that not all the methods of developing latent fingermarks are equally applicable, due to different properties of surfaces on which they can be found.

Brass is an alloy of copper and zinc, and its properties vary according to the proportions of the components in the alloy. The color of brass is yellow-red - the higher the proportion of copper in the alloy, the closer the shade is to reddish. The most common are copper and zinc in a ratio of 2:1. It is very resistant to corrosion and friction. The melting point of brass is 900-940°C, and the density of brass is ρ = 8.4-8.7g/cm^3. Brass is not a ferromagnetic material (Symetric.co.uk, 2016). As fingermarks at the scene can often be found on brass surfaces (ammunition casings, decorative items, etc.), this paper discusses a possibility of applying electrochemical deposition of metal to develop fingermarks on the surface of brass.

In the paper of Swiss scientists who analyzed a number of publications in the 2019-2022 period in which the topic is related to fingermarks, it can be found that a large number of published papers (30) dealt with fingermarks on metal surfaces and cartridge cases. In the mentioned period, the number of papers dealing with fingermark development (photography and optical - 13, chemical imaging - 26, amino-acid reagents – 19, cyanoacrylate fuming – 21, vacuum metal deposition – 8, physical developer – 4, powder dusting – 188, powder suspensions – 10, nanoparticles in solutions – 29, lipid stains – 6, other - 22) shows that the application of electrochemical deposition of metals was not singled out (Bécue & Champod, 2023). In the last decade, possibilities for a wider application of different electrochemical techniques for developing fingermarks have been explored (Qin et al, 2013; Yuan et al, 2021; Yao et al, 2023). Electrochemical deposition or in short, electrodeposition, is a well-known and conventional process of coating a layer of one metal on top of a different metal to modify its surface properties. It is a fast technique, and easy to use, but it is conditioned by the existence of a current source and a specific electrolyte. For the purpose of developing latent fingermarks, it is important to mention that the electrochemical process of metal deposition can occur only on valleys between ridges (spatially selective electrodeposition) and that by properly chosen metal to be deposited and the conditions under which the process takes place, it is possible to achieve good contrast and resolution. Electrochemical deposition of nickel is a very suitable process for many technological applications due to its low resistivity, low cost, and easy growth on different surfaces in a well-controlled manner.

Brass foil (260 1/2H, thickness 125 μm) was chosen for the substrate in the experiment in accordance with the assumption that there is a certain probability that fingermarks can be found on brass surfaces (ammunition casing, decorative objects, etc.) at the crime scene. The rectangular samples with the dimensions of 50 x 20 mm, 50 x 15 mm, and 50 x 10 mm were cut from brass foil. A brass thin plate as the cathode was first mechanically and chemically polished, then cleaned of impurities with ethyl alcohol and deionized water and dried by a flow of compressed air. Then the chosen areas of the plate surface were covered with an insulating tape, as nickel would not be deposited on the entire surface (Figure 1). The nickel anode was prepared in such a way that it was polished with sandpaper and washed in ethyl alcohol and distilled water, after which it was dried.

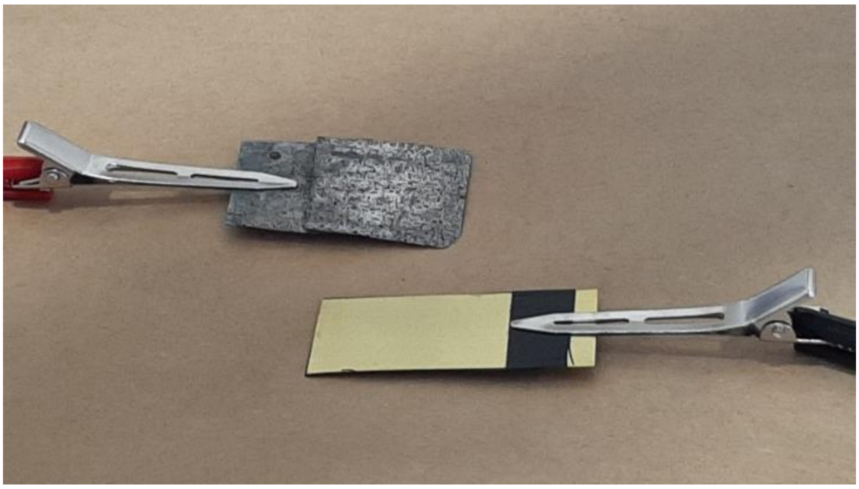

Figure 1 – Nickel anode and a sample of brass foil before electrodeposition

Fingermarks of the right finger were left by the donor on the surface of the plate after the hand was in a silicone glove for 5 minutes to ensure that there would be sweat on friction ridges. After the light contact of the finger and the brass plate, a fingermark remained, which is not clearly visible (latent fingermark). The surface of the mark consists of friction ridges and interpapillary space. By immersing the electrodes in the electrolyte and connecting them to a current source in a closed electrical circuit, the process of electrodeposition begins (Figure 2). The surface of the brass electrode that is not covered by sweat corresponds to the interpapillary space. Then the resulting evidence will appear so that the friction ridges are brass-colored, and the interpapillary space is bright nickel-colored. An important fact is that a metal has been chosen to contrast with brass in color. The obtained contrast in these lines will enable the characteristics, i.e., minutiae, to be clearly visible, and the evidence is suitable for person identification.

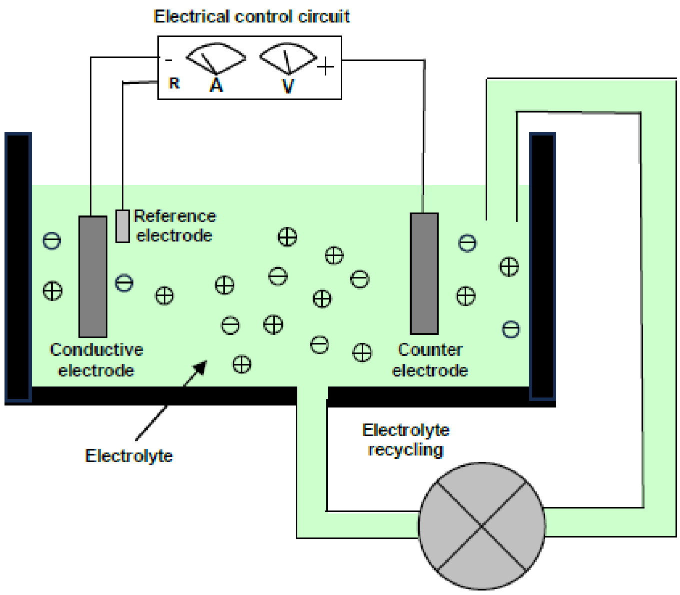

Figure 2 – Schematic representation of a set-up for electrochemical deposition

The electrodeposition of nickel was performed from a laboratory-made speed nickel electrolyte consisting of 300 g/l $Ni(NH_2SO_3)_2 \cdot 4H_2O$, 30g/l $NiCl_2 \cdot 6H_2O$, 30g/l H_3BO_3 and 1g/l saccharine. The electrolyte was constantly stirred on a magnetic stirrer. The temperature and the pH value of the electrolyte were maintained at 50 ± 2°C and 4 ± 0.05, respectively. Electrochemical deposition was carried out using the direct current (DC) galvanostatic mode. The current source could provide currents of 50, 100, 150, and 200 mA. The deposition rate was determined for each current strength. The deposition time was determined based on the deposition rate at a given current strength. After the electrodeposition, the samples were rinsed with deionized water and dried by compressed air. Before and after each deposition, the samples were weighed on an analytical balance to calculate the current efficiency of the process. The experiments were performed in controlled conditions, inside a laboratory with a temperature of 28°C, and air humidity of 46%.

The laboratory setup for the electrochemical deposition of nickel is shown in Figure 3. The experiments were carried out in the Forensic Training Center of the Ministry of Internal Affairs of the Republic of Serbia at the University of Criminal Investigation and Police Studies.

Figure 3 – The laboratory setup for the electrochemical deposition of nickel on brass

The developed fingermarks were examined by visual inspection under magnification and photographed with a camera (Samsung A50, 16 MP resolution). The assessment of the quality of the developed fingermarks by the electrochemical method was performed by comparison with the developed fingermarks using the standard method of applying ferromagnetic powder with an applicator called "magnetic brush" (Magnetic latent print powder, regular black No. BPM114L, Sirchie, Standard Magnetic Powder Applicator). The friction ridges were painted in black, while the interpapillary space was brass-coloured. The appearance of the fingermark visualized with magnetic fingerprint powder, photographed with a scaled photograph, is shown in Figure 4. This method is standard and has been routinely used in forensic practice for years. By applying this standard method on brass plates, the identification characteristics (minutiae), are clearly expressed.

Figure 4 – Fingermark on brass surface developed with the use of black magnetic fingerprint powder

Determination of the deposition rate and the microstructure of electrodeposited nickel films

Current density and deposition time are the parameters that determine the deposition rate and the microstructure of the deposited metal film. Increasing the current density leads to the deposition of fine-grained films.

Four samples were selected and prepared to determine the rate of nickel deposition on brass substrates. On the brass samples, a 10x10 mm surface was defined using a non-conductive tape, due to the easier determination of the current density value. The deposition time was fixed at 60 s, and by measuring the difference in the mass of the sample before and after the process, it was possible to calculate the thickness of the films and the deposition rate. The rates of the nickel electrodeposition were determined as EDNi (50 mA/cm^2) = 1.03 μm/min, EDNi (100 mA/cm^2) = 1.98 μm/min, EDNi (150 mA/cm^2) = 3.44 μm/min, and EDNi (200 mA/cm^2) = 4.04 μm/min.

It is known that electrodeposited nickel films have fine-grained columnar microstructures (Tutulugdžija, et al, 2017). The process of nickel electrodeposition is followed by the release and adsorption of hydrogen bubbles on the brass cathode, and there is a need for intensive stirring during the process. With increasing the current density (the deposition rate) from 50 mA/cm^2 to 200 mA/cm^2, the efficiency of the stirring was not good enough and the porous metal films were obtained (Figure 5). The best quality of the film microstructure was achieved with a current density of 50 mA/cm^2, and it was decided not to exceed this current density value in the experiments.

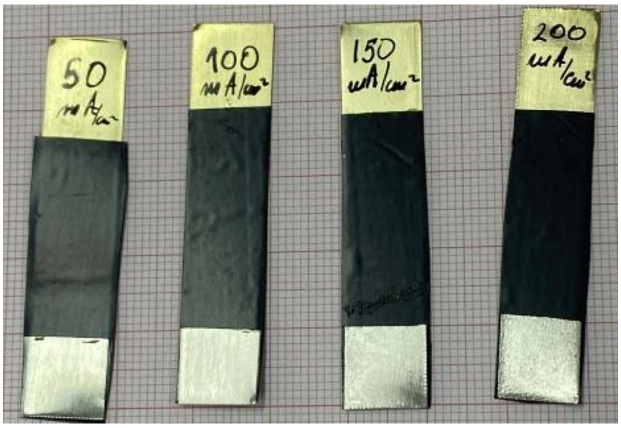

Figure 5 – Determination of the deposition rate on an area of 10x10 mm

Experimental determination of the optimal conditions for the development of latent fingermarks

Initial experiments were performed with a defined maximum current density value of 50 mA/cm^2. With the known, calculated deposition rate for different current densities, it was possible to approximately determine the thickness of the nickel deposit. The initial deposition time was decided to be 60s, with an estimated film thickness of about 1 µm. As it can be seen in Figure 6, the deposition time is too long and the nickel film has fully covered the fingermark.

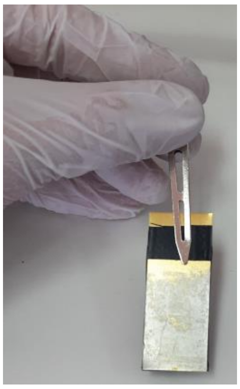

Figure 6 – Fingermark on the brass developed by the electrodeposition of nickel with the 50 mA/cm^2 current density and a deposition time of 60s

It is clear from Figure 6 that it was necessary to reduce the deposition time. The following experiments were performed with the same current density but with a deposition time of 10s, (5s + a stop for control + 5s) and 7s. The deposition duration of 5s was not enough to develop a fingermark. As shown in Figure 7, reducing the deposition time improved trace development.

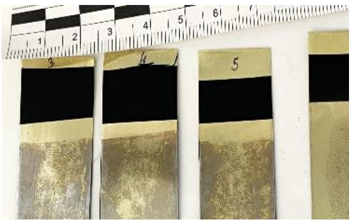

Figure 7 – Fingermark on the brass surface developed by the electrodeposition of nickel with the 50 mA/cm^2 current density and a deposition time of 10s (sample 3), 5+5s (sample 4), and 7s (sample 5). On the right is sample 6, on which the fingermark was developed using the standard powder application method

When nickel deposition is performed on specific surfaces (which is the case here, because it is about surfaces on which there are fingermarks), a high deposition rate is not an advantage because it reduces control of the thickness and the uniformity of nickel films on such surfaces.

The deposition rate decreases with the decrease in the current density. The following experiments were performed with a reduced current density of 30 mA/cm^2. Due to the decrease in the deposition rate, the deposition time was extended and the experiments were performed for 25s and 12s. The results of the development of the fingermarks under new conditions are shown in Figure 8.

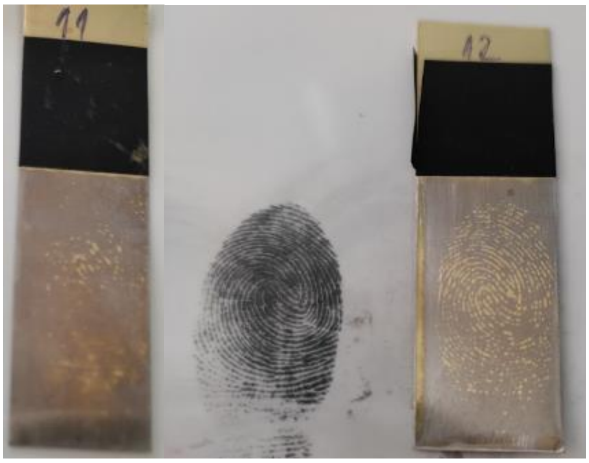

Figure 8 – Fingermark on the brass surface developed by the electrodeposition of nickel with the 30 mA/cm^2 current density and a deposition time of 25s (sample 11) and 12s (sample 12)

It can be concluded from Figure 8 that the change in the process parameters and new conditions of nickel deposition on brass substrates with fingermarks led to better quality. Lower current density and slower deposition enabled uniform coverage of the brass substrate surface. A deposition time of 25s for a current density of 30mA/cm^2 (sample 11), proved to be too long as fingermark overlap occurred. In sample 12, the characteristic details of the fingermark are clearly visible.

The following experimental research went in the direction of evaluating the quality of developing fingermarks with the further reduction of the current density. In Figure 9, four brass samples with deposited nickel films obtained with the 10mA/cm^2 current density and different deposition times are shown.

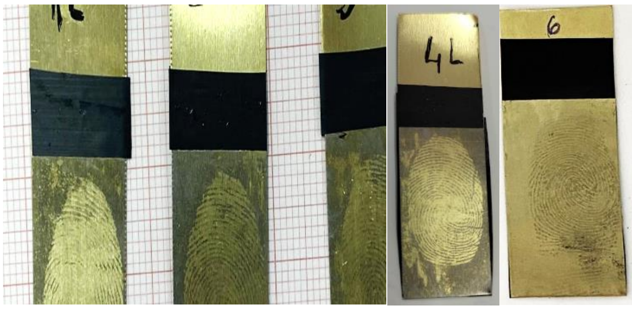

Figure 9 – Developments of fingermarks on the brass surface by the electrodeposition of nickel with the 10 mA/cm^2 current density and a deposition time of 60s (sample 1L), 30s (sample 2L), 25s (sample 3L) and 12s (sample 4L). On the right, sample 6 is shown, on which the fingermark was developed using the standard powder application method

On the basis of Figure 9, it can be concluded that good results for developing fingermarks were obtained by using a current density of 10mA/cm^2 and reducing the deposition time to 12s (sample 4L). Further reduction in deposition time led to incomplete fingermark development.

In sample 4L, some characteristic details are clearly visible, which can be important for identifying a person, and they are presented in Figure 10.

Figure 10 – Development of a fingermark on the brass surface by the electrodeposition of nickel with the 10 mA/cm^2 current density and the 12s deposition time. Some characteristic details of the fingermarks, minutiae (fingermark developed with conventional magnetic latent print powder Sirchie – left and sample L4 after photo editing - right) are shown

Discussion

During the experiment, tests were carried out with different values of current strength, time of nickel deposition, and different values of electrolyte temperature in order to find optimal values at which the developed fingermark will be suitable for person identification. Fingermarks are suitable for the identification of a person in the Republic of Serbia. It is necessary to have twelve clearly expressed characteristics, i.e. minutiae. Smaller values of current density, shorter deposition time, and smaller values of electrolyte temperature gave a smaller thickness of the deposition layer. Then the fingermark is not clearly visible, i.e., it is of lower quality, and thus the potential of identification is small. Also, during the tests, no high-quality fingermarks were obtained when a longer time of nickel deposition was chosen. The deposition time of one minute showed that the entire surface of the brass plate will be covered with a deposited layer of nickel, i.e., the thickness of the nickel deposition layer is greater than the depth of the interpapillary space. Such a fingermark is completely covered with a layer of deposited nickel and is unsuitable for identification. The optimal current strength at which it was shown that a high-quality fingermark would be developed by electrochemical nickel deposition was I = 50 mA, while the deposition time was 60s. The electrolyte temperature was 54.2°C.

Developed fingermarks were observed under a magnifying glass in order to analyze the identification characteristics and test the usability of the fingermark for identification.

The application of fingerprint powder has been widely used for several decades in forensic practice and is suitable for developing fingermarks on various surfaces, both metal and other surfaces such as glass, plastic, porcelain, ceramic, lacquered surfaces, etc. A comparison of fingermarks developed by electrochemical nickel deposition and the method of fingerprint powder application was made.

Conventional fingerprint powders have been used for decades in forensic practice worldwide to develop fingermarks at the crime scene and such evidence is later used in fingerprint laboratories for identification. This method is very simple to apply, it does not require complex training, the equipment is not bulky and heavy (a jar with powder, a brush, and fingerprint foils for lifting the evidence), it is not expensive, and the application does not require a lot of time. It can be performed both at the scene and in the laboratory. The surface on which there is a fingermark is not damaged after the application of the powder (it is enough to pass a dry cloth over the surface on which the mark is developed and the surface returns to its original state), i.e., this method can be characterized as non-destructive. This method can be applied to both movable and immovable objects.

The application of the electrochemical deposition method in these tests proved to be equally applicable, considering that in both cases, minutiae can be found (minimum 12). However, this method is only suitable for metal surfaces, i.e., surfaces that conduct electricity. Also, this method is suitable for application on objects of small dimensions, i.e., it is necessary that the dimensions of brass objects, on which there are latent fingermarks, be smaller than the dimensions of the container with the electrolyte in order for immersion to be possible. This method is more complicated to apply at the scene, considering that it is necessary to carry the equipment (DC source, conductors, electrodes, electrolyte container, and heating element), provide the space for the equipment at the scene where it will be installed, etc. When it comes to damaged surfaces with latent fingermarks, this method can be characterized as destructive, considering that the caused trace cannot be removed so easily, but requires mechanical removal such as grinding.

Conclusion

The method of electrochemical deposition of metals is not in routine forensic application. In recent years, there have been attempts to investigate the possibility of applying this method. In this paper, experiments have shown that it is quite possible to apply this method to develop latent fingermarks on a brass surface.

The use of fingerprint powders for developing fingermarks is applicable on movable and immovable objects, at the scene and in the laboratory. It has been confirmed in forensic practice worldwide as a non-destructive method.

The limitations when performing electrochemical nickel deposition refer to the necessity of equipment at the scene, and the small dimensions of moving objects with fingermarks. Also, an object with fingermarks must be a current conductor, which brass is.

Both methods for developing fingermarks, fingerprint dusting and electrochemical deposition of nickel, are suitable for identification because the identification characteristics were clearly expressed.

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Desarrollo de huellas dactilares latentes mediante deposición electroquímica de níquel sobre superficies de latón

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CAMPO: materiales, tecnología química, ingeniería mecánica, criminalística
TIPO DE ARTÍCULO: artículo científico original

Resumen:

Introducción/objetivo: Se pueden encontrar huellas dactilares latentes en la escena del crimen en varias superficies y se pueden hacer visibles mediante diferentes métodos forenses. Como esta evidencia se puede encontrar a menudo en superficies de latón (cartuchos de munición, artículos decorativos, etc.), el artículo analiza las posibilidades de aplicar la deposición electroquímica de níquel sobre latón. La condición para la aplicación de esta técnica es la existencia de un sustrato conductor. Los componentes grasos de las huellas dactilares latentes tienen propiedades aislantes e impiden el proceso de galvanoplastia.

Métodos: Se utilizaron piezas experimentales delgadas y rectangulares de lámina de latón como sustratos para las marcas dactilares latentes. Las muestras se desengrasaron en acetona y alcohol etílico, se enjuagaron con agua desionizada y se secaron en una corriente de aire comprimido antes de dejar las marcas de los dedos. Para mejorar la presencia de sudor en las crestas de fricción, se colocó la mano en el guante de silicona durante cinco minutos. Un ligero toque del dedo índice quedó sobre los azulejos. Se desarrollaron marcas dactilares en muestras de latón mediante polvo para huellas dactilares y la deposición electroquímica de níquel sobre otra superficie de latón simultáneamente. Para obtener la mejor evidencia posible, los parámetros que afectan la velocidad de deposición (densidad de corriente, tiempo de deposición) se cambiaron hasta que se obtuvo una marca dactilar clara.

Resultados: Las marcas dactilares se compararon visualmente utilizando una lupa con iluminación para observar el contraste entre las líneas papilares y el espacio interpapilar y los detalles característicos (minucias). Los resultados óptimos se lograron con una densidad de corriente (velocidad de deposición) de 50 mA/cm2 durante 10 s.

Conclusión: La deposición electroquímica de níquel sobre latón es una técnica aplicable para desarrollar marcas dactilares latentes con ciertas limitaciones.

Palabras claves: marcas dactilares latentes, espacio Inter papilar, latón, desarrollo de marcas dactilares, deposición electroquímica.

Выявление скрытых отпечатков пальцев методом электрохимического осаждения никеля на латунных поверхностях

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РУБРИКА ГРНТИ: 55.00.00 Машиностроение,
61.00.00 Химическая технология,
10.85.31 Криминалистическая экспертиза
ВИД СТАТЬИ: оригинальная научная статья

Резюме:

Введение/цель: Практика судебной экспертизы показала, что скрытые отпечатки пальцев можно обнаружить на различных поверхностях места происшествия, а выявить их можно различными методами. Поскольку эти следы часто встречаются на латуни (гильзы, украшения, декоративные предметы и т.д.), в данной статье обсуждаются возможности нанесения никеля на латунную поверхность методом электрохимического осаждения. Условием применения этого метода является наличие проводящей подложки, так как жировые компоненты следов папиллярных линий обладают изолирующими свойствами и препятствуют процессу электроосаждения.

Методы: В качестве подложки использовались экспериментальные тонкие прямоугольные кусочки латунной фольги, на которых остались следы папиллярных линий. Образцы были обезжирены ацетоном и этиловым спиртом, затем их промывали деионизированной водой и обдували струей сжатого воздуха до появления следов папиллярных линий пальцев. Для увеличения потовыделения на папиллярных линиях, на руку в течение 5 минут надевали силиконовую перчатку. После легкого прикосновения указательного пальца к пластине оставался след. Следы папиллярных линий на латунных образцах выявлены с помощью дактилоскопического порошка и одновременного электрохимического осаждения никеля на другую латунную пластину. В целях получения лучшего отпечатка, параметры, влияющие на скорость осаждения, менялись до тех пор, пока не был получен четкий след папиллярных линий.

Результаты: Визуальное сравнение следов производилось с помощью лупы с подсветкой, которая усиливала контраст между цветом папиллярных линий, межсосочкового пространства и характерных деталей (минуции). Оптимальные *результаты были достигнуты при плотности тока (скорости осаждения) 50 мА/см2 в течение 10 с.*

Выводы: Электрохимическое осаждение никеля на латунную поверхность является применимым методом (с некоторыми ограничениями) выявления скрытых следов папиллярных линий.

Ключевые слова: скрытые следы папиллярных линий, межсосочковое пространство, латунь, выявление скрытых следов, электрохимическое осаждение.

Изазивање латентних трагова папиларних линија методом електрохемијске депозиције никла на месингу

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ОБЛАСТ: материјали, хемијске технологије, машинство, криминалистика
КАТЕГОРИЈА (ТИП) ЧЛАНКА: оригинални научни рад

Сажетак:

Увод/сврха истраживања: Латентни трагови папиларних линија прста се у форензичкој пракси могу наћи на различитим површинама на месту догађаја и учинити видљивим различитим методама. Како се ови трагови често могу наћи на месингу (муницијска чаура, украсни предмети и друго), у раду су размотрене могућности примене електрохемијске депозиције никла на месингу. Услов за примену ове технике јесте постојање проводног супстрата. Масне компоненте трага папиларних линија имају својства изолатора и спречавају процес електродепозиције.

Методе: Експериментални танки правоугаони делови месингане фолије коришћени су за подлогу на коју су остављани трагови папиларних линија. Узорци су одмашћени у ацетону и етил-алкохолу, испрани у дејонизованој води и осушени струјањем компримованог ваздуха пре него што су остављени трагови папиларних линија. Ради повећања присуства зноја на папиларним линијама, рука је стављена у силиконску рукавицу на 5 минута. Лаганим додиром плочице кажипрстом остављен је траг. Трагови папиларних линија изазвани су на узорцима месинга коришћењем дактилоскопског праха и, истовремено, електрохемијским таложењем никла на другу месингану плочицу. Ради добијања што квалитетнијег трага, мењани су параметри који утичу на брзину депозиције све док није добијен јасан траг папиларних линија.

Резултати: Трагови су визуелно упоређивани помоћу лупе са осветљењем како би се уочио контраст између боје папиларних линија и међупапиларног простора и карактеристични детаљи (минуције). Оптимални резултати постигнути су струјом густине (брзином таложења) 50mA/cm^2 за 10 s.

Закључак: Електрохемијско таложење никла на месингу је применљива техника за изазивање латентних трагова папиларних линија са одређеним ограничењима.

Кључне речи: латентни трагови папиларних линија, међупапиларни простор, месинг, изазивање латентних трагова, електрохемијска депозиција.

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