Application of Electrostatic Image Reproduction Method to Detect Traces of Papillary Patterns on Paper-Based Documents

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Numerous forensic sources reveal the main stages of fingerprint identification introduction in law enforcement activities, the work of researchers to develop a reliable method of forensic registration based on taking into account and using physiological peculiarities of the skin of human fingers and other aspects related to the conduct of fingerprint examination, the introduction of relevant automated databases, etc. At the current stage, forensic science is constantly developing. The range of methods and technical means for detecting fingerprints is expanding depending on the type of trace carrier, conditions of trace formation, as well as the tasks facing pretrial investigation bodies. Development of latest achievements of criminal investigation technique requires constant updating methods of using modern forensic technology and adoption of positive experience of applying achievements of science and technology in activities of law enforcement agencies of foreign countries, in particular Great Britain, during investigation of crimes and further work with physical evidence within the limits of forensic researches. The purpose of this article is to expand and deepen understanding of law enforce-

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ment staff of mastered method and conditions for its application for detection of traces of papillary patterns on paper surfaces. For achieving this goal, general scientific, as well as special optical and microscopic research methods were applied. Methodological aspects of detecting traces of papillary patterns on paper surfaces by the method of electrostatic reproduction of images with visual examples of the results of using the ESDA 2/B device are considered. Difference between this method of research and existing methods of detecting traces of papillary patterns is analyzed.

Keywords: *forensic science; fingerprint research; traces of papillary pattern; ESDA 2/B device; method of electrostatic image reproduction.*

Research Problem Formulation

Detection effectiveness of traces of papillary patterns depends on the choice of research methods and sequence of their application, as well as on the surface of probable placement of traces. A separate problematic task is the detection of traces of papillary patterns on paper-based documents, since the research is complicated as by material structure as by the color of the background and handwritten records, printed texts and prints of seals and stamps available on.

It is known that forensic expert determines the application sequence of research methods and appropriate technical means independently. In addition, forensic expert should use the most non-destructive methods and only if the research purpose is not achieved, it is advisable to resort to destructive methods. The application sequence of research methods should be based on the principle that each previous method should not be an obstacle to application of the following (i.e. from non-destructive to destructive ones).

In modern forensic expert practice, the following methods and means are used to detect and fix papillary patterns:

1) *Physical* one including optical (based on a visual inspection of objects using optical devices: magnifying glass, microscope, etc.) and powder (based on adsorption of powdered substances by a fatty substance);
2) *Chemical* one, from which the interaction (binding) of components of trace fatty substance with various chemical reagents occurs;
3) *Physicochemical* one, based on two processes: physical (adsorption of a substance on the surface of traces) and chemical (reaction with unsaturated fatty acids) [1].

Visual inspection of objects at different angles using forensic magnifier in scattered and directed light and in ultraviolet rays does not change the characteristics of the trace and precedes the use of

1 Борзов О. П., Костильова О. А., Кузнєцов В. А., Щавелєв А. В., Єрмолаєва А. О. Комплексне дослідження слідів рук на вогнепальній зброї : метод. рек. Київ, 2011. 23 с.

physical methods based on properties of adhesion and selective adsorption of the trace substance, as well as chemical or physicochemical methods.

In Ukraine, as in most countries of the world, to determine the location of hidden fingerprints invisible to the naked eye on most non-porous surfaces, the *RUVIS* optical imaging system is used, based on the technology of forming an image by reflected ultraviolet radiation. In this case, no prior use of fingerprint powders, chemicals, or fumigation treatment is required. Unlike systems that use special light sources and lasers, *RUVIS* device does not depend on ambient lighting: it can be used in different conditions: in daylight or in complete darkness, indoors or outdoors [2]. Although examination in ultraviolet rays with light filters is neutral with respect to physical properties of sweat, DNA sections can be damaged in this way.

As for the use of powders, not only the fatty substance is exposed, but the surface on which it is placed.

Chemical methods for detecting fingerprints affect as surface background of the carrier as color of papillary lines themselves. For example, among the mastered and recommended methods for detecting traces of papillary patterns on paper surfaces (in particular, with handwritten records available), method of using ninhydrin solution in petroleum ether is common and quite non-destructive. However (in spite of influence lack of solution on the handwritten notes) during its application, surface damage occurs in the form of a slight deformation of the paper due to wetting due to the treatment with the solution, and papillary lines are painted with a resistant colored product called Ruhemann purple [3].

Experts face a difficult choice between the use of appropriate method and technical means for detecting traces of papillary patterns, especially on paper, and the negative impact on original state of the document.

Thus, let us consider in more detail possibility of using electrostatic image reproduction method to detect traces of papillary patterns, primarily on paper-based documents.

Article Purpose

Expand and deepen knowledge of those involved in the law enforcement system about the mastered method of electrostatic image reproduction, to analyze the conditions of its application for detecting traces of papillary patterns on paper surfaces. It should be noted that we have omitted the topic of the influence of electrostatic charge on the possibility of conducting further biological studies of human samples that could potentially remain in fingerprints on the objects under research.

Research Methods

For achieving this goal, as general scientific as special optical methods (reflex, shadow and in oblique rays of daylight), as well as microscopic research methods were used.

2 Мусієнко О. Л. Використання цифрових технологій при розслідуванні злочинів. *Інноваційні методи та цифрові технології в криміналістиці, судовій експертизі та юридичній практиці* : мат-ли міжнар. «кругл. столу» (Харків, 12.12.2019). Харків, 2019. С. 99—102. URL: https://surl.li/lidspo (date accessed: 20.02.2026).

3 *Ruhemann's* purple is a dark blue or purple pigment formed by a chemical reaction between ninhydrin and amino acids, peptides, or proteins.

Analysis of Essential Researches and Publications

Analysis of many information sources on the history of development of fingerprinting and its application in investigation and disclosure of crimes since 1904 on territory of Ukraine (during its time as part of Russian Empire and the USSR, as well as during the time of independent Ukraine) makes possible to identify a number of problematic issues [4].

The issues of updating already mastered and developing as new methods for detecting hand traces and new algorithms for collecting trace information during investigative actions remain unresolved.

Not enough attention is paid to the issues of detecting hand traces using, in particular, the method of electrostatic image reproduction, since this method is used mainly in Questioned document examination.

Theoretical and practical aspects of detecting traces of papillary patterns on paper surfaces using *ESDA 2/B* device are given in the methodological recommendations prepared by a group of authors: O. Haiduk, D. Baniev, Ye. Riabokon [5]. However, these guidelines are intended for employees of state specialized institutions that carry out forensic activities on the basis of Law of Ukraine: *On Judicial Examination* [6], as well as for teachers of specialized educational institutions.

Main Content Presentation

Development analysis of modern foreign forensic technology indicates the need to use current pilot projects and introduce technical and forensic tools of Ukrainian manufacturers, as well as use the latest samples of foreign origin.

Technical means, methods and materials for detecting traces of fingerprint origin, presented on the Ukrainian market by manufacturing companies, are various, allowing to qualitatively detect these traces on different surfaces with different statute of limitations [7].

As part of forensic research on documents for detection of invisible or weakly visible (hardly visible) pressed images on paper, effective non-destructive method for their detection is the method of electrostatic reproduction of images. This method is based on distribution phenomenon of charged particles formed by a corona discharge, and the subsequent development (visualization) of obtained electrostatic image using a toner sensitive to electromagnetic fields [8].

One such device is the *ESDA 2/B (foster+freeman)* (*cf.: Fig. 1*), the first prototype

4 Кофанова О. С. Сучасні можливості та новітні розробки в сфері виявлення слідів дактилоскопічного походження. *Криміналістика і судова експертиза*. 2017. Вип. 62. С. 228—237. URL: https://surl.li/pojtpq (date accessed: 20.02.2026).

5 Гайдук О. Г., Банєв Д. І., Рябоконь Є. А. Виявлення слідів папілярних узорів на паперових поверхнях із використанням приладу ESDA 2/B (foster+freeman) : метод. рек. Київ, 2025. 15 с.

6 Про судову експертизу : Закон України від 25.02.1994 р. № 4038-XII (зі змін. та допов.). URL: https://zakon.rada.gov.ua/laws/show/4038-12#Text (date accessed: 20.02.2026).

7 Техніко-криміналістичне забезпечення діяльності інспектора-криміналіста / НАВС : офіц. вебсайт. URL: https://arm.navs.edu.ua/books/insp_krym/technique/forensic_technique1_2.html (date accessed: 20.02.2026).

8 FOSTER+FREEMAN : web. URL: https://fosterfreeman.com/ (date accessed: 20.02.2026).

of which was created by Doug Foster and Bob Freeman with the support of the UK Home Office in Doug's garage.

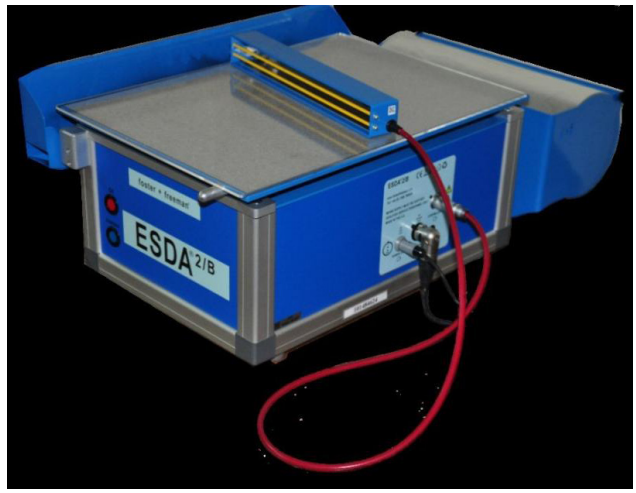

Fig. 1. General view of ESDA 2/B appliance (foster+freeman)

Table

Main components of *the ESDA 2/B device (foster+freeman)* and their functions

Component	Function
Main unit	Central system that controls other components containing
Control panel	Located on the main unit, it allows the operator to control various *ESDA* functions: for example, adjusting corona discharge or controlling the vacuum
Toner tray	Toner accumulation tray after surface treatment
Original holder (working surface)	Surface on which the document is placed. It has a vacuum function to firmly hold the document during examination
Crown *Wand*	Portable device acting on document with an electrostatic charge
Image Processing Film Holder	Holds a thin transparent polymer film that is used to develop an electrostatic charge

Procedure for using *the ESDA 2/B* contains the following operations.

1. The document is fixed on original holder (working surface) of the device. It is placed, straightened and the vacuum pump is switched on using control buttons. Vacuum ensures that the document is held securely without air bubbles preventing any movements that may affect the result. If the device is used for the first time or when it has not been used for a long time, it is recommended to check the device using a control sample that is close in its characteristics to the test object.

2. Document is covered with an ultra-thin polymer film that matches the paper contours and allows you to draw it into recesses or copy contours of the protrusions.

3. Apply an electric charge using a portable device Crown *Wand*. The device moves evenly over the polymer film and paper. In this stage, static charge is applied to the polymer film and paper. It should be uniform and controlled, last for a constant glow of the control blue indicator. Recommended time for electrostatic charging and distribution (spreading) of the charge after the coronation completion is up to 5 minutes.

4. Working surface is lifted and turned at an angle to the tray, polymer film within the test document is evenly sprinkled with powdered toner to create positively charged marks of irregularities of the sheet surface and make them visible by creating contrast image. Specially for *ESDA*, almost 200 g of cascade developer is used, containing a mixture of small-diameter glass balls with toner acting as a carrier.

5. Capture the developed image using photography, as well as subsequent copying using adhesive tape "AT" or fingerprint film. It is recommended to place captured image on the film against a light background to increase the contrast of the detected image.

During practical application of this device, traces of papillary patterns were searched for by electrostatic reproduction of images on sheets of paper with different densities and thicknesses (sheet of notebook, envelope, fiscal receipt, pieces of newspaper and advertising booklet) with a limitation period of up to 6 days, from 6 to 14 days and more than 14 days (some surfaces of the objects contained handwritten notes and marks made with a ballpoint pen with a blue dye and a marker).

It is worth noting that objects-carriers on working surface can be placed both individually and in groups, since the size of the surface allows to place documents in A3 format inclusive.

Let us give an example from our own practice. As a result of the application of the method of electrostatic reproduction of images using the *ESDA 2/B* device, traces of papillary patterns, single papillary lines and their fragments were displayed on the surface of the polymer film, which covered the objects-traces (*cf.*: *Fig. 2–4*).

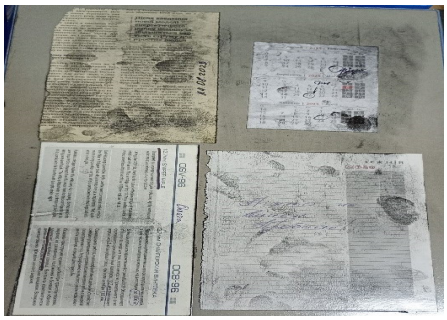

Fig. 2

Fig. 3

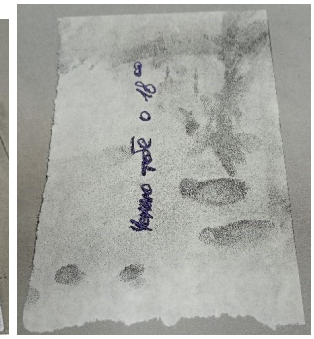

Fig. 4

Fig. 2—4. Images of the studied objects with traces of papillary patterns displayed on

The traces displayed on the polymer film were copied in two ways: using adhesive tape "AT" followed by gluing on a sheet of white paper (*cf.: Fig. 5*) and using a transparent fingerprint film (*cf.: Fig. 6*).

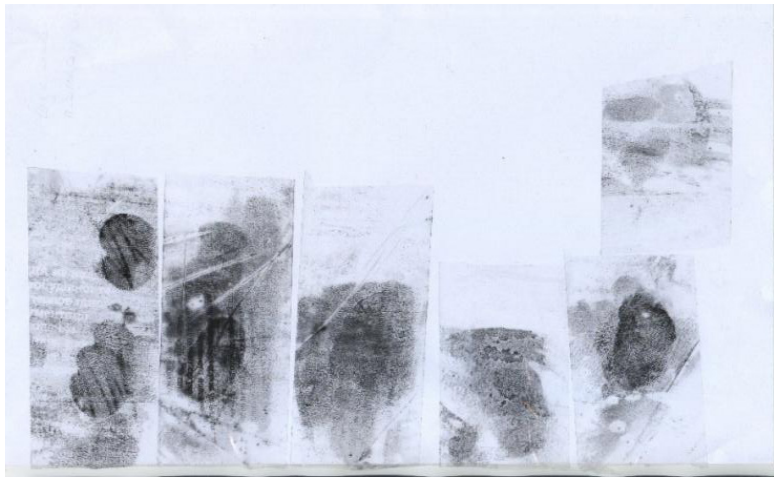

Fig. 5. Image of sheet of paper with glued adhesive tapes "AT", on which traces of papillary patterns are copied

Fig. 6. Image of a light fingerprint film with copied traces of papillary patterns

After copying the traces, the trace objects were inspected for damage to the existing handwritten records and marks. As a result of the study, it was found out that the handwritten records remained clear and did not suffer any damage.

Next, we performed a research on the copied "fresh" traces using a magnifying glass (magnification: 4.5×) using various lighting methods: reflex, shadow and in the peripheral rays of daylight. According to the results of the survey, traces were selected, in which the general signs of papillary patterns were displayed to some extent informatively (*cf.: Fig. 7–13*).

Fig. 7

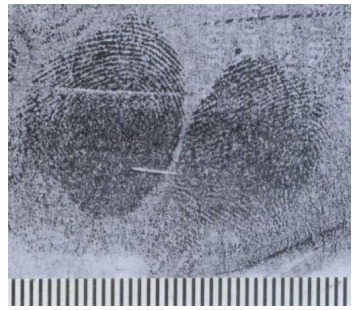

Fig. 8

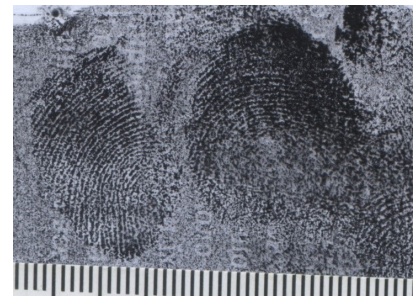

Fig. 9

Fig. 10

Fig. 11

Fig. 12

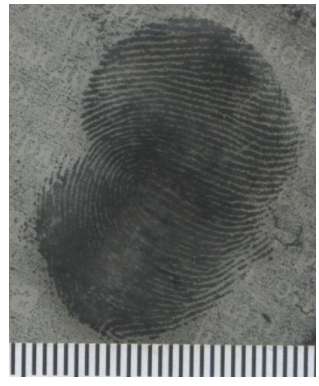

Fig. 13

Fig. 7–13. Enlarged image of detected traces of papillary patterns

For further study of the traces of papillary patterns, we selectively selected the same traces of papillary patterns found on a sheet of newsprint, which were first copied onto "AT" adhesive tape and after repeated detection onto light fingerprint film.

By studying the copied traces of papillary patterns on the adhesive tape "AT"

and the light fingerprint film, it was found that the traces are positive, they reflected a sufficient number of individual signs of papillary pattern of high and low identification weight in the form of beginnings, endings, mergers, branches of papillary lines, dots, etc. Existing general and individual signs of traces of papillary patterns formed a set sufficient to recognize them as suitable for identification.

For determining quality of displaying traces of papillary patterns, a comparison was made of the clarity of displaying individual signs of papillary patterns displayed in the above traces, as well as in the papillary pattern of the fingerprint from the fingerprint map (*cf.: Fig. 14–16*).

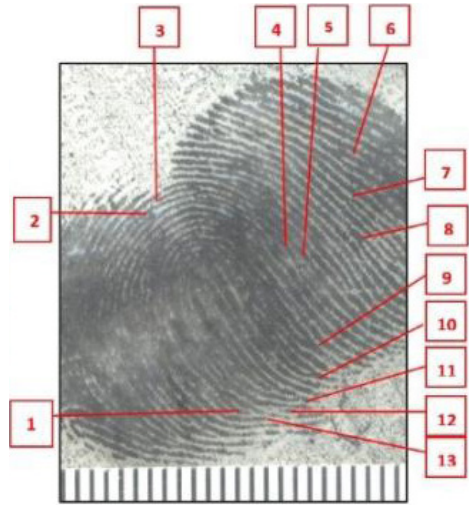

Fig. 15

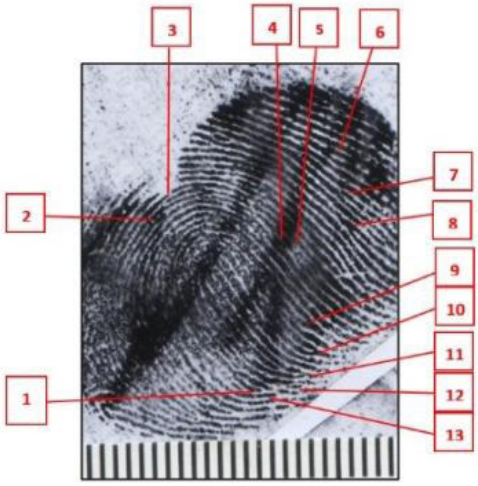

Fig. 14

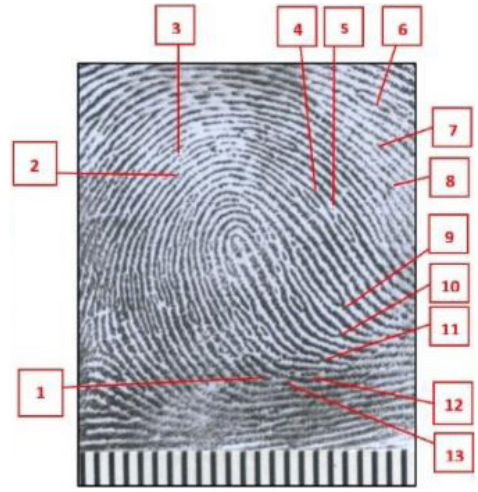

Fig. 16

Fig. 14—16. Image of traces of papillary patterns found on a sheet of newsprint and copied to adhesive tape "AT", light fingerprint film, as well as an enlarged image of the corresponding fingerprint from the fingerprint card

During comparison, it was found that the detected traces reflected such general features as the number and direction of papillary line flows, and the distance between them was the same. Individual features of the papillary pattern (in particular, such small individual signs as "fragments of papillary lines" and "dots") were clearly reflected, and their location and mutual arrangement corresponded to similar signs in the fingerprint map.

However, during research on detected traces for possibility of conducting pore and edgeoscopic researches, it was found that

even if highest quality traces were selected from among detected traces, such signs as availability and mutual arrangement of pores, their shape and size were not reflected in the traces. The configuration of the contours of the papillary lines in the traces and the fingerprint images on the fingerprint map are not identical (*cf.: Fig. 17–20*).

Fig. 17

Fig. 18

Fig. 19

Fig. 20

Fig. 17–20. Image of detected trace of papillary pattern, copied to light fingerprint film, and fingerprint on fingerprint map, as well as enlarged image of their fragments

Ability of the method to detect "ancient" fingerprints on surfaces of sheets of paper has been studied. Previous objects, on which traces of papillary patterns were already detected, were re-examined from 6 to 14 days after their abandonment using the *ESDA 2/B* device.

According to research results, traces of papillary patterns were found on the sheets of thick paper of the advertising booklet (*cf.: Fig. 21*).

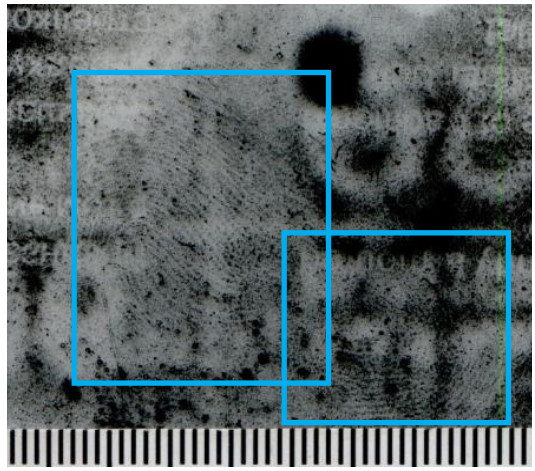

Fig. 21. Images of fragments of fingerprint films with copied traces of papillary patterns (indicated by blue frames)

During research of these traces of papillary patterns using magnifying glass (magnification: 4.5×) using various lighting methods, it was found that these traces were displayed less intensively and on a smaller plane compared to "fresh" traces. The traces are positive, but despite the fact that sufficient number of individual signs of the papillary pattern are reflected in the traces, which form a set sufficient to recognize some traces as suitable for identifying the person (s) behind them, their number has decreased significantly, as has their identification significance (*cf.: Fig. 22, 23*).

Fig. 22

Fig. 23

Fig. 22, 23. Enlarged image of copied traces of papillary pattern of the same finger on documents with different statutes of limitations

Conclusions

Based on performed researches conducted, it has been determined that the method of electrostatic reproduction of images using *the ESDA 2/B* device can belong to physical non-destructive methods for detecting traces of papillary patterns.

Application of this method:

- allows to detect traces of papillary patterns suitable for identification of a person, but they are unsuitable for identification of a person on the basis of microrelief of papillary lines;
- does not require any chemical processes due to the use of an electrostatic process that leaves the document unchanged chemically;
- does not change or affect visible handwritten records or any other marks on the paper that allows to conduct other types of forensic researches;
- lasts a relatively short time for the detection of traces of papillary patterns, but is not suitable for use in the "field" conditions;
- inappropriate for detecting traces left more than 14 days ago.

Застосування методу електростатичного репродукування зображень для виявлення слідів папілярних узорів на документах з паперовою основою

Олег Гайдук

Численні криміналістичні джерела розкривають основні етапи запровадження дактилоскопії у правоохоронну діяльність, роботу дослідників з розроблення надійної методики криміналістичної реєстрації, яка базується на врахуванні й використанні фізіологічних особливостей шкірного покриву пальців рук людини, та інші аспекти, пов'язані з проведенням дактилоскопічних експертиз, запровадженням відповідних автоматизованих баз даних тощо. На сучасному етапі наука криміналістика невпинно розвивається. Розширюється спектр методів і технічних засобів для виявлення слідів рук залежно від виду слідоносія, умов слідоутворення, а також завдань, які стоять перед органами досудового розслідування. Розвиток новітніх досягнень криміналістичної техніки потребує постійного оновлення методики користування сучасною криміналістичною технікою та перейняття позитивного досвіду застосування досягнень науки й техніки в діяльності правоохоронних органів іноземних держав, зокрема Великої Британії, під час розслідування злочинів і подальшої роботи з речовими доказами в межах судово-експертних досліджень. Мета цієї статті — розширити та поглибити розуміння причетними до правоохоронної системи особами опанованого методу й умови його застосування для виявлення слідів папілярних узорів на паперових поверхнях. Для досягнення поставленої мети застосовано загальнонаукові, а також спеціальні оптичні й мікроскопічні методи дослідження. Розглянуто методологічні аспекти виявлення слідів папілярних узорів на паперових поверхнях методом електростатичного репродукування зображень з наочними прикладами результатів користування приладом ESDA 2/B. Проаналізовано відмінність цього способу дослідження від наявних методів виявлення слідів папілярних узорів.

Ключові слова: *судова експертиза; дактилоскопічне дослідження; сліди папілярного узору; прилад ESDA 2/B; метод електростатичного репродукування зображень.*

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Disclaimer

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Participants

Author contributed solely to the intellectual discussion underlying this document, case law research, writing and editing and assumes responsibility for its content and interpretation.

Declaration of Competing Interest

Author declares no conflict of interest.

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