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Visualization of latent fingermarks on thermal paper: A new method based on nitrogen dioxide treatment

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Highlights

- A new method for visualization of latent fingermarks on thermal paper is presented.
- The new method is based on chemical treatment with NO_2 gas.
- The new method is simple, fast, safe, non-destructive and inexpensive.
- This method does not require post-treatment and has a high identification capacity.

Abstract

A new chemical method for visualization of latent fingermarks on thermal paper, based on a treatment with nitrogen dioxide (NO_2) gas, is presented in this work. The gas is generated by a reaction between concentrated nitric acid and a copper chamber. This newly proposed method does not require fingermark's fixation reagent after the treatment with NO_2 i.e. the visualized fingermarks remain permanent for more than one week and without any changes in its quality. The general visualization mechanism is according to basic oxidizing conditions in order to induce tautomeric transformation of the leuco dye's molecules in the thermal layer, accompanied by a color change of the papillary lines throughout the whole fingermark. The NO_2 method provides satisfactory contrast between the visualized fingermarks and the background surface i.e. thermal layer. The visualized fingermarks are qualified with high clarity and continuity of the friction ridges, and clarity of the 2nd level characteristics. The proposed method was evaluated by dactyloscopic comparison of the number of 2nd level characteristics and according to the results it can be exemplified with high identification capacity. The proposed method is simple, safe, cheap, non-destructive, non-time consuming, applicable for visualization of aged fingermarks, and potentially applicable under terrain (field) conditions in real forensic casework.

Graphical abstract

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Introduction

Thermal paper is a material widely used for printing bills, ATM cash machine slips, invoices, faxes, medical recipes, public transport tickets, etc. Actually, this material presents a paper which is one-side coated with a thin layer (known as a thermal layer) that consists of leuco dyes, developers, sensitizers, stabilizers and solid solvents with a low melting point in the temperature interval of 45–65 °C [1], [2], [3]. The printing process on this kind of paper is achieved by applying localized heat on its surface that leads to a slight melting of the solid solvent (composed of fatty acids, amides, alcohols, etc.). This allows contact between the components in the thermal layer and chemical transformations are instantaneously induced [1], [2], [3]. These processes include reactions between leuco dyes (lactones with chromophore groups in their structures, such as crystal violet [2]), and color developers that include organic acids based on phenolic derivatives (such as bisphenol A), fatty acids, and other compounds [3], [4], [5]. The thermally initiated net chemical reaction is based on a tautomeric shift mechanism that includes opening of the lactone ring in the dye's structure under low acidic conditions [2], [6], accompanied with a color change. The other two kinds of materials known as sensitizers and stabilizers are also based on organic compounds and they are added in the thermal layer in order to increase the coloration effect, and to avoid reversible discoloration of the dyes, respectively.

The visualization of latent fingermarks on thermal paper is still a challenge in the common forensic practice. There are many published methods in the literature in this research field, but not all of them are reliable for application in real casework. The methods that are applied or known nowadays are classified in different categories. One of the most informative classifications of 19 methods in seven groups is published by Fitzi et al. [1], where the methods mentioned there were compared and their performance was evaluated on randomly collected thermal paper samples. However, the methods that are known nowadays could be simply divided into two groups i.e. as chemical and physical methods.

The chemical methods include different variations of chemical treatment during the process of fingermark's visualization [1], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21]. They mainly encompass treatment of the thermal paper with conventional reagents like ninhydrin, 1,2-indanedione, 1,8-diazafluoren-9-one, and their derivates dissolved in certain organic solvents [1], [7], [8], [9], [10], [11], [12], [13]. Unfortunately, the excess of some organic solvents could cause overdevelopment i.e. darkening of the background surface due to partial dissolution of the solid solvent that causes contact and leads to chemical reactions between the leuco dyes and the developers in the thermal layer [1], [2], [3]. These processes can enhance a significant contrast reduction of the visualized fingermarks. In order to overcome this issue, a variety of substantial modifications were proposed in the literature. These modified chemical methods include adaptation of their recipes [1], incorporation of additional pre- or post-treatment [1], [14], [15], usage of so-called "sandwich" procedures [1], [17], [18], [19], and etc. Besides them, there are chemical methods that involve treatment with fumes and gases, and thus avoiding any dipping of the thermal paper in organic solvents. They are based on inducing fast transformation in the leuco dye's structure accompanied by color change. These methods encompass fuming with acidic fumes (such as HCl [22] and CH_3COOH [23]), alcoholic fumes [23], iodine - I_2 [6], and amino aldehydes [24].

The group of physical methods encompass procedures for applying heat using thermal sources [25], [26]. These methods are based on heat-caused coloration effect due to the structural transformations in leuco dye's molecules and thus achieving visualization of the latent fingermarks.

The applicability and reliability of each method is directly connected with several benchmarks that should be fulfilled and they include sensitivity, simplicity, relatively low time-consuming, reproducibility, non-destructiveness, cost-effectiveness and applicability in practice. There is no method that yet fulfills all benchmarks and that is why there is still an ongoing research for new methods for visualization of latent fingermarks on thermal paper. Namely, according to the evaluation results published by Fitzi et al. [1], the best performing method in terms of its sensitivity are the chemical methods that involve treatment with 1,2-indanedione and ninhydrin-based reagents. On the others side, these methods are time-consuming (24–48 h [1]) which makes them inapplicable under terrain conditions. Another example is the I_2 fuming method which did not show significant performance in the method evaluation conducted by Fitzi et al. [1], but on the other side this method is simple, fast and commercially available for application under terrain conditions [27].

The new method that is proposed in this research includes chemical treatment with nitrogen dioxide (NO_2) gas for visualization of latent fingermarks on thermal paper. This method belongs to the group of chemical methods that are based on applying fumes and vapors. The newly proposed method is simple, fast, cheap, non-destructive and reliable.

Section snippets

Equipment, materials, and reagents

The materials, chemicals and equipment that were used for preparation and visualization of latent fingermarks on thermal paper by using the novel NO_2 method, and the well known I_2 fuming/benzofluorene and ninhydrin methods (for comparison and evaluation of the novel method) are listed in Table 1....

Preparation of thermal paper test samples

The thermal paper samples (from each brand) were carefully cut into small pieces (~2.5 × 2.5 cm) and ordered on a flat plastic surface with the thermal layer turned upwards. Two types of latent...

Fingermarks analysis strategy, performance of the NO_2 method on fingermarks impressed on different thermal paper brands and dependence of the identification outcome from the applied mass when impressing fingermarks

The analysis of the scanned fingermarks that were previously visualized is mainly focused on the 1st and 2nd level characterization. This examination procedure was carried out in accordance with a determination of several important qualitative and quantitative parameters such as: a possibility of recognizing the pattern of each fingermark (arch, loop, and whorl), a clarity and continuity of the friction ridges, an influence of the applied pressure when impressing the fingermarks on the thermal...

Conclusions

A new chemical method for visualization of latent fingermarks on thermal paper is described in this paper. The method is based on a NO_2 gas generation in a closed chamber by reactions between HNO_3 and Zn, and treatment of thermal paper samples with the as-generated gas. The most possible mechanisms that provide visualization are based on parallel chemical reactions between NO_2 and sebaceous (lipidic) compounds, developers, and leuco dyes, thus inducing synergistic acidification that is...

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... Preliminary/Pilot studies – The addition of liquid glue to a NIN solution (0.02–0.05 g/ml) was claimed to prevent the darkening of thermal papers while allowing NIN to react with fingermarks [231]. Exposure to nitrogen dioxide fumes, generated in situ by the reaction of nitric acid and zinc, is presented as a solvent-free method to detect fingermarks on thermal papers [429]. Note: these preliminary/pilot studies relying on limited sample sets (e.g., one donor, few depositions, sebum-rich secretions, fresh fingermarks), an overestimation of the reported performances is expected,...

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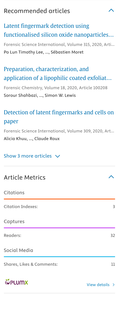

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