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Technical note

Latent fingermark development using low-vacuum vaporization of ninhydrin

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ABSTRACT

The vacuum technique is a method of vaporizing a solid material to its gas phase, helping deposit reagents gently on target surfaces to develop latent fingermarks. However, this application is rarely reported in the literature. In this study, a homemade fume hood with a built-in vacuum control system and programmable heating system designed by the Taiwan Criminal Investigation Bureau is introduced. Factors that affect the instrument's performance in developing fingermarks are discussed, including the quantity of chemicals for vaporization, heating program arrangement, and paper of different materials.

The results show that fingermarks are effectively developed by vaporizing solid ninhydrin. This would be an alternative application in selecting a solvent-free method for protecting the environment and reducing health hazards in the lab. In terms of the heating program, the result indicates that under a low-vacuum condition (50 mTorr), 80–90°C is a suitable temperature range for ninhydrin vaporization, allowing ninhydrin to be vaporized without bumping and waste. In terms of the performance on different material papers, this instrument demonstrates its capacity by developing latent fingermarks on thermal paper without discoloration or damaging the original writing, and the same results are also observed on Taiwan and United States banknotes. However, a coherent result could be hardly obtained using the same vaporization setting because different banknotes have their own surface features and water absorption ability or other unique factors may influence the effect of ninhydrin deposition. This study provides a reliable application for developing latent fingermarks without using solvents, and it is also expected to contribute to environmental protection along with the trend of green chemistry technology.

1. Introduction

Ninhydrin is the most commonly used reagent for the development of latent fingermarks on porous surface [1,2]. All ninhydrin formulations inevitably use large amounts of organic solvents and increase the load on the environment. However, as environmental awareness gains ground, the concept of "green analytical chemistry" is playing an important role [3]. Among the industrial processes, vacuum deposition is used to deposit layers of material on a solid surface. On the basis of the source material, vacuum deposition can be subdivided into vacuum metal deposition (VMD) and vacuum organic compound deposition. Following the introduction of VMD by Theys et al. in the 1960s [4,5], VMD has become an established method for the development of latent fingermarks, particularly for old or weathered prints [6]. There is now an alternative application to assist in developing fingermarks [5–8].

In addition, Schwarz et al. introduced a vacuum organic compound deposition technique to develop latent fingermarks [9]. Ninhydrin was heated in a vacuum environment for vaporization; then, the gaseous ninhydrin was deposited on target specimens, banknotes, and thermal paper, for visualizing latent fingermarks. The results showed the successful visualization of latent fingermarks on both banknotes and thermal paper [10]. The same results have been reported when other chemicals, such as dimethylaminocinnamaldehyde (DMAC) [11,12] and copper phthalocyanine [13], were used. Sublimation with iodine [14] or dyes [15] under atmospheric pressure is also reported.

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Vacuum deposition, which is confined to equipment costs, is not a widespread latent fingermarks development technique. However, the vacuum organic compound deposition is a technique capable of solvent-free property and low-reagent quantity [16]. From the perspective of green analytical chemistry, the vacuum organic compound deposition is worth further investigation. This study aims to optimize the vacuum deposition parameters, for example, the temperature program of the heating source, vacuum pressure, and quantity of vaporization source, to investigate the development of latent fingermarks on three different types of paper.

2. Materials and methods

2.1. Instrument

In practice, paper made from specific materials, such as thermal paper, is usually discolored or even damaged with solvents, consequentially hindering fingermark collection; to resolve this issue, the Taiwan Criminal Investigation Bureau designed a fume hood comprising a low-vacuum system (approximately reaching 10^{-3} Torr) and a programmable heating source. As few references could be found, this prototype instrument was built following continual discussion with the manufacturer and fingermark experts. In this study, ninhydrin was used as the fingermark development reagent prior to the discovery of alternative chemicals.

2.2. Experiment

2.2.1. Sample preparation

According to the code established by the Internal Fingerprint Research Group, this research belongs to PHASE1 [17]. Four types of paper were provided to each of the three participants to obtain palm prints and fingermarks. These included printing paper, envelope paper, thermal paper, and New Taiwan dollar (NTD) and United States dollar (USD) banknotes. To simulate "natural marks," which are real eccrine-rich specimens usually left by suspects in high-tension physical conditions in three volunteers (one female and two males), participants were asked to jog for 10 min first and then press both the hands' palms and fingertips on each type of paper; owing to size limitation, only fingermarks were pressed on banknote samples. After the prints were set, all of the papers were stored at room temperature for one month before fuming [17–19].

2.2.2. Experimental procedure and data collection

Ninhydrin (reagent grade purchased from BVDA International, Netherlands) was put in a glass crucible and placed inside a vaporization source. Once the vacuum inside the fume hood reached 50–100 mTorr, the eight stages of the heating program automatically started. After the temperature reached the final stage in minutes, the samples were kept in the chamber for 20 min before photographs were taken under 1 atm pressure. After the vaporization process (approximately 24–26 min), depending on the quantity of ninhydrin consumed, fingermarks would be developed in an hour to one day. The samples were then stored at that pressure and room temperature for obtaining photographs on the next day and the third day.

Samples were photographed using a Canon EOS 20D digital camera with operating conditions set as "exposure, automatic white balance, and ISO 400," using a Video Spectral Comparator (VSC-5000) from Foster & Freeman Limited (Worcestershire, United Kingdom).

2.2.3. Optimizing the quantity of ninhydrin

Different weights of ninhydrin were prepared for estimation, including 50, 100, 150, 250, and 500 mg. To test the possibility of false negatives being created by the direction of reagent deposit, the print paper type samples were folded in half with one side of the fingermarks being parallel to the vaporization source and the other side having its back to the source.

2.2.4. Optimizing the temperature program

The instrument offers eight stages of temperature control for vaporization. Although there are solid references indicating that the vaporization point of ninhydrin (FW = 178.14 Da) is 241°C under 1 atm, the detail change below 1 atm remains unclear. Thus, the optimized program was considered to vaporize ninhydrin in the shortest time, and the heating slope was moderate enough to cause no ninhydrin crystal bumping.

2.2.5. Comparison with Schwarz and Frerichs [9]

On the basis of the application for split marks investigation, a comparison between the condition reported by Schwarz and Frerichs [9] and this study is listed below (Table 1).

3. Results and discussion

3.1. Instrument design and construction

The initial concept of the homemade instrument is based on the ideal gas law, introducing a low vacuum (10^{-3} Torr) into a traditional fingermark development fume hood to vaporize a solid fuming reagent more easily and increase the efficiency of the fingermark development process.

The main part of the instrument is a 40-cm diameter hollow stainless steel cylinder having a depth of 50 cm. The vacuum system containing a VDN-301 rotary vane vacuum pump produced by ULVAC (Kanagawa, Japan) coupled with a Terranova vacuum gauge controller produced by Duniway stockroom cooperation

Table 1
Applications comparison of ninhydrin vaporization under low-vacuum for latent fingermarks development.

Instrument settings and experiment conditions	Parameters about experiment	
	Bundeskriminalamt (BKA) [9]	Taiwan Criminal Investigation Bureau
Volume of fume hood	Vacuum chamber (50 × 50 × 50 cm)	Stainless steel (tall 50 cm with 40 cm inside diameter)
Vacuum level	2–5 mbar (1.5–3.75 Torr)	50–100 mTorr
Distance between sample holder and heating source	15 cm	20 cm
Dose of ninhydrin	500, 250, 200, 100, 50 mg	500, 250, 200, 100, 50 mg
Temperature of heating source	100, 125, 150, 200, 250°C	Programmed temperature rising from 80°C
Heating source	Electric resistance heater	Electric resistance vaporization coupled with a glass crucible
Processing time	30 min	20 min
After fuming	1 atm, 50°C, 50%RH[a], 30 min	1 atm, RT[b], over night

[a] RH represents the relative humidity.
[b] RT represents the room temperature.