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## TECHNICAL NOTE

*Lothar Schwarz,*[1] *Dr. Phil. Nat. and Inga Frerichs,*[1] *C.T.A.*

# Advanced Solvent-Free Application of Ninhydrin for Detection of Latent Fingerprints on Thermal Paper and Other Surfaces

**ABSTRACT:** This work presents the first known experiments of ninhydrin sublimation in vacuum to detect latent fingerprints on thermal paper. In this method, latent fingerprints become visible in rich detail without the background black staining known from the application of ninhydrin solutions to thermal paper.

The method involves hanging the thermal paper samples 15 cm above a heating source with dispersed ninhydrin crystals in a vacuum chamber. The optimized conditions for ninhydrin sublimation are 50 mg ninhydrin, 2 to 5 mbar vacuum, and 150°C heating source temperature for 30 min.

The application of this method is also successful on the new euro notes. Latent fingerprints can be developed across the transitions from paper to optical variable device (OVD).

**KEYWORDS:** forensic science, fingerprint, detection, ninhydrin, sublimation, thermal paper, solvent-free, euro notes

Detection of latent fingerprints on thermal paper is an increasing problem in German police forces, because thermal paper prevails on the credit card receipt market. Some thermal papers show background black staining on the heat-sensitive front side when treated with ninhydrin solutions. Consequently, fingerprints and information on the receipt will be destroyed.

Ninhydrin (2,2-dihydroxy-1,3-indandione) is the oldest and best known detection reagent for latent fingerprints on porous surfaces and reacts with amino acids of fingerprint sweat (1,2). In solution the solvents start the undesirable background black staining on thermal paper.

In literature we found some alternative methods for detection of latent fingerprints on thermal paper: ninhydrin derivative, ninhydrin sandwich process (development of thermal paper between dry ninhydrin containing blotting paper under pressure for several days), dimethylaminocinnamaldehyde (DMAC) fuming, elemental mapping by using electron probe microanalyzer (EPMA), and iodine fuming for fresh fingerprints (3–7).

Our idea for better fingerprint detection on thermal paper was the ninhydrin sublimation under reduced pressure as a solvent-free application.

Ninhydrin with a molecular weight of 178.14 should be able to transfer into the gas phase. In the literature we found no data on the sublimation and partial pressure of ninhydrin, only a melting point of 241°C with decomposition and one non-detailed hint of using ninhydrin fumes at normal pressure (8,9).

[1] KI 24-6 "Research, Development, and Testing of Fingerprint Detection Methods," Kriminalistisches Institut des Bundeskriminalamtes, Wiesbaden, Germany.

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After a positive initial experiment, we optimized the sublimation conditions for fingerprint detection.

### Experimental Setup

The experiments were carried out in a 50 by 50 by 50 cm vacuum chamber with a frontal glass door. Inside was a temperature-controlled heating source 5 cm in diameter and 10 cm above the bottom of the chamber.

The test samples were fixed in the upper part of the chamber. The minimum distance between heating source and test samples was 15 cm.

The samples were fixed in the chamber, and a defined amount of ninhydrin was dispersed onto the heating source. Then pressure was reduced to an end pressure of 2 mbar (0.2 kPa, 1.5 mm Hg or ca. 0.002 atm), which was reached after 5 to 10 min. Finally, the heating source was switched on.

After the desired sublimation temperature was reached (which took about 1 min), the time counting was started.

To accelerate the development under identical conditions, all test samples were stored for 30 min in a climate chamber at 50°C and 50% RH after ninhydrin treatment. For comparison of the different ninhydrin application conditions, the developed samples were rated by visual examination of several people.

### Results and Discussion

In the initial experiment, big crystals of ninhydrin (250 mg) were heated up to 250°C. After 4 min, new crystal needles had grown out of the ninhydrin, the color of which turned from white to red. In a light beam, some small particles were observed moving along with the heat convection in the vacuum chamber. The same experiment

with fine crystals of ninhydrin showed no new crystal needle growing, but many more small particles were observed in a light beam. These small particles precipitate and form a snow-like rug at the bottom of the chamber. After the developing treatment (50°C and 50% RH) on both sides of the thermal paper, fingerprints were developed without discoloring of the heat-sensitive side.

For systematic experiments, test samples of standard white DIN A4 writing paper with invisible alanine square lines (4 mm line distance) were carried out. The alanine square lines were printed with an aqueous solution of alanine by a modified ink jet printer, and the prepared papers were stored up to 20 days at room climate before ninhydrin application was applied. The papers were fixed at the left side, right side, at the back, and at the top of the vacuum chamber.

The experiments should give information about the distribution of ninhydrin gas in the chamber under different setup conditions by contrast of the developed samples. For these experiments, the sublimation temperature and the ninhydrin amount used were varied. The experimental setups are given in Table 1. For each experiment, the time of sublimation and the quality of the developed samples are noted. All these experiments were carried out by using fine crystalloid ninhydrin (Sigma Aldrich).

In experiments with 500 mg of ninhydrin heated for 30 min, 400 mg of ninhydrin were left on the heating source at 150°C, 300 mg at 200°C, and no ninhydrin is left after 15 min at 250°C.

In experiments with 50 mg of ninhydrin, 34 mg were left after 60 min at 100°C and about 10 mg after 60 min at 125°C. In all other experiments, the ninhydrin disappeared completely from the heating source.

In the 500 mg experiments on all test papers, sharp square lines were observed in good contrast all over the sheet surface after development in the climate chamber. By visual comparison, no influence of the heating source temperature was observed. The sample from the top of the vacuum chamber was slightly better contrasted than the other three sample sheets, which showed a slight decrease of contrast from the bottom to the top of sample sheets.

In the experiments at 250°C and with variation of the ninhydrin amount, the contrast on the test sheets decreased with the decreasing ninhydrin amount.

In the 50 mg experiments, the contrast increases with decreasing the temperature of the heating source.

Tests with up to 30 samples (7 by 10 cm) of alanine square line standard writing paper and thermal paper hanging parallel in the upper part of the chamber were also successful. All samples showed rich detailed and sharp developed lines.

TABLE 1—*Time of sublimation by different temperatures and ninhydrin amounts; visual quality of sample contrast: + = good, 0 = bad, − = no development; ÷ = no experiment.*

| Temperature of Heating Source | Amount of Used Ninhydrin | | | | |
|---|---|---|---|---|---|
| | 500 mg | 250 mg | 200 mg | 100 mg | 50 mg |
| 250°C | $15_{min}$ + | $15_{min}$ + | ÷ | $15_{min}$ + | $15_{min}$ 0 |
| 200°C | $30_{min}$ + | ÷ | $30_{min}$ + | ÷ | ÷ |
| 150°C | $30_{min}$ + | ÷ | ÷ | ÷ | $30_{min}$ + |
| 125°C | ÷ | ÷ | ÷ | ÷ | $60_{min}$ + |
| 100°C | ÷ | ÷ | ÷ | ÷ | $60_{min}$ 0 |

All these experiments show that ninhydrin gas is distributed in the chamber and is able to develop latent fingerprints. It is possible to develop many samples in a time-efficient way with one treatment in the chamber. Through the heat, ninhydrin molecules can be transferred into the gas phase. After some time, which depends on the heating source temperature and amount of ninhydrin used, ninhydrin molecules aggregate to small particles that are visible in a light beam and that precipitate to the chamber bottom without use.

The chamber pressure does not reach more than 5 mbar during the sublimation process. This indicates that the partial pressure of ninhydrin cannot be very high and only a small amount of ninhydrin is available in the gas phase. Obviously, the maximum ninhydrin gas concentration is reached when the aggregated small particles are observed in a light beam.

The quality of developing fingerprints increases with the number of ninhydrin molecules reaching the amino acids of the latent fingerprints. This is possible by increasing the contact time of the sample to the ninhydrin gas and by increasing the ninhydrin gas concentration, which has its limit due the physical properties of ninhydrin. Because increasing the ninhydrin gas concentration is only possible by increasing the chamber temperature, which is limited by the properties of thermal paper. Treatment of less heat-sensitive samples may be done by higher temperature. As shown in Table 1, increasing the heating source temperature means a short application time but produces a higher amount of wasted ninhydrin precipitate. With decreasing temperature, less ninhydrin will be wasted as precipitate but a longer application time is needed. According to the visual evaluation of all test samples, we consider 50 mg ninhydrin at 150°C for 30 min to be the optimal conditions.

In Fig. 1, some fingerprints on thermal paper developed by ninhydrin sublimation are shown. The application of ninhydrin sublimation is also successful for the detection of latent fingerprints on the new euro notes across the transitions from paper to optical variable devices (OVD). The dipping method fails on these security marks, probably due to the non-porous surface of the OVD, but with ninhydrin sublimation fingerprints become readily visible on the OVD (Fig. 2).

## Conclusions

Ninhydrin sublimation is very useful for porous samples. The described tests show that it works on normal white paper, thermal paper, and euro notes. Each sample material has an age up to 20 days, stored at room climate before ninhydrin treatment. The optimized conditions for ninhydrin sublimation are 50 mg Ninhydrin, 2 to 5 mbar vacuum, and 150°C heating source temperature for 30 min. It has been shown that it is possible to treat many paper samples in one run. The ninhydrin sublimation takes not much more time than the commonly used dipping process.

Further advantages result from the lack of organic solvents in the sublimation process. Costs for purchase and disposal of the solvents can be saved as well as time for preparing the solutions.

On visual comparison of alanine square-lined normal paper samples dipped in ninhydrin solution versus the same treated with ninhydrin sublimation, the dipped samples showed slightly better contrast (Fig. 3).

Further investigations are planned to improve contrast, based on densitometric measurement, for objective comparison of gradual differences. Furthermore, the sample materials have to be enlarged (different paper quality and other (semi) porous surfaces) in consideration of sample age up to one year, and the vacuum sublimation of other reagents like 1,8-diazafluoren-9-one (DFO),

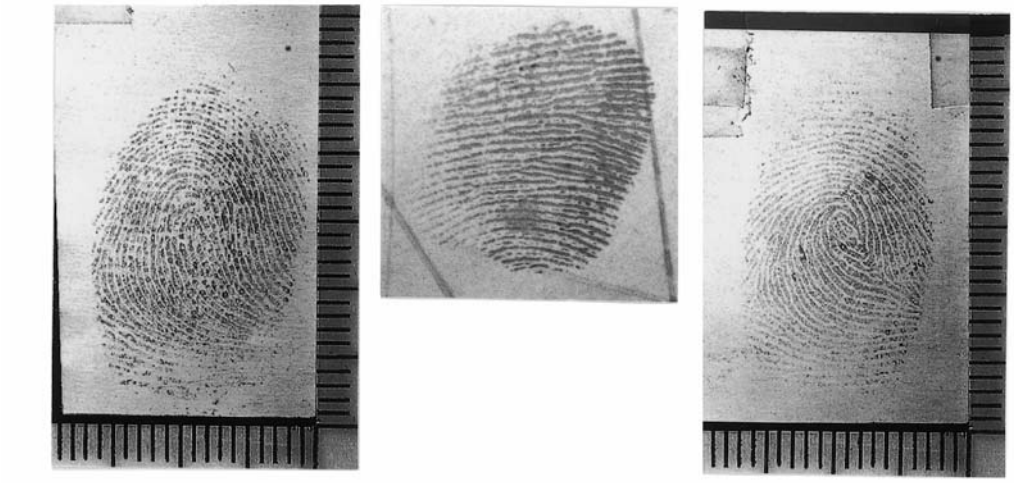

FIG. 1*a–c—Fingerprints on thermal paper developed by ninhydrin sublimation.*

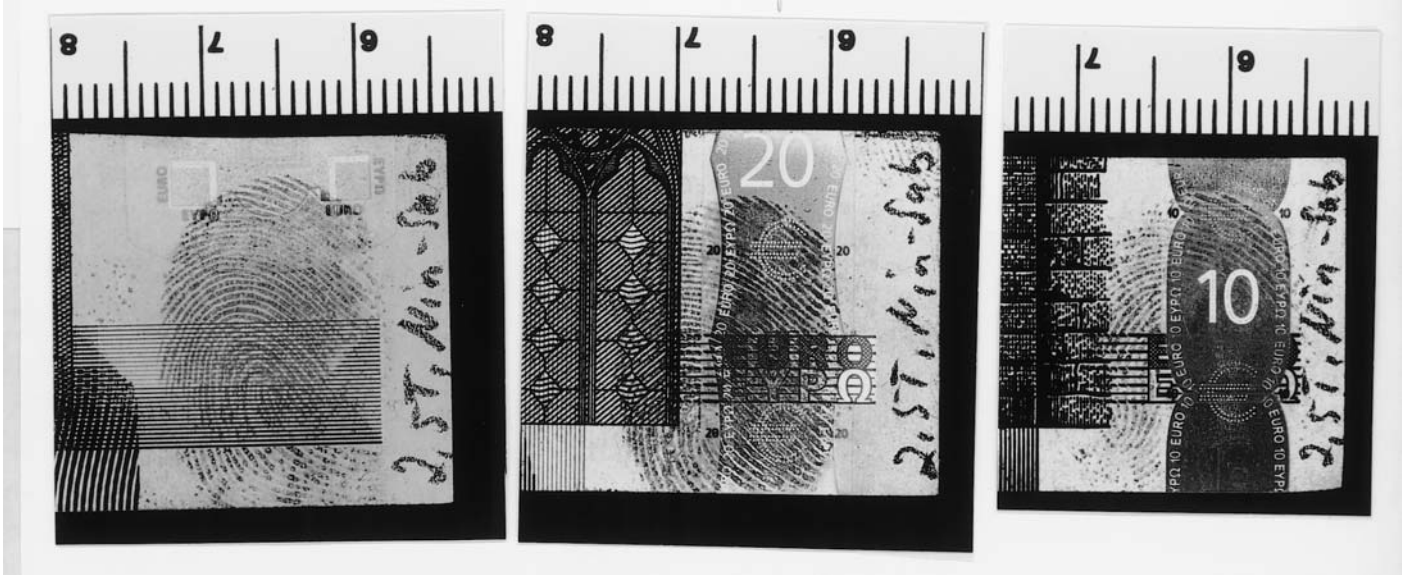

FIG. 2*—Fingerprints on euro notes across the OVD developed by ninhydrin sublimation,* (a) *front side of a 50 € note;* (b) *front side of a 20 € note,* (c) *front side of a 10 € note.*

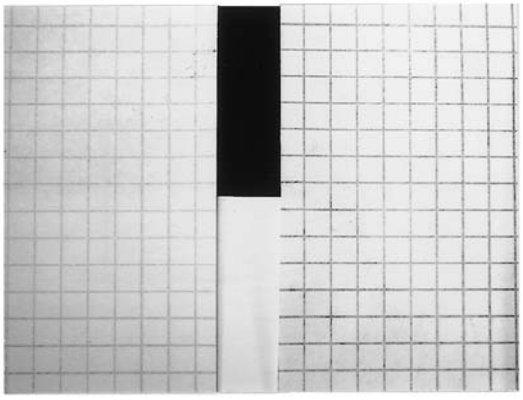

FIG. 3*—Comparison of ninhydrin development of alanine square lined paper, left sublimated, right dipped.*

1,2-indandione, dimethylaminocinnamaldehyde (DMAC), or 8-hydoxyquinoline will be tested.

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Additional information:
Dr. Lothar Schwarz
KI 24, Bundeskriminalamt
65173 Wiesbaden
Germany