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**TECHNICAL NOTE**

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# Fingerprint Detection on Counterfeit US$ Banknotes: The Importance of Preliminary Paper Examination

**ABSTRACT:** Two seizures of counterfeit 100 US$ bills related to the same indicative number were submitted for processing of latent fingerprints. On one group of notes, identifiable fingerprints could be detected by the routine application of amino acid reagents. In the second case, this technique gave no results, even on deliberately deposited prints. Fingerprints could be revealed, however, by cyanoacrylate fuming followed by magnetic powder. Comprehensive paper analysis showed that banknotes from both seizures differed remarkably by chemical composition as well as paper macroscopic properties. The difference in surface free energy (related to surface tension) of the banknotes in the two groups seemed to be the major factor responsible for the great variance in fingerprint detectability.

**KEYWORDS:** forensic science, latent fingerprints, counterfeited banknotes, ninhydrin, DFO, amino acid reagents, cyanoacrylate fuming, paper chemistry, surface energy

Counterfeit paper banknotes are often submitted for latent fingerprint detection. In many cases, latent fingerprints that develop on the banknotes are the only link between the evidence and the culprits. The routine procedure begins with visual examination followed by chemical treatment in solution, containing amino acid reagents. In high profile cases, this may be followed by application of physical developer (PD) (1).

In the cases presented herein, two separate seizures of counterfeit 100 US$ bills were submitted to the Latent Fingerprint Laboratory of the Division of Identification and Forensic Sciences (DIFS) of the Israel National Police a few days apart. In the first case (Case A), 50,000 US$ were seized on a suspect in Haifa. In the second case (Case B), two million US$, in $100 bills, wrapped in a plastic bag, were seized at Ben Gurion Airport. The money was found in the suitcase of a traveler arriving from Uzbekistan. In both cases, the bills were related to the same indicative number (12A22004), according to the List of Counterfeit U.S. dollars banknotes (Interpol, Amsterdam). The same indicative number indicates a common forgery origin and is related to 450 additional cases in Israel between 2000 and 2003.

Following routine laboratory protocol, fingerprint processing was conducted in both cases by applying the DFO-ninhydrin sequence (1). A sample of 367 banknotes from Case A was processed with DFO with negative results. After the subsequent treatment with ninhydrin, several identifiable prints and a few unidentifiable prints appeared. However, no fingerprints could be visualized on banknotes sampled from Case B after DFO and ninhydrin application. Forty additional bills from Case B, grouped in tens, were then treated with one of the following reagents: ninhydrin (1), DFO (1), or indanedione (in two formulations (2,3). No prints were revealed on any of the bills. Controlled prints from a good donor were deposited on additional bills and processed using the aforementioned techniques to no avail. A few bills bearing deliberately deposited prints were then processed by cyanoacrylate fuming, a technique usually applied to non-porous and semi-porous surfaces. Several prints were developed and were subsequently enhanced with black magnetic powder. Three hundred sixty bills were then processed with cyanoacrylate, followed with black magnetic powder. Several prints developed on some of the bills.

The paper from the two seizures described above looked and felt slightly different from each other. There was no indication, however, that any of them were unsuitable for conventional fingerprint processing on a porous surface. Negative results are not unusual in routine work, as about 50% of our casework files come up negative for fingerprints. It is noteworthy that several Israeli and international fingerprint experts that received the bills for examination admitted they all would have used the conventional paper fingerprint techniques on both types of banknotes.

The above results, and a few other similar cases, led us to investigate more thoroughly the relationship between paper properties and fingerprint detectability. Such knowledge would hopefully enable fingerprint practitioners to adjust the optimal sequence of fingerprint techniques for each type of paper, and, perhaps develop some

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new techniques. Our initial results will be reported in a forthcoming paper. In this particular instance, two $100 bills from each seizure were submitted for comprehensive paper characterization to VTT Technical Research Centre of Finland in Espoo. This study was done in collaboration with the National Bureau of Investigation in Vantaa, Finland.

## Materials and Methods

The following techniques were utilized as described in the VTT report (4): 1. Measurement of contact angle (CAM 200® analyzer, KSV Instruments Ltd.). Contact angles between paper sample and a drop of five model liquids (of different surface tension and polarity) are measured and surface free energy, relative polarity and acid-base components of the sample surface can be calculated. Surface energy properties determine how different types of liquids and solid surfaces interact with each other (how the liquid wets the surface; how the liquid adheres to the surface). 2. Analysis of paper surface topography and small scale smoothness/roughness with PaperMap–profilometer. This optical profilometer measures topography of paper non-contact and with higher resolution than conventional roughness measuring methods. Conventionally the roughness/smoothness is the ability of the paper surface to resist an air stream flowing between the paper and a surface or an edge pressed against it (5). 3. Analysis of the origin of the paper fiber components by staining methods (Herzberg or Graff C reagents, standard method ISO 9184) and microscopic analysis of colored fibers. 4. Pore size distribution by mercury porosimetry. The pores are the channels between the fibers in the paper. 5. Determination of common paper properties: grammage, thickness, density, ash content, pH–value. The grammage of the paper (basic weight) is the mass of unit area expressed as grams per square meter. The density is the mass per unit volume calculated as the ratio between basis weight and thickness of the paper. The ash content is the inorganic residue after the incineration of the paper (total mineral content) (5).

## Results and Discussion

Very few forensic laboratories carry out extensive paper analyses. Experts are generally satisfied with ink or glue properties and the main features of the paper are occasionally examined (6). As can be seen from the test results (Table 1, (4)), considerable differences have been noticed between the banknote paper of the two groups. They differed in their microscopic as well as macroscopic properties. These were the main differences:

- The banknotes of Case B were of higher grammage and density (and lower thickness).
- The porosity of Case B banknotes was lower than of Case A (lower cumulative pore volume and smaller average pore size).
- The surface free energy of Case B banknotes was quite low for a paper sample, possibly due to some kind of coating or sizing applied to the paper's surface. The low level of surface free energy means that paper B was more hydrophobic than A. The surface energy of the Case A banknote was in the typical range for uncoated papers (30–50 mN/m).
- Surface roughness of Sample B was smaller than that of A (Samples B were smoother than A). The negative value of the skewness of the surface roughness in Sample B means that the paper's surface had "valleys" in it, and the positive value for Sample A indicated that there were "hills" on the paper's surface.

TABLE 1—*Paper analysis results of counterfeit banknotes from Cases A and B (4).*

| Property Tested | Banknotes Case A | Banknotes Case B |
|---|---|---|
| Grammage ($g/m^2$) | 78 | 86 |
| Density ($g/cm^3$) | 0.65 | 0.86 |
| Thickness (mm) | 0.12 | 0.10 |
| pH | 5.5 | 5.7 |
| Ash content (%) | 10.8 | 5.9 |
| Cumulative pore volume ($cm^3/g$) | 0.35 | 0.25 |
| Average pore size (μm) | 2.21 | 1.75 |
| Surface free energy (mN/m) | 33.3 | 21.5 |
| Surface roughness, front (μm) | 8.13 | 6.51 |
| Skewness, front | 0.07 | −0.35 |
| Surface roughness, back (μm) | 8.05 | 6.42 |
| Skewness, back | 0.16 | −0.21 |
| Small scale formation parameters | | |
| Grammage ($g/m^2$) | 78.4 | 86.3 |
| Standard deviation ($g/m^2$) | 8.0 | 8.0 |
| Variation coefficient | 0.10 | 0.09 |
| Variance | 63.9 | 64.1 |
| Skewness | 0.21 | 0.13 |
| Peakness | 3.17 | 2.90 |
| Floc diameter (mm) | 2.31 | 2.73 |
| Floc area ($mm^2$) | 1.64 | 2.49 |
| Floc shape | 1.41 | 1.10 |

- The uniformity of fiber distribution is called "formation". As seen in Table 1 (small scale formation parameters), Sample B contained large bunches of fibers (flocs). The floc diameter (mm) is obtained from the formation image data using run-length-coding method (5) in both vertical and horizontal directions (machine (MD) and cross-machine (CD) directions, respectively). The area of the floc ($mm^2$) is calculated by multiplying floc diameters in machine and cross-machine directions, whereas the shape of floc is calculated by dividing the MD-floc diameter with CD-floc diameter. Floc sizes (diameter and area) depend on many factors including, for instance, raw material (fiber dimensions) and running parameters of the paper machine. The floc sizes are used to describe structure of paper and classify paper grades. The texture of Sample B was smooth, "cloudlike." The periodical wire marking could be distinguished and the safety thread could slightly be detected. The formation of Sample B recalls the formation of fine paper (for instance, copy paper). The formation of Sample A was totally different. There were no large flocs and the texture was sharper. Single, threadlike, heavier (lighter in formation map) areas could be detected. These patterns could possibly have been caused by flax or cotton fibers. No significant difference was found between the variation coefficients (ratio between standard deviation and mean grammage) and the variances (2nd power of standard deviation) of the grammage distribution for both paper samples.
- The treatment of banknote samples with iodide-iodine staining solution (Herzberg solution) showed different behavior between the two groups: there was a very faint yellowish reaction on the materials that form the Sample B, and some of the fibers were stained blue. This indicated that the Sample B paper consisted of mechanical and chemical mass fibers. In Sample A, a strong purple color in some of the fibers was noticed and some of the fibers appeared to stain dark blue. This kind of color reaction indicated that the Sample A consisted of rag mass (flax, cotton, hemp) and possibly of some chemical mass. The composition of Sample A might have been identical with, or

close to, real banknote paper (typically, the banknote paper is made of cotton fibers). The grammage and thickness of the series A banknote was near genuine dollar banknotes in composition.
- The examination of banknote paper by optical microscopy showed clear differences in the quality of fibers between the two series. Sample B seemed to have some kind of coating or sizing on the fibers (the low amount of ash in Sample B indicates an organic coating). The setting of printing ink also looked different in the samples examined. In Sample B, the ink seemed to be more on the surface. In A, the ink was absorbed into the paper (or there might have been less ink used in the Sample A).

As listed above, both types of paper differed from each other by many properties. However, in this particular instance, it seemed that the very low surface free energy of banknote type B might explain the non-porous nature of this paper. The fingerprint deposit barely penetrated into the paper, and hence, could not be visualized by conventional amino acid reagents in solution. The free energy value of group B banknotes is unusual for paper articles and is similar to a Teflon surface.

## Conclusions

In the cases described, both types of counterfeit banknotes were classified according to the same indicative number. One might expect great similarity between them, including fingerprint processing. Paper analysis showed this assumption to be incorrect. One group of the paper exhibited behavior like a smooth, non-absorbent surface, rendering it unsuitable for common fingerprint techniques normally used on a porous surface.

In high-profile cases, we suggest careful investigation of the paper properties prior to fingerprint processing. These cases triggered us to launch a full-scale research project aimed at a better understanding of the relationship between paper properties and fingerprint development.

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