The Effects of Latent Print Processing on Ballpoint Pen Inks

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Abstract: Latent print (LP) processing and subsequent examination of twenty-five ballpoint inks revealed significant changes in ultraviolet fluorescence (UVF), infrared luminescence (IRL) and infrared reflectance (IRR) that could result in the incorrect identification or elimination of ink when addressing alterations, multiple authorship, or comparing a specific pen to questioned entries. The inks were processed with three common ninhydrin solutions, then processed with physical developer. Subsequent examination revealed frequent dequenching of UVF and IRL, as well as changes to IRR properties and visible color. Thin-Layer Chromatography (TLC) plates were run for fifteen inks, but did not reveal any significant changes to inks after LP processing. Sometimes there were little or no visible signs of LP processing, suggesting police departments should notify examiners if they process documents for LPs prior to submission.

Introduction

Forensic document examiners (FDEs) routinely determine whether more than one ballpoint ink was used to write a document, frequently as a secondary exam to a handwriting comparison. It may be done to support a finding that only one author was involved, such as in an extended text writing like a personal letter, suicide note or other multi-page document.

Sometimes, it is done to uncover an alteration made with a second ink, such as on a personal check, money order or contract. Occasionally, a FDE is asked to determine if the ink on a questioned document is consistent with, or is the "same" ink, that appears on another document or that is contained within a specific pen. This exam is more difficult than merely differentiating two inks, as many inks will appear similar under certain conditions.

Questioned documents are not always examined by FDEs before they are processed for LPs. Sometimes documents are processed at police departments prior to their arrival in the lab (especially personal checks). Further, some labs do not require documents being submitted for multiple exams to be examined in the Questioned Document (QD) section first. Even if they do, an initial submission may be for LPs only and a document may not be examined by a FDE until a later date, or a subsequent submission. If a questioned document has already been processed for latent prints should a FDE expect that ink color and properties will be unaltered? Should a FDE be able to tell if a document has already been processed for LPs? The apparent answers to these questions could result in some interesting opinions.

There are many ways for a FDE to differentiate ballpoint pen inks. Sometimes a visible or microscopic exam will suffice. But usually methods involve non-destructive examinations with visible and non-visible light, and subsequent generation (or absence) of UVF,

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IRL and IRR. Other chemical examinations including thin layer chromatography (TLC), which involves perforation of the document or removal of some ballpoint pen ink, may also be conducted. In some instances, these types of exams will allow an FDE to determine that more than one ink was used to prepare a document, or to suspect that it is likely only one did. If only one document is involved, similarities may support a contention that only one ink was used to write it. The author uses a phrase like "the same type of blue ballpoint pen ink was used to make all of the questioned maker entries on the front of the check..." One must exercise more caution if two or more documents are involved, since the similarity of inks does not mean the same brand or batch of ink was used or that the same pen was used. And, of course, there is that rare case when part or all of the ink on a document is tainted by a liquid, covered with tape, or otherwise contaminated and its properties (may) change. Of concern to the authors is when an entire document is contaminated.

Dequenching of IRL in ballpoint pen inks by application of transparent tape has been discussed in detail by Nelson [1, 2] and McKasson [3]. Gupta, Mukhi and Bami discuss UV fluorescent quenching and dequenching in an interesting case involving questioned entries in a company ledger [4]. Shiver noted that NCR Damage Detection Agent altered the luminescent properties of some inks [5]. But no literature or research was located that addressed one of the most common sources of document contamination-processing for LPs.

When examining documents for LPs, an important consideration for the LP examiner (LPE) should be the impact that chemical processing will have on subsequent exams. The type of solvent in a ninhydrin formula may drastically affect the visual appearance of a written ink, causing it to "run" or separate (especially if the ink is water-based.) Although background discoloration from the running of ink may interfere with an LP exam, it frequently will have a significant impact on a forensic document exam.

For many years the freon/ninhydrin formula was successful in developing LPs , and also in minimizing the influences of the solvent on inks (regarding ink run and visible color change.) But due to environmental considerations, the search for an effective replacement for freon/ninhydrin continues. Solvents like heptane, pentane and petroleum ether have been used with some success. A heptane/ninhydrin solution yields LPs of equal or better clarity and intensity than those developed with most other solvent reagents, with minimal damage to inks [6]. But consideration should be given to the flammability of this formula. Other viable replacements for Freon, such as HFC43 10mee and HFE-7100, have also been suggested [7, 8].

The visual changes caused by ninhydrin solutions to writing inks is of concern to both the FDE and LPE. However, there are additional concerns regarding the effects LP processing may have on UVF, IRL and IRR when comparing or differentiating inks. These considerations have been relatively overlooked by the LP community when selecting solvents, and by the forensic document community in general.

The purpose of this study was to gauge the effectiveness of ink comparison and differentiation after a document is processed with various commonly used LP solutions. Specifically, the authors attempted to determine whether there are visible changes in the color of inks after they are processed, or if there are changes to UVF, IRL and IRR properties. TLC plates were run on some of the inks to determine if any processing solution components were added to the inks or if any ink components were washed away.

Experimental Method

Twenty-five ballpoint pens containing inks of several different colors were selected for this study. Rollerball-type pens and markers were intentionally avoided, as they tend to run excessively during LP processing and often cannot be further examined. Nine inks were black; nine inks were blue; and seven inks were various other colors. One ink was erasable.

Numerous lines of writing were made with each pen on separate sheets of white Hammermill Tidal DP Long Grain 8.5X11 Xerographic bond paper (a typical paper used in our photocopier machines.) The sheets were then cut into seven pieces- one for control purposes and six for LP processing with various LP processing solutions (A-F)(see below). The control inks were examined for UVF, IRL and IRR.

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Examination for UVF was conducted with a Spectroline UV Fluorescent Analysis Cabinet, model CX-20, which allows shortwave (SW) UV examination at 254nm and longwave (LW) UV examination at 365nm.

Examinations for IRR and IRL were conducted with a Doya System 35 Infrared Video Analyser. The Doya uses a high resolution infrared-sensitive CCD video camera, a built-in six-position filter wheel, multiple light sources, and a black-and-white monitor. Two light sources are used to excite IRL and one is used for IRR. A high resolution video frame storer allows the camera to capture and enhance low-light images. All images can then be printed on a Sony thermal printer. For further information, see the Doya instruction manual [9].

The LP processing techniques and various solutions used in this study appear to be commonly used in the LP profession, and are believed to be representative of what the FDE will frequently encounter. Formulations used are listed below:

A- Aerosol Ninhydrin Spray (Chem Print)™
B- Acetone/Ninhydrin
C- Petroleum Ether/Ninhydrin

Test samples A, B & C were sprayed with the above ninhydrin solutions in a Riming hood, allowed to air dry, and steam-ironed to accelerate the process. A humidity chamber is normally used in the authors' lab to accelerate the process, but for the purposes of this experiment it was believed the iron is more commonly used in the LP community. Test samples D, E & F were processed as A, B & C above, then subjected to a maleic acid prewash and processed with physical developer [10].

After LP processing, the inks were examined for visible evidence of separation or ink "run", and for visible color or tint changes. Next they were examined for apparent changes in UVF, IRL and IRR. The authors recognize these examinations are subjective in nature, particularly the visible color and tint changes. However, all cited color changes are quite dramatic and obvious. None of the control inks produced visible UVF. Nineteen of the control inks did not produce any visible IRL with any Doya filter/light combination. These inks were subsequently examined for IRL, after processing, using all Doya filter/light combinations. In all cases, the cited UVF, IRL and IRR properties are based on the perceptions of the authors.

TLC plates were run on fifteen of the inks (control samples and processed samples), representing all ninhydrin and physical developer solutions (A-F) as well as paper control samples. The TLC plates were run in accordance with the American Society for Testing and Materials (ASTM) standards.

Results

Three inks (two red, one purple) visibly changed their tint after processing with one or more solvent. One blue ink totally changed color (to green) after processing with physical developer. The remaining inks did not visibly change their color or tint.

Processing with the ninhydrin solutions dequenched most of the inks, as eighteen of nineteen inks that did not appear to produce visible IRL prior to LP processing did so after being processed by one or more solution. Sometimes the IRL was faint and not easily detected, but other times it was strong and obvious. Frequently the IRL was a "halo" effect and involved obvious ink run (leeching out of some ink components). Considering the fact that the dyes in the inks frequently did not leech out (based on the observation that many inks did not appear to run after initial processing), and the fact that TLC plates did not show any obvious changes to the inks, it is suspected that the processing solutions merely caused a separation of the ink components dequenching those that luminesce (rather than generating IRL by chemically altering the inks.) Sensi and Cantu [11] noted that even a single ink line can show differences in infrared luminescent ink components caused, for example, by exogenous materials placed on paper (before or after writing).

Further, five of seven inks in the "other" group produced UVF after being processed by one or more technique. None of these inks produced UVF before being processed. The UVF was not a "halo" effect, but rather was the entire ink line.

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Seven of twenty inks appeared to lose their ability to transmit infrared (IR) light after being processed with the physical developer. (No changes were observed after the initial processing with the various ninhydrin solutions, only after reprocessing with physical developer.) In all cases, the control inks faded to complete invisibility (transmitting the IR light) but the processed inks were visible on the screen. It is suspected that the physical developer causes chemical changes to some of the inks.

Twenty-three of twenty-five inks visibly "ran" out into the paper after being processed with acetone. Conversely, very few inks visibly ran after being processed by Chem Print™ or petroleum ether solutions (one and three inks, respectively).

Of note, the inks processed with the Chem Print™ or petroleum ether ninhydrin solutions showed the least visible evidence of processing as some of the papers did not appear to have been processed at all. If LPs are not developed on a document when a LPE uses these solutions, it may not be possible for a FDE to determine the document was processed.

As previously stated, TLC plates were run on fifteen inks and there were no apparent changes when ASTM standards were followed.

The most significant results are summarized as follows:

-18 of 19 inks (95%) displayed IRL only after processing by one or more technique;
-8 of 8 blue inks (100%) displayed IRL only after processing by one or more technique;
-6 of 6 black inks (100%) displayed IRL only after processing by one or more technique;
-4 of 5 other inks (80%) displayed IRL only after processing by one or more technique;
-23 of 25 inks (92%) ran after processing by acetone (some inks ran or spotted slightly with other types of processing);
-7 of 20 inks (35%) lost their ability to transmit IR light after processing;
-5 of 7 other inks (71%) displayed UVF only after processing by one or more technique;
-3 of 7 other inks (43%) changed color/tint after processing;
-One blue ink changed color (to green) after processing;
-none of the black inks displayed visible color change after processing;
-all of the inks that displayed IRL before processing, also displayed IRL after processing;

See Tables 1-3 for an ink-by-ink breakdown

(Note: if changes to ink properties were observed after processing, they were listed in columns A-F. No entry was made if there were no apparent changes to the inks.)

Conclusions

The results of this study suggest that extreme caution should be exercised by a FDE when comparing or differentiating inks, as LP processing may result in a change in visible color, or UVF, IRL or IRR properties. Specifically, if multiple questioned checks, or a multiple page document, are submitted, and one or more check or pages have already been processed for LPs, then it may react differently to various non-destructive lighting techniques and be misidentified as a different ink.

More importantly, if it is requested that a specific pen or ink be compared to a questioned document, and the document has been processed for LPs, it may appear to have been written by a different pen when it actually was not. For example, if a suicide note was submitted for comparison to the pen found near a victim, and the letter has already been processed for LPs, then it may appear to be a different ink even though it is not. In this instance, a TLC plate of the two inks should be the same and would apparently clear up the issue. This scenario is more dangerous if a FDE does not know the letter was processed before submission.

Ideally, a forensic document exam will be completed before a LP exam is conducted. But since this is not always the case, precautions should be taken when selecting a solvent for Ninhydrin formulas. Documentation of specific processes is essential for future reference, and photography before processing will still en-

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able certain types of document exams to be done.

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Table 1: *Wavelength tests on the 25 inks for Infrared Luminescence (IRL)*

Black Inks

Writing Instrument	*Control*	*A*	*B*	*C*	*D*	*E*	*F*
Bic, medium pt	Y						
Bic Round Stic, medium pt	Y						
Bic Round Stic, fine pt	Y						
VB soft touch, fine pt	N	Y	Y	Y	Y	Y	Y
Papermate Flex Grip, fine pt	N		Y	Y		Y	
Zebra F-301 BP	N		Y	Y	Y	Y	
Sanford Saga, fine pt	N		Y	Y		Y	
Garland, medium pt	N	Y	Y	Y			
Papermate, medium pt	N		Y	Y			

Blue Inks

Writing Instrument	*Control*	*A*	*B*	*C*	*D*	*E*	*F*
Pentel RSVP BK 90 fine pt	N	Y	Y	Y	Y	Y	Y
Parker, US Govt., medium pt	N		Y	Y	Y	Y	Y
AT Cross Co., medium pt	N		Y	Y			
Skilcraft US Govt., medium pt	Y						
Papermate Write Bros., medium pt	N		Y	Y			
VB Soft Touch, fine pt	N		Y	Y		Y	
Bic Round Stic, medium pt	N			Y			
EraserMate 2, medium pt	N	Y	Y	Y	Y	Y	Y
Zebra BP, fine pt	N	Y	Y	Y	Y	Y	Y

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Table 1—*Wavelength tests on the 25 inks for Infrared Lujminescence (IRL)* cont.

Other Inks

Writing Instrument	*Control*	*A*	*B*	*C*	*D*	*E*	*F*
Skilcraft US Govt, medium pt (red)	N	Y	Y	Y	Y	Y	
Pilot BP-S fine pt (red)	N	Y	Y	Y	Y	Y	
VB Soft Touch , fine pt (red)	N	Y	Y	Y		Y	Y
Niji Hi Super (pink)	Y						
Pilot BP-S, fine pt (green)	N		Y	Y			
Pilot BP-S, fine pt (purple)	Y						
Spectra-Point, medium pt (gold)	N						

Blue Inks

Writing Instrument	*Control*	*A*	*B*	*C*	*D*	*E*	*F*
Pentel RSVP BK 90 fine pt	Y						
Parker, US Govt., medium pt	Y				N	N	N
AT Cross Co., medium pt	Y						
Skilcraft US Govt., medium pt	Y						
Papermate Write Bros., medium pt	Y				N	N	N
VB Soft Touch, fine pt	N						
Bic Round Stic, medium pt	Y				N	N	
EraserMate 2, medium pt	Y						
Zebra BP, fine pt	Y						

Table 2—*Wavelength tests on the 25 inks for Infrared Reflection (IRR)*

Black Inks

Writing Instrument	*Control*	*A*	*B*	*C*	*D*	*E*	*F*
Bic, medium pt	Y					N	
Bic Round Stic, medium pt	Y						
Bic Round Stic, fine pt	Y				N	N	N
VB soft touch, fine pt	N						
Papermate Flex Grip, fine pt	Y				N	N	N
Zebra F-301 BP	Y						
Sanford Saga, fine pt	N						
Garland, medium pt	N						
Papermate, medium pt	N						

Other Inks

Writing Instrument	*Control*	*A*	*B*	*C*	*D*	*E*	*F*
Skilcraft US Govt, medium pt (red)	Y						
Pilot BP-S fine pt (red)	Y						
VB Soft Touch , fine pt (red)	Y						
Niji Hi Super (pink)	Y				N	N	
Pilot BP-S, fine pt (green)	Y						
Pilot BP-S, fine pt (purple)	Y						
Spectra-Point, medium pt (gold)	Y						

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Table 3-*Wavelength tests on the 25 inks for Ultraviolet Fluorescence (UVF)*

Black Inks

Note: none of the black inks produced UVF under any circumstances before or after processing with any of the solvents or solutions.

Blue Inks

Note: none of the blue inks produced UVF under any circumstances before or after processing with any of the solvents or solutions.

Other Inks

Writing Instrument	*Control*	*A*	*B*	*C*	*D*	*E*	*F*
Skilcraft US Govt, medium pt (red)	N	Y	Y	Y	Y	Y	Y
Pilot BP-S fine pt (red)	N	Y	Y	Y	Y	Y	Y
VB Soft Touch , fine pt (red)	N	Y	Y	Y	Y		
Niji Hi Super (pink)	N	Y	Y	Y	Y	Y	Y
Pilot BP-S, fine pt (green)	N						
Pilot BP-S, fine pt (purple)	N	Y	Y	Y	Y	Y	
Spectra-Point, medium pt (gold)	N						