Ink Differentiation for the Fiscally Challenged

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Being asked to distinguish between two or more inks that may have been used to alter a document is a common problem posed to the Forensic Document Examiner. In today's modern laboratory, sophisticated instruments have been made available, such as the *VSC- 4* and *VSC2000*, manufactured by Foster & Freeman, Worcestershire, England, that are specifically designed to aid in the differentiation of inks. However, the considerable expense may make these instruments unavailable to many government and private laboratories. The present study introduces a low cost ink differentiation system, comprised of simple commercially available components, and tests its ability to distinguish between various black inks.

Introduction

Being asked to distinguish between two or more inks that may have been used to alter a document is a common problem posed to the Forensic Document Examiner. Additions and/or obliterations in most cases are made with ink of the same color as the original entries. Once the authenticity of a document has been questioned, or if a possible unauthorized alteration has been made, the examiner is charged with determining, preferably using nondestructive techniques, the true history of the document.

Studies have demonstrated that various inks can be differentiated and categorized by illumination with light sources of various light wavelengths, then observing the resulting reactions in specific regions of the visible and nonvisible (infrared) spectrum (Cantu and Prough, 1988; Cowdhry, Gupta and Bami, 1989; Constain and Lewis, 1973; Godown, 1964; Hoover and MacDonell, 1964; Packard, 1964; Sensi and Cantu, 1982; and Trzcinska, 1990; Horton and Nelson, 1991; Noblett, 1982; Totty, Ordidge and Onion, 1985; Zimmerman and Mooney, 1988). The present study introduces an ink differentiation system comprised of simple commercially available components, and tests its ability to distinguish between various black inks.

Theory

Modern inks are a combination of synthetic or natural dyes or pigments held in suspension, along with a volatile solvent. The resultant color may be the result of a single coloring agent or a mixture of several dyes and/or pigments. And, depending on the different coloring agents used, the reaction to light stimulus (visible and nonvisible) will vary.

When ink is exposed to a specific range of light energy (infrared or visible), three different reactions can occur:

1) The light, all or partial, will be reflected by the ink. This will cause the ink to appear paler or to disappear.

2) The ink will absorb the light and convert it to heat or undergo structural or chemical changes. This will cause the ink to appear darker.

3) The light will be absorbed by the ink and then be re-emitted at a different wavelength, a process known to questioned document examiners as "infrared luminescence" (Richards, 1977). The ink will brighten or appear to "glow" when visualized in the infrared region.

It is possible to document various reactions among different inks when multiple excitation/visualization techniques are used. In the current study, the following methods are used to differentiate inks: 1) infrared luminescence 2) infrared reflectance and 3) visible examination with a dichroic filter.

Infrared Luminescence

The ink is illuminated with monochromatic light in the visible spectrum using a specific excitation filter. The ink is then observed using various barrier filters that allow observation of infrared radiation (Figure 1). Using this technique, infrared luminescence (Figure 2) along with varying degrees of reflectance and absorbance can be observed.

Infrared Reflectance

The ink is illuminated with infrared radiation and the reflected light is observed in the infrared region (Figure 3). The observed reaction depends upon the degree of absorbance or reflectance. For example, if total infrared absorption occurs the ink will appear dark black; however, if total reflectance occurs, the ink will visually disappear (Figure 4).

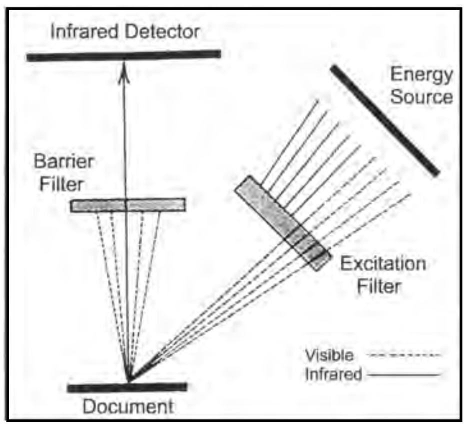

Figure 1. Schematic for Infrared Luminescence

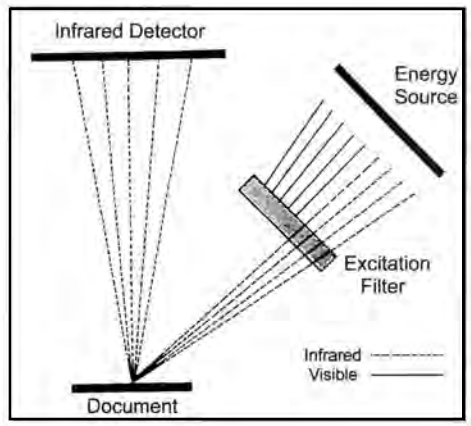

Figure 3. Schematic for Infrared Reflectance

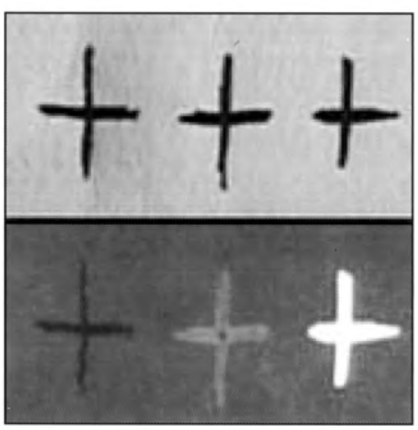

Figure 2. *Top* - Inks observed under white light
Bottom – Infrared luminescence of inks

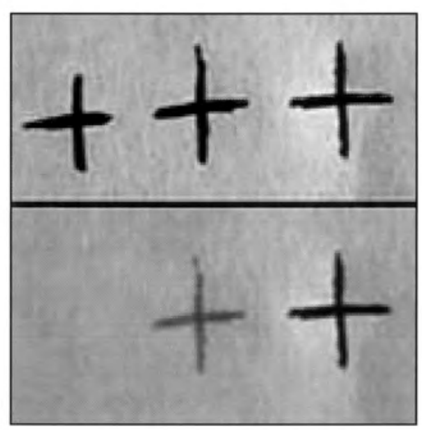

Figure 4. *Top* - Inks observed under white light
Bottom - Infrared reflectance of the inks

Dichroic Filter

The ink is illuminated with broadband white light and observed in the visible region. The light source is unfiltered while a dichroic filter, a two-filter system that allows the transmittance of two wavelengths simultaneously, is used in combination with the detector. The specific dichroic filter can vary, however all perform basically the same; they transmit heavily in the red region while minimally in the blue/green region (Dick, 1970). Using this technique, absorbance and/or reflectance can be observed. If absorbance occurs the ink will appear black; if reflectance occurs the ink will appear red (Figure 5).

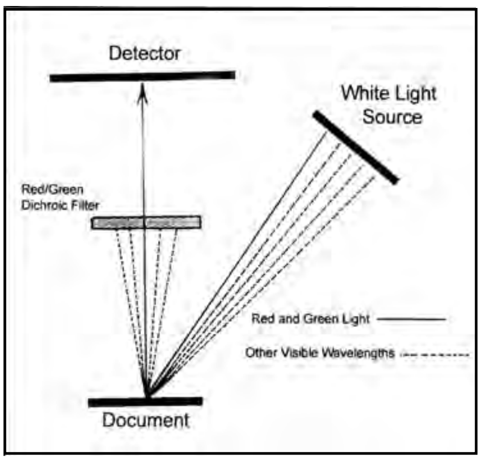

Figure 5. Schematic for observation with a selected dichroic filter

Methods of Detecting Luminescence

Initially, infrared photography was the only method available to observe the infrared luminescence of inks. This involved the use of costly infrared sensitive film, long exposure times, and proper selection of excitation and barrier filter combinations. Any resulting ink reactions could not be observed until the film was developed.

Today, sophisticated instruments have been introduced (e.g. *VSC2000*, Foster & Freeman, Worcestershire, England) that are specifically designed for document examination and the differentiation of inks. However, the considerable expense can make these instruments unavailable to many document examiners.

Recent developments in the videotape recorder technology have resulted in video cameras sensitive to not only visible light, but to infrared radiation as well (i.e. Sony *Handycam* with *Nightshot*®, Sony Corporation, Tokyo, Japan). The utility of this new technology in a simple system for the differentiation of like inks will be the subject of this report.

Methods and Materials

Video Camera - Sony Handycam®

In order to use the Sony *Handycam* for the differentiation of inks, modifications to the camera are necessary:

1) The *Nightshot*® feature makes the camera sensitive to radiation in the infrared region. However, when the *Nightshot*® feature is activated, the camera also emits infrared radiation. The observable reaction of the inks in the infrared region is masked if this emitted radiation is not eliminated. Accordingly, a simple covering of the infrared window, located below the lens, with cardboard and tape proved sufficient (Figure 6). It is noted that the *Nightshot*® feature is not activated when viewing ink reactions resulting from dichroic filtration.

2) Although the various barrier filters can be held by hand in front of the camera lens, it is more convenient that the filters be secured by some other means. This was accomplished by fitting the camera lens with screw-in, step-up rings (37 mm to 49 mm to 52 mm to 55 mm). This extension allows for the attachment of a clip-on filter

Figure 6. Modified Sony camcorder with step-up rings and filter holder

holder (Figure 6). The filter holder allows for easy positioning and substitution of selected barrier filters.

Light source

Several possible light sources were investigated. Because of the necessity for intense excitation energy, most light sources tested were inefficient. A standard *Kodak Carousel* slide projector positioned at an angle of approximately 25° to the document provided adequate illumination. Increasing or decreasing the projector distance to the document and manipulation of the lens focus allows for light intensity and field of illumination adjustments.

The slide projector provides light of a broad spectrum of illumination. However, for infrared luminescence, specific monochromatic light is necessary. This is accomplished by fitting the camera lens with a blue/green Corning filter. To hold the filter in place a modified Alpo® dog food can, housing the filter, proved adequate (Figure 7).

Observation and Documentation

Visualization and documentation of the various reactions of the inks under the various lighting conditions can be accomplished by two methods:

1) A television monitor can be connected to the video camera output and the television screen photographed with standard photographic equipment. The image can be adjusted for maximum image resolution through manipulation of the contrast, tint, and brightness adjustments.

2) The video camera output can be attached to a digital video capture device coupled with a computer. Commercially available image capturing devices such a Snappy® (Play® Incorporated, Rancho Cordova, CA) and digital imaging software such as Adobe Photoshop® (Adobe Systems Incorporated, San Jose, CA) allow enhancement to improve image quality. The enhanced image can then be printed on any standard color printer. Our test system utilizes a color television for initial observations, and a Snappy® coupled with a computer/color printer for documentation. The video camera can be placed in the record mode for additional documentation.

Materials

Darkened Examination Room
Modified *Sony Handycam*® Model Number CCD-TR416
Panasonic® 20″ color television
Modified *Kodak*® Ektagraphic III AM slide projector
Sufficient Video Connection Cables
Photographic Copy Stand
Wrattan Barrier Filters Nos. 25, 29, 70, 87, 87C, 88, 89b

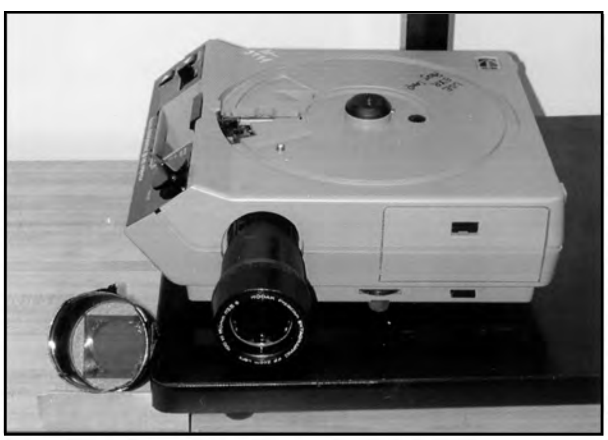

Figure 7. Slide projector with excitation filter and filter holder (left)

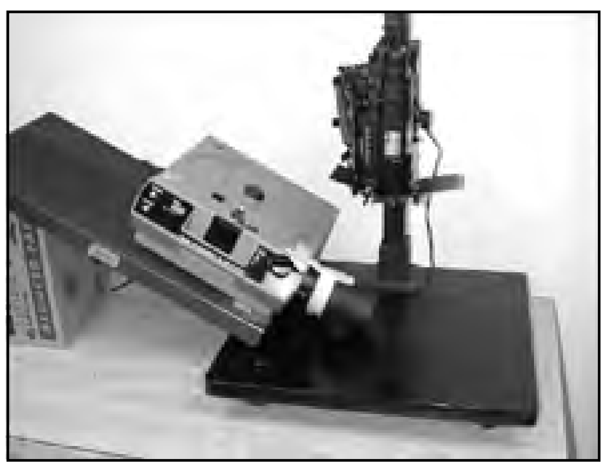

Figure 8. System arrangement

Cokin Barrier Filter No. 90
Schott Barrier Filters RG 830, RG 850, RG 1000
Dichroic Barrier Filter (813/856, orange/blue)
Corning No. 9782 Excitation Filter (bandpass of 310 nm to 630 nm)
Gateway® Pentium II computer
Snappy® digital capture device
Hewlett Packard DeskJet 870Cxi color printer

Inks

Nineteen black ink pens were randomly chosen from sources including home and laboratory. Included in our sample to simulate the various possible sources of writing inks were ballpoint, roller ball, and fiber pens. The sample pens are listed as follows:

1) Bic Micormetal
2) Bic Regular Point
3) Unknown (Promotional)
4) Bic Roundstick
5) Expresso Medium Tip
6) Expresso Fine Tip
7) Universal Ballpoint
8) Bic Roller
9) Pilot Precise
10) Senator
11) Chromatic
12) Stabilo Write-4-All
13) Papermate Flexgrip
14) Universal Fiberpen
15) Pilot BP-S
16) Uni-Ball Micro
17) Erasermate II
18) Papermate

Paper

Numerous paper samples were collected and tested for background luminescence. *Champion*® Multipurpose paper (Champion International Corporation, Stamford, CT) was selected for this study because of its medium luminescence and availability.

Sample Application

The sample sheets of paper were cut into small squares approximately 3″ X 3″. For each paper square, ink from 2 different pens was applied, side-by-side, in the shape of a plus (+) symbol, for a total of 171 ink pair comparisons. To eliminate the possibility of sample concentration variability, each plus symbol was produced using multiple strokes in each direction.

Results

All ink pair samples were compared using the above described system. Infrared luminescence, infrared reflectance, and dichroic differentiation, utilizing various combinations of excitation and barrier filters, was attempted. Ink pairs were deemed differentiated utilizing the same standards that would apply to normal forensic casework (i.e. only those ink pairs that exhibited a documented difference in their reactions were determined different). The same samples were then examined using the commercially available Foster and Freeman VSC-4.

Table 1 compares the discrimination capabilities of the experimental system when compared to the Foster and Freeman VSC-4. The differentiation of each system is described by the number of ink pairs discriminated divided by the total number of ink pairs possible (171). Specific results on all ink pairs compared are listed in Table 2 (experimental system) and Table 3 (VSC-4).

System Tested	***Differentiation Capability***
Experimental	.906
VSC-4	.918

Table 1

Experimental System																				
INK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	**INK**
1																				1
2				X																2
3																				3
4																				4
5						Y														5
6																				6
7										X	X						X	X	X	7
8														Y						8
9																				9
10											X							X	X	10
11																	X	X	X	11
12																				12
13															X					13
14																				14
15																				15
16																				16
17																				17
18																			X	18
19																				19

Table 2

X- indicates indistinguishable ink pairs
Y – indicates ink pairs not distinguished on experimental system, but distinguished on VSC-4
Gray area indicates duplicate ink pairs

Discussion

A system was constructed of simple and inexpensive commercially available components, for the differentiation of inks. Differentiation was accomplished by taking advantage of the reactions of ink to various light excitation energies, then visualizing the reactions at specific wavelengths. Test samples were produced using 19 randomly selected black ink pens of various types and manufacturers. The experimental system developed was able to discriminate between 90.6% of the sample ink pairs.

Once the samples were differentiated with the test system, the samples were then examined using the Foster and Freeman VSC-4. Out of the

VSC-4

INK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	INK
1																				1
2				X																2
3																				3
4																				4
5																				5
6																				6
7										X	X						X	X	X	7
8																				8
9																				9
10											X							X	X	10
11																	X	X	X	11
12																				12
13															X					13
14																				14
15																				15
16																				16
17																				17
18																			X	18
19																				19

Table 3

X- indicates indistinguishable ink pairs
Gray area indicates duplicate ink pairs

171 ink pairs possible, the VSC-4 was able to differentiate 91.8% of the test sample (2 additional pairs) when compared to the test system.

The test system developed here is adequate for most examinations, simple to operate, and affordable (less than $1,000 without the computer). However, some limitations exist. The excitation light source is limited in intensity and is deficient in the capability to excite at various wavelengths (purchasing additional filters is suggested). Enhancing weak reactions through image integration, available on the VSC2000, is not possible. Finally, uniform illumination of large areas of a questioned document is difficult, and in doing so, will decrease the illumination intensity. However, considering the overall cost of the experimental system, its portability, and the capability to record and display video of an examination, the system does provide an adequate alternative.

Acknowledgments

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