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Nondestructive Differentiation of Full-Color Photocopies

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ABSTRACT: There has been a recent increase in the use and availability of full-color copiers. With this increase comes a greater potential for criminal use. Research by the authors has shown that many products of full-color copiers can be differentiated by the use of microscopy, infrared luminescence, infrared reflectance, and laser luminescence.

KEYWORDS: questioned documents, photocopiers, cylithographic, laser

In 1985, Piper [*1*] of the U.S. Secret Service reported "a dramatic increase in the use of office copiers to produce counterfeit currency and other documents." Since that time, a revolution in the full-color copier market has increased the potential for such crimes.

This technology is not new. The 3M company introduced a full-color copier in 1969 called the Color-in-Color. Xerox introduced the 6500 Color Copier in 1974 [*2*]. Only recently, however, has there been a real interest in the full-color copier market. One source states that "1989 may go down in the record books as the year full-color copiers began to be taken seriously" and that a 1989 survey revealed that "34 percent of responding dealers now sell full-color copiers and 36 percent plan to add full-color models to their product lines" [*3*].

Many of the full-color copiers are very expensive, costing up to $60 000. Less expensive models now retail in the $7000 to $8000 range. These lower prices will tend to increase the availability of the full-color copier to the counterfeiter.

To date, the number of criminal cases known to the authors which made use of full-color copying have been comparatively few. One counterfeiter was recently convicted in an operation that produced $800 000 in counterfeit currency using a Canon Color Laser Copier [*4*].

In 1989 a con man deposited $3 000 000 in phony cashier's checks drawn on a New York branch of a European bank. The checks, which cleared the New York branch, were produced on check stock made with a full-color copier [*5*].

A college dropout in Ste. Catherines, Ontario, wrote a check for $25 000 (Canadian) as half payment for a Canon Color Laser Copier. Then he ran off more than $24 000 in U.S. and Canadian bills. Before he passed any of the notes, the check bounced and the

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copier was repossessed. Beneath the cover were a couple of new bills, which the retailer reported to the Royal Canadian Mounted Police. He was arrested and convicted [6].

The authors' laboratory has not yet received a case involving questioned documents produced on a full-color copier, but recently a case was received in which a mail-room clerk successfully negotiated two stolen U.S. Treasury checks with an altered black and white photocopy of a green military identification card. The clerk was arrested while trying to negotiate a third check. He probably would have been successful had he used a full-color copier to produce the fake card. The authors have produced a very good replica of a military identification card on a full-color copier. Once laminated, it would almost certainly enable the bearer to cash checks on U.S. military installations anywhere in the world. Such cards would also provide access to a host of other services.

Document examiners may soon be asked frequently to examine questioned documents produced on full-color copiers. Techniques have long been available to identify black and white copies with individual copy machines. These techniques are basically the same for full-color copiers. Differentiation of full-color copiers, based on class characteristics present in their copies, is a different problem. The authors are not aware of any research that has been published in this area. The current research is aimed at addressing the problem.

Materials and Methods

There are several full-color copiers on the market today. These include the Canon Color Laser Copier (CLC) and the Canon CLC200 and CLC500, the Eastman Kodak ColorEdge, the KIS Color One, the KIS Futural, the Konica Color 7, the Multigraphics Multicolor 101, the Savin Prism I, the Savin Magician, the Sharp CX-7500, the Xerox 1005, the Brother CC5500, the Seiko-Mead Cycolor 3000, the Panasonic FP-C1, the Ilford Cibacopy System 120, the Ricoh Artage 5330, and the Gestetner Color Copystation (Table 1). New models will soon be released. The full-color market is very volatile—new models are being added each year and old ones are being deleted.

The Canon CLC, CLC200, and CLC500, the Kodak ColorEdge, the Savin Prism I, the Panasonic FP-C1, the Brother CC5500, the Konica Color 7, and the Xerox 1005 were selected for the purpose of this study. Table 2 lists the basic characteristics for each of the seven copiers.

All of the copiers selected make use of toner, with the exception of the Brother machine, which uses a cylithographic process, and the Konica model, which uses the photographic process.

The Sharp CX-7500 and the Gestetner Color Copystation were not considered because they are actually the same machine as the Savin Prism I. All three machines are the product of the Colorocs Corp., which also markets its own version of the copier as the FC2207 in the Atlanta, Georgia, area only.

The Konica copier utilizes the same photographic process used by Ilford, KIS, and Multigraphics (the KIS Color One is also marketed as the Multigraphics Multicolor 101). The Savin Magician and the Seiko-Mead Cycolor 3000 use the same cylithographic technology as that used in the Brother CC5500.

Specimens from each machine were subjected to a microscopic examination utilizing a Bausch & Lomb Stereo Zoom 4 microscope. The microscope was equipped with $\times 20$ oculars and a $\times 2$ converter for the zoom objective. This allowed magnification in a range of $\times 28$ to $\times 120$.

Infrared luminescence (IRL) and infrared reflectance (IRR) examinations were conducted using a Foster and Freeman VSC-1 Video Spectral Comparator utilizing the FS1 and FS2 filters, respectively.

Laser luminescence examinations were conducted using a Spectra Physics Model 2030

TABLE 1—*Dates of introduction of full-color copiers.*[a]

Vendor	Model	Date Introduced	Process[b]
3M	Color-in-Color[c]	1969	E
Xerox	6500[c]	May 1973	E
	1005	Nov. 1986	E
Canon	NP Color Copier[c]	July 1983	E
	NP-Color T[c]	March 1984	E
	CLC[c]	Sept. 1987	E
	CLC500	July 1989	E
	CLC200	Oct. 1989	E
Kodak	ColorEdge	Jan. 1988	E
KIS	Color One	Nov. 1985	P
	Futural	July 1987	P
Konica	Color 7	1987	P
Multigraphics	Multicolor 101	May 1987	P
Savin	Prism I	July 1988	E
	Magician	July 1989	C
Sharp	CX-5000S[c]	July 1986	T[d]
	CX-7500	July 1988	E
Panasonic	Iris[c]	July 1987	T[d]
	FP-C1	April 1989	E
Gestetner	Color Copystation	July 1989	E
Ricoh	5330	July 1989	E
Ilford	Cibacopy 1217Z	1986	P
	Cibacopy 120	1988	P
Brother	CC5500	March 1989	C
Seiko-Mead	Cycolor 3000	1989	C

[a]This list does not purport to be all-inclusive.
[b]E = electrophotographic, P = photographic, C = cylithographic, T = thermal transfer.
[c]No longer marketed.
[d]The Panasonic Iris and Sharp CX-5000S, which are no longer marketed, used none of the processes outlined in this paper. They used a thermal transfer method which involved an inked ribbon of four colors (black, cyan, magenta, and yellow) and specially treated paper. They also utilized a digital scanner.

TABLE 2—*Comparison of the seven copiers studied.*

	Toner						
	Magenta	Yellow	Cyan	Black	Luminescence	Pitch Lines	Black[a]
Canon	yes	yes	yes	yes	yes	yes	CB
Savin	yes	yes	yes	yes[b]	yes	no	CB
Kodak	yes	yes	yes	no	yes	no	CB
Panasonic	yes	yes	yes	yes	yes	no	BA
Xerox	yes	yes	yes	no	no	no	CB
Konica	no	no	no	no	no	no	CB
Brother	no	no	no	no	yes	no	CB

[a]CB = combination of colors; BA = black toner alone.
[b]not used with full-color copies.

argon laser operating between 457.9 and 514.5 nm. An orange filter was used to block blue-green light and transmit only the higher wavelength luminescence.

Ultraviolet (UV) fluorescence examinations were conducted with both long and short-wave UV light in a UV light box.

Discussion

The copiers used in this research can be divided into three distinct categories, the electrophotographic, photographic, and cylithographic. The electrophotographic copiers make use of toners.

> These copiers can be further divided into analog copiers and digital copiers. An analog copier . . . images the original right onto a photoconductor. Much like your reflection in a mirror, what you see is what you get. On the other hand, the digital process works quite differently. Unlike analog copying, the original is imaged onto an image sensor. This optical image is then converted to data. Information is sent to the print head, types of which include LED (Light Emitting Diode) array or a laser scanner. Basically, digital copiers contain a scanning part and a printing part connected by a digital channel [7].

Digital copiers allow electronic manipulation of the finished product by the user.

Photographic copiers use a silver halide photographic process on photosensitive paper. The cylithographic process will be discussed in detail later in this paper.

It should be stated from the outset that none of the copies examined exhibited UV fluorescence (except from the paper) and this area of examination will not be further discussed.

Examinations for IRL, IRR, and laser luminescence proved more fruitful and are detailed below. A comparison chart for all the copiers will follow.

Canon CLC, CLC500, and CLC200

The Canon CLC is a digital laser photocopier which utilizes the electrophotographic method. It uses black, yellow, magenta, and cyan toners. The color copiers are made by four passes through the machine. One color toner is added on each pass. Although the copier uses black toner, the color black is made from a combination of cyan, magenta, and yellow, with black toner on top of the three. One of the most striking microscopic features of the Canon copier is the presence of "pitch lines" (the toner appears to line up in rows), which are a result of minute vibrations during the copying process. The same vibrations do not allow the copy to be made in perfect register, and the edges of black letters will tend to have a "rainbow effect" from the other three colors. The Canon CLC does not have a black-toner-only feature (unless manually programed by the user), so black and white copies will still be composed of all four colors.

The Canon CLC500 and CLC200 are basically the same for the purpose of document examination. Only the special features are different. The CLC500 and CLC200 do differ from the CLC in that they use smaller toner particles and have a smaller laser beam. Also, these two machines, unlike the CLC, have a black-toner-only feature. The color black in these two copiers is sometimes made of all four toners, one or two toners and black, or only black depending on how the copier interprets the color of the original. This is distinctly different from the CLC. The presence of pitch lines is also readily apparent in these copiers. Other characteristics noted in this paper concerning the CLC are the same for the CLC500 and CLC200.

During the IRL examinations, the magenta toner exhibited a very strong luminescence. The cyan and yellow toners exhibited no luminescence. As a result of the layering of toners to make black, copies from the Canon exhibit a halo of luminescence around black

images. This is due to the luminescence of magenta toners that is not in exact register with the masking black toner.

During laser examinations the same type of luminescence effects were found, except that black took on an orange color and the cyan and yellow toners became darker.

IRR examinations revealed that at 800 nm the image was still visible, but words became undecipherable by 900 nm.

Savin Prism I

The Prism I is an analog electrophotographic photocopier. It uses black, cyan, magenta, and yellow toners; however, only the cyan, magenta, and yellow toners are used for color copies. The black toner is only used for black and white copies. On a full-color copy, the color black is made from a combination of the other three toner colors.

The Savin copier and other copiers manufactured by Colorocs produce their copies on one pass on a photoconductor belt. As the paper proceeds through the machine, it passes each toner module in turn. On all other full-color copiers which use toner, the paper makes repeated revolutions on a photosensitive drum. A different color toner is added on each revolution (Fig. 1).

Both the magenta and the yellow toners exhibited IRL. The magenta toner luminesced brighter than the yellow. The cyan toner became darker. The color black, which was a combination of all three colors, exhibited a medium level of luminescence.

During Laser examinations the black gave off a yellow/orange luminescence, the cyan appeared black, the magenta stayed magenta, but the yellow took on a light green cast.

During IRR examinations, the images were still visible at 800 nm and became unreadable at 900 nm.

Kodak Color Edge

The Color Edge is an analog electrophotographic copier and uses only the magenta, cyan, and yellow toners. Black is made from a combination of the three. The rainbow effect seen in Canon copiers will also be found in this copier.

Both black and magenta will exhibit a bright luminescence when under IRL and laser examinations. Cyan and yellow toners will exhibit no luminescence and will become darker under laser light.

Images are still visable at 800 nm and words are still readable at 900 nm during IRR examinations.

Panasonic FP-C1

The FP-C1 is a digital laser electrophotographic photocopier. The Panasonic is the only other laser copier besides the Canon copiers. No pitch lines were found. Four toner colors are used in the Panasonic copier. Unlike the copiers described previously, the FP-C1 uses black toner alone to make black images.

During IRL and laser examinations, magenta toner exhibited bright luminescence, black and yellow toners did not luminesce, and cyan became darker.

During IRR examination, black images were clearly readable up to 1000 nm.

Xerox 1005 Color Copier

The Xerox 1005 copier is an analog electrophotographic copier. The Xerox copier uses cyan, yellow, and magenta toners. Black is made from a mixture of the three. None of the words on the sample were found to be out of register.

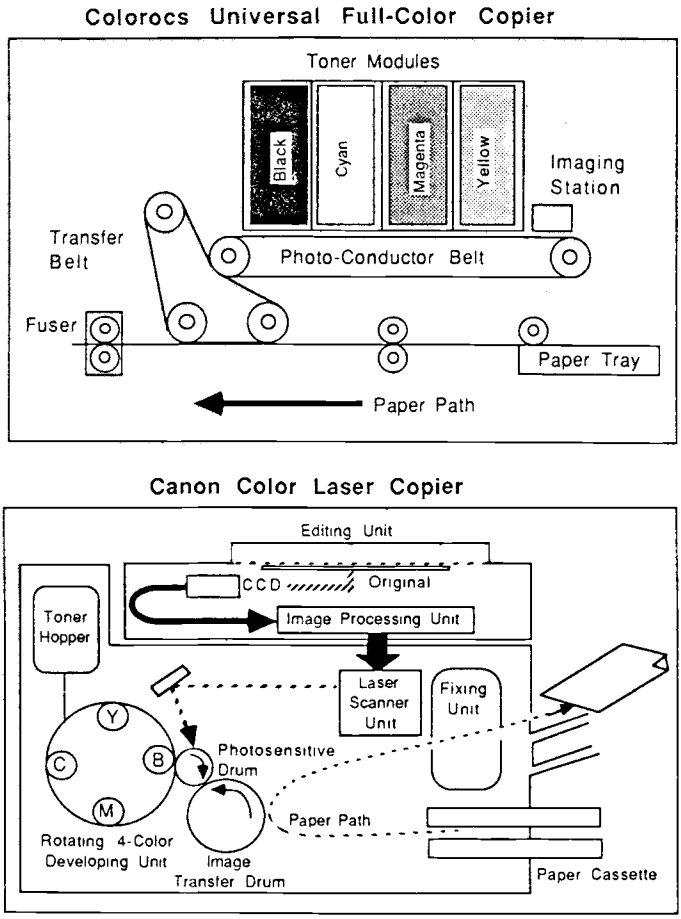

FIG. 1—*The Colorocs process versus the Canon copy process. (Reprinted by permission from Datapro Research* [2]*).*

None of the toners used in the Xerox copier will exhibit luminescence under either IRL or laser examinations. In this regard, the Xerox 1005 stands apart from the other copiers using toners.

During IRR examinations, words are readable at 900 nm.

Konica Color 7

The Konica copier uses a silver halide photographic process and photosensitive paper. No toners are required. Photocopies made on this type of copier will always have a glossy, photograph-like, appearance. Copying on plain paper is not possible. Because of the high quality of the copy, any pitch lines present in the original may be mimicked in the copy. This machine does not produce pitch lines. The copier even does a good job of reproducing halftone dots in the original.

At $\times 120$ magnification, it can be seen that the image is formed by colored spots. These spots are easily distinguished from toner particles. The shape and appearance of the spots is similar to those of the Brother CC5500.

Examination for both IRL and laser luminescence disclosed no luminescent qualities.

During IRR examinations, words appearing on the copy were readable at 800 nm, but invisible at 900 nm.

Brother CC5500

The Brother copier, first introduced in March 1989, uses neither toners, ribbons, photoconductors, or a photographic process. A new technology, known as cylithography, is utilized. The process was developed by Mead Imaging of Miamisburg, Ohio. Mead defines cylithography as a color imaging process using the Cycolor reproduction technology. Cycolor (a Mead trademark) is a non-silver color imaging technology for reproducing printed, written, or pictorial matter in which light-sensitive microcapsules, called cyliths, are exposed to light and compressed in combination with a treated receiver sheet (Cycolor paper or transparency) to produce a full-color image or copy.

In Cycolor technology, a polyester-film base is coated with millions of light-sensitive cyliths which are sensitive to red, green, and blue light. Each cylith resembles a water-filled balloon about one tenth the diameter of a human hair. The cyliths contain a monomer in which is dissolved a light-sensitive photoinitiator and a color-forming leuco dye. The film is exposed to light reflected from an original color image. The resulting latent image resembles the negative used in photography. Exposure to light hardens the cyliths in proportion to the amount of exposure, rendering them resistant to physical rupture. The latent image is a pattern of hard (exposed) and soft (unexposed) cyliths. The final image is developed by bringing the cyliths into direct contact with a sheet of specially treated paper in a system of pressure rollers. The unexposed cyliths release the monomer containing the leuco dye onto the paper to form the color image. Color is achieved by mixing three different types of cyliths, containing either a cyan, magenta, or yellow leuco dye, along with the photoinitiators. Exposure to red light hardens the cyan cyliths, exposure to green light controls the magenta dye, and exposure to blue light hardens the yellow cyliths. Exposure of all of the cyliths results in no color, and exposure of none of the cyliths results in black. By controlling the relative proportion of the three dyes, any color can be formed [*8*].

During microscopic examination, an "alligator" pattern was noted in the coating of the paper. This pattern was not present in a sample of the paper which had not been run through the copier. This pattern is probably a result of heat and the pressure roller system. Copies made on glossy paper in other copiers may have a similar alligator pattern.

The color spots that make up the copy in this process can be extremely small, even at $\times 120$. The spots are more easily discernible at magnifications up to $\times 240$. These color spots are easily discernible from photocopier toner particles. Toner particles under high magnification resemble glass beads and may give a melted appearance. Toner particles appear to be on or between the paper fibers. These color spots appear to be in the coating of the paper. Paper fibers cannot be seen. Due to their fine resolution, these copies may mimic the pitch lines found in Canon copiers if the lines are already present in the original. This copier does not produce pitch lines.

Under IRL examinations, all three of the basic colors and black will exhibit luminescence. The luminescence exhibited by the color yellow is so bright that it will almost overpower the VSC-1.

During laser examinations, cyan becomes darker, magenta lumineses, black has a yellow luminescence, and yellow has a bright yellow luminescence.

Under IRR examination, images are totally invisible at 800 nm. Cyan is barely visible at 700 nm.

An additional feature of interest to document examiners is the polyester-film base.

This film retains a negative image of the copy. It is rolled up inside the machine and retained until the roll is changed.

The authors have used the VSC-1 mirror switch to reverse the negative, which enables the negative to be read easily. The images on the negative will also luminesce under IRL examination. Exposure of the negative to UV or laser light will reveal the color of the copy to some degree. When it is suspected that a questioned document was prepared on this type of copier, the film roll should be seized and reviewed to determine if the negative of the questioned document is present.

Summary

This research demonstrates that all seven of the types of copiers tested can be distinguished from one another by nondestructive examination of their copies. None of the seven possesses the same combination of class characteristics when examined by microscopy, IRL, IRR, and laser examinations.

While it is the authors' belief that this four-pronged test can be of great value in differentiating the products of various full-color copiers, a word of caution is in order. It must be reiterated that some full-color copiers are the very same machine, using the same process, but marketed under different names. Also, copier manufacturers are constantly changing processes, developing new models, and withdrawing others from the market. While the principles outlined in this research should remain valid, because of these changes, the results may not remain so.

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