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Office Paper DeCopier*

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ABSTRACT: DeCopier Technologies, Inc., of Framingham, MA, has developed an office paper DeCopier that uses a thermo-chemical process to soften toner and loosen its bond with paper. The toner is then brushed away and the sheet dried. The result is a "clean" sheet of paper that is ready to be reused. DeCopier Technologies, Inc. reports that this process will not only work on documents prepared by a photocopy machine or laser printer, but on transparencies, facsimiles, and other documents with toner components/entries.

An experiment design was developed to demonstrate how the DeCopying process affects toner as well as other applications (i.e., ink, typewriting, rubber stamps, etc.) that are typically seen in documentary evidence. The results indicate that, although DeCopier Technologies' ability to successfully remove toner from paper is currently limited to relatively few types of toner, the technology does have the potential to not only do what it purports, but also to affect various other applications found on documentary evidence. The DeCopying process affected all the additional applications, except watermarks, but did not completely remove any of them. However, the toner was removed successfully from the specimens prepared on transparencies. The extent to which the various applications were effected varied.

KEYWORDS: forensic science, questioned documents, photocopy, DeCopier, photocopy technology, document security

DeCopier Technology

Led by President Sushil Bhatia, DeCopier Technologies, Inc. has developed innovative technology that has the potential to significantly impact the forensic examination of questioned documents. DeCopier technology is designed to reverse the photocopy process and remove toner from laser-printed and photocopied documents, leaving them image free, clean, and ready for reuse. (DeCopier technology is currently in the developmental stages and has a proprietary patent pending.)

Most modern office photocopy machines use a plain paper electrostatic copying process, also known as the xerographic process. Xerographic copiers operate on the principle that light will dissipate an electrostatic charge when it strikes certain substances, while leaving intact a charge in unexposed areas. After being formed on the surface of a metal drum, images are produced by fusing toner, using heat and pressure, onto the receiving surface. The DeCopying process loosens the bond between the toner and the receiving surface, allowing the toner to be removed.

The DeCopier Solution

The technology uses a nontoxic, thermochemical process to soften toner and loosen its bond with paper. The DeCopier chemical solution is an undisclosed, white, pasty liquid. Currently, there is not one fixed chemical solution that successfully removes all commercial toners. The chemical components of the DeCopier solution vary with the type of toner to be DeCopied.

There are over 120 different kinds of toner available for today's office equipment machines, such as photocopiers, laser printers, and facsimiles. Because there are so many different types of toner, DeCopier Technologies, Inc. uses a trial and error method to fine-tune the DeCopying solution for each specific type of toner. To date, DeCopier Technologies, Inc. reports that they have successfully DeCopied approximately 20 different kinds of toners from the following photocopy machine and laser printer manufacturers: Xerox, Ektaprint, Toshiba, Minolta, Canon, Konica, Lanier, Sharp, and Ricoh.

DeCopier Technologies, Inc. proudly boasts that third-party consultants have confirmed that their process is nontoxic and environmentally friendly. The DeCopier solution was designed to be recycled by the machine and reused again and again. The toner waste product is very small and can be reused as a filler material. Bhatia and his engineers state that the DeCopier solution is a relatively inexpensive, stable chemical with an indefinite shelf life and can be safely disposed of down a household drain.

The DeCopying Machine

The DeCopying machine is currently only in a prototype stage (Fig. 1). DeCopier Technologies, Inc. has one hand-fed DeCopier prototype but primarily employs a manual DeCopying process when developing and testing their solutions. A DeCopier consulting engineer is working on developing a sleeker, more compact, and smoother-functioning machine (Fig. 2). The hand-fed machine is designed to DeCopy approximately 20 sheets per minute, while automatically fed machines are projected to DeCopy approximately 60 sheets per minute. The primary components of the DeCopier machine are as follows: paper transport belt (conveyor); fluid dispensing system; heated platen; brush; and the fluid removal, drying, and calendaring system. The conveyor is a stainless steel belt that provides support for the paper and eliminates potential jamming problems. The fluid dispensing system releases the DeCopier solution. The heated platen provides an isothermal environment that varies in temperature but averages approximately 160°F. The plastic bristled brush is designed to lightly sweep the document to remove the toner while not abrading the paper. The drying system is composed of

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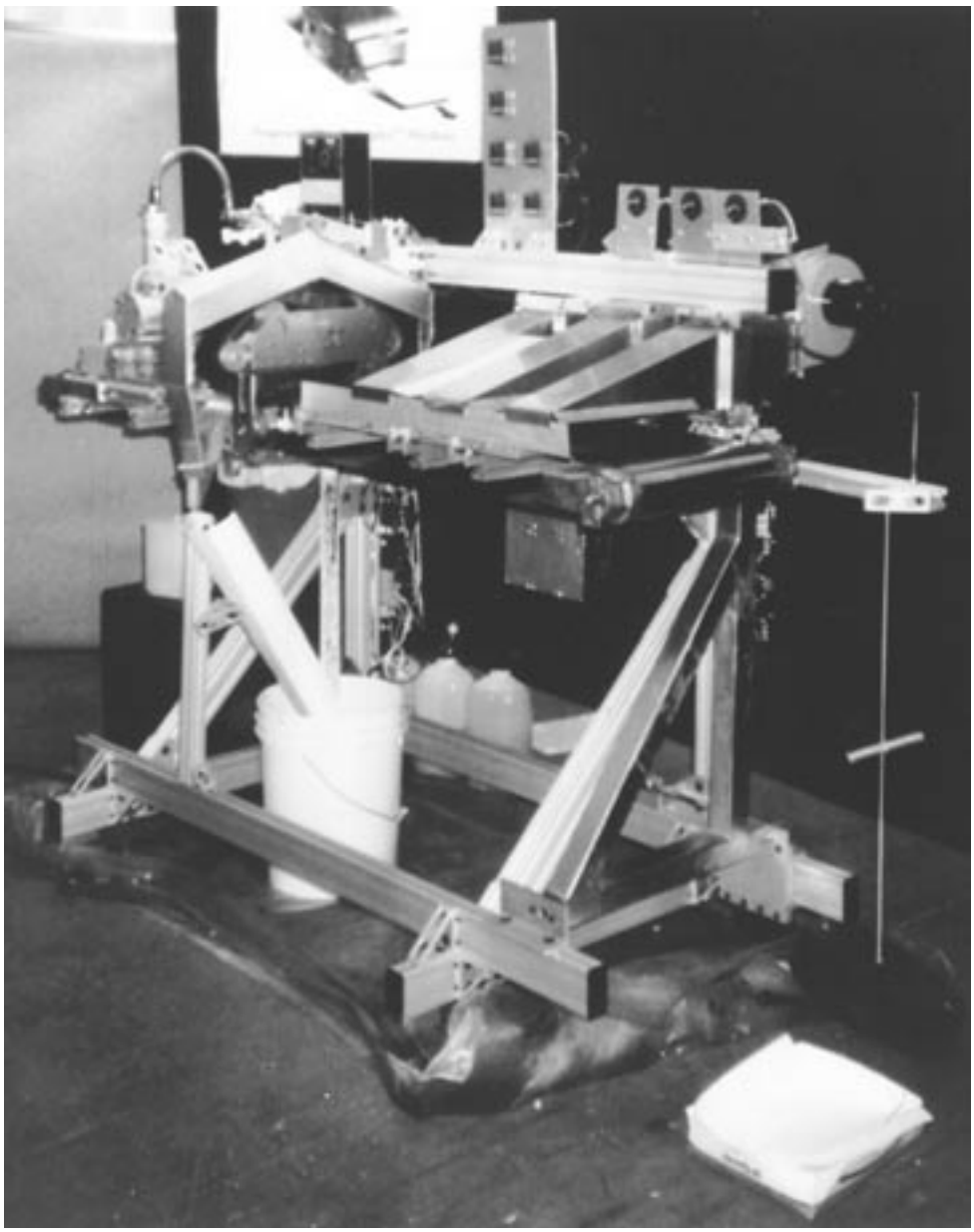

FIG. 1—*DeCopier prototype model located at DeCopier Technologies Inc., Framington, MA.*

a fluid-removal component, duct dryers, and a calendaring component.

The DeCopying Process

The procedure of DeCopying documents attempts to reverse the xerographic process but is actually a much simpler undertaking. The document is fed sideways (due to the way paper swells), either automatically or manually, onto the conveyor belt. The fluid-releasing system then uniformly sprays approximately 10 g per sheet of DeCopier solution. The document is entirely saturated with the solution. As the document is passed over the heated platen, the chemicals react with the document, causing the toner to release its bond with the paper. The toner lifts off the paper surface and is suspended in the solution. The brush sweeps the solution and suspended toner off the document and into a recycling container. The fluid is removed and redirected (for recycling and reuse), and the sheet is dried and then calendared. The calendaring component irons the paper with heated rollers to restore the paper to a reusable sheet. Theoretically, the DeCopied sheet is now cleaned of all toner and ready for reuse.

The used solution, containing the removed toner, remains in a recycling container until the toner settles to the bottom. The separated solution on top is available for reuse in the DeCopier machine. The removed toner can later be recovered and recycled as filler material.

DeCopier Benefits

The DeCopier machine has been designed for the modern office, which is projected to demand 15.29 million tons of uncoated, freesheet paper this year alone (1). The benefits the DeCopier offers

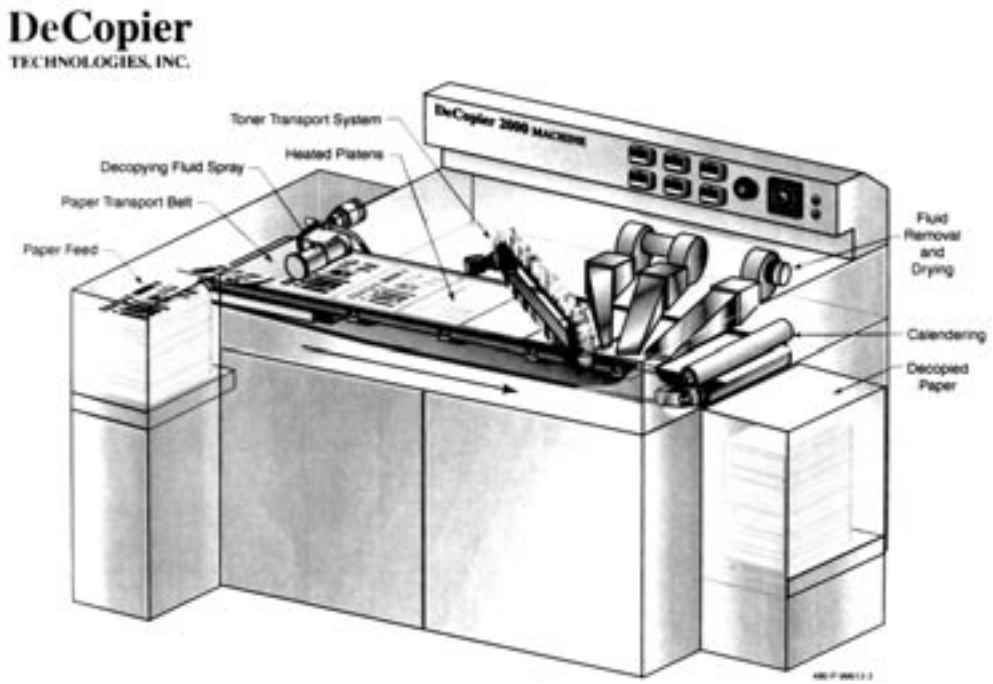

FIG. 2—*DeCopier Technologies, Inc. design model of the DeCopier 2000 machine.*

to its potential clients are protecting confidential information, reducing waste accumulation, and cutting operating costs.

A major benefit of and potential market for the DeCopier is document security. Through information removal, DeCopier technology attempts to alleviate the security risk of traditional paper destruction. Most common ways of protecting confidential information focus on paper destruction, not information removal. But shredded documents can be reassembled, and partially charred documents can be deciphered through alternative light source examination.

Industrial espionage has become a large problem for the business world. Documents containing important information are frequently stolen from businesses by competitors. There is an annual loss of approximately $24 billion in intellectual property from stolen documents (2). As a result, paper shredders have become an increasingly popular home and office machine. In 1998, the number of shredders sold was close to 2.5 million (3). A typical office shredder ranges from $30 to $300. The cost of the shredder is much less than the DeCopier, but it does not offer the same benefits. Paper shredders simply cut the document into small pieces, but the information remains on the paper. The shredded paper can be collected and successfully reassembled. The DeCopier actually removes the information and leaves no chance of restoration. Bhatia hopes that companies will recognize that the benefits of the DeCopier outweight the cost.

Bhatia's initial interest in developing the DeCopier came from his involvement in the recycling efforts of his local community. Today, he still sees recycling as one of the great benefits of the DeCopier. Modern computer technology has not created a paperless society as once intended but has actually triggered an annual 4.5% average increase in office paper usage over the past decade (1). Environmental movements have called for recycling, reusing, and reducing waste in our landfills, as well as maximizing the use of natural resources. This interest in protecting environmental resources makes DeCopier technology both an appealing concept and a marketable product.

The federal government has attempted to lead the country in using recycled papers, and an executive order, effective January 1, 1999, asked the administrative branches of the United States Government to use paper with at least 30% recycled content in their purchases (4). Historically, many companies have shied away from recycling paper and using recycled papers due to the nuisance and expense. The DeCopier offers the modern office a self-contained way of using, recycling, and reusing office paper without leaving the building.

Cost saving is an additional benefit of the DeCopier machine. DeCopier Technologies, Inc. believes the cost of a DeCopier will have a payback period of about one year. They believe that the use of the DeCopier would dramatically reduce the overhead costs for new paper and transparencies. Bhatia projects that the cost of DeCopying a sheet of paper will be less than the cost of a new sheet of paper. The estimated cost of an industrial DeCopier machine is approximately $45 000, while the smaller office version could be as low as $7000, and a personal home model under $2000.

Effects on Documentary Evidence

Experimentation

Thirty-nine specimens were prepared, each containing two repetitions of the "London Business Letter" applied to paper and transparencies, using one of the following office machines: laser printer, indirect electrostatic photocopier, facsimile, inkjet printer, and inkjet photocopier. Though the DeCopier machine is designed to only remove toner, documents often contain a variety of applications such as pen inks, pencil lead, and typewriting. Most of the specimens contained one additional application. It was of interest to observe how the DeCopier process would affect other applications. The chosen applications were a representative sampling of the types of documentary evidence examined by the forensic document examiner.

The prepared specimens were initially set to be run through the DeCopier prototype. However, due to unforeseen circumstances, this was not possible. Alternatively, the DeCopier chemist attempted to DeCopy the specimens manually in his laboratory. In the manual process, the solution's chemistry can be adjusted in order to best DeCopy the document. This manual processing also created variables that were not accounted for in the design of the experiment and therefore may have influenced the results. Thus, the results of the DeCopying process on the specimens reflect the ability of the technology, not the mechanics of the machine.

The manual process involved the same components as the prototype, only the equipment was not assembled into one functioning unit. The document is placed on a heated platen (used in photographic processing) and a spray bottle dispenses the DeCopying solution. A brush, similar to a small paintbrush, is used to remove the toner. The document is left to dry on the heated photographic platen and is ironed in an attempt to replicate the drying and calendaring process.

The manual DeCopying process performed on the specimens added the following variables:

1. *Toner Remover Brush*

The manual brush used differs from the machine brush in both its appearance and the way it was utilized. The manual brush was manipulated over the document with varying degrees of pressure and an inconsistent number of passes. The additional friction on the specimens caused significant paper fiber disturbance (compared to machine-fed specimens provided by DeCopier Technologies, Inc.) that may not have been as obvious in machine DeCopied samples. Additionally, the chemist made repeated efforts to remove some of the applications on the specimens; if the prototype machine had been used, the documents would only have been subjected to one "passing" of the brush. This may have provided a more accurate representation of what would happen to other applications on documents when machine DeCopied.

2. *Drying and Calendaring Process*

The manually processed DeCopied specimens were dried on a heated photographic platen and were not calendered. The result was wrinkled paper. This may have influenced the observations of the changes in the paper properties as opposed to machine DeCopied documents. Additionally, the change in paper thickness before and after DeCopying was not measured, as the results would not reflect a realistic comparison since these specimens were not dried and calendared as they would have been in the prototype machine.

3. *DeCopying Time and DeCopying Solution Amount*

Due to the manual processing, the amount of solution applied to the specimens and the amount of time spent DeCopying them were not controlled. The resulting DeCopied specimens vary in the amount of remaining readable text. If the specimens were machine DeCopied, the results may have been more consistent.

An additional issue that was encountered during the experiment was the type of toner on the specimens. DeCopier Technologies, Inc. has only been successful with DeCopying paper documents with specific types of toner. The specimens provided for DeCopying did not contain toner that has thus far been tested for DeCopying. The DeCopier chemist is currently fine-tuning the solution in order to DeCopy a greater variety of toner.

Observations

All samples that the chemist attempted to DeCopy were collected and examined in the Questioned Documents Unit at the FBI Laboratory in Washington, DC. The specimens were examined microscopically with a stereo microscope, with alternative light sources on the Foster and Freeman Video Spectral Comparator 2000 (VSC), and appropriate specimens were further examined utilizing the Foster and Freeman Electrostatic Detection Apparatus (ESDA) (Table 1).

The following is an explanation of a portion of the observations:

Toner

Paper

Specimens 1 through 4 and 6 through 38 contained toner entries. The toner appeared partially or completely removed as a result of DeCopying. However, there was a residue left on the paper. The residue was visible to the naked eye and on a few specimens the text was decipherable. Of note was specimen 3, which contained facsimile toner that retained a distinct purple residue after DeCopying.

All of the specimens were examined under alternative light sources. The area of removed toner did not react to any alternative light sources.

Transparencies

Specimens 8 and 23 were transparencies containing toner entries. The transparencies were the most successfully DeCopied specimens. No toner remained on the specimens and no trace of the previous text was observed. However, a cloudy residue was present on the transparencies after DeCopying.

Indented Writing

Specimens 18 and 33 contained indented writing. After DeCopying the specimens, no indented writing was observed by side lighting or ESDA.

Dry Seal

Specimens 22 and 37 contained dry seal impressions. The seal impressions were not removed as a result of DeCopying but the details of the impressions appeared swollen and not crisp.

Obliterated Text

Specimens 19 and 34 contained an obliterated (correction fluid) portion of toner text before DeCopying. In natural light, the DeCopying process appeared to have removed the correction fluid on both specimens. The toner on Specimen 19 also appeared to have been removed. The previously obliterated text on Specimen 34, however, was still visible in natural light, but a significant amount of the toner had been removed. The obliterated areas on each specimen were examined with different lighting with the VSC 2000. The obliterated area of Specimen 19 was visible with transmitted light and a transparent outline of the text that had been obliterated was visible. Under infrared light the obliterated area of Specimen 34 appeared opaque; therefore, the obliterated portion of text was not visible.

Ink Applications

Specimens 9 through 14, 17, 21, 24 through 29, 32, and 36 contained ink applications. All ink applications faded and/or bled. Specimens 11 and 26 contained gel ink applications. The gel ink was the most resistant to the DeCopying process and only faded slightly. Some of the ink applications that appeared faded

TABLE 1—*Observations of DeCopied specimens.*

Specimen #	Toner Source* + Additional Application	Paper Fiber† Disturbance	Observations of DeCopied Specimens: Additional Application Change‡	Readable Text§	Text Residue‖	Paper Texture Change¶
1	LJ toner	yes	n/a	no	yes	yes
2	LJ toner, double sided	yes	n/a	partial	yes	yes
3	Fax toner	yes	n/a	no	yes	yes
4	PC toner	yes	n/a	partial	yes	yes
5	Color inkjet copier	yes	n/a	yes	n/a	yes
6	Color laser photocopier toner	yes	n/a	yes	n/a	yes
7	Color laser photocopier toner, heavier paper	yes	n/a	partial	yes	yes
8	LJ toner, transparency	n/a	n/a	no	no	n/a
9	LJ toner + ball point inks	yes	yes	partial	yes	yes
10	LJ toner + roller ball inks	yes	yes	no	yes	yes
11	LJ toner + gel inks	yes	yes	no	yes	yes
12	LJ toner + felt tip inks	yes	yes	no	yes	yes
13	Ball point inks over LJ toner	yes	yes	partial	yes	yes
14	LJ toner over ball point inks	yes	yes	partial	yes	yes
15	LJ toner + pencil	yes	no	no	yes	yes
16	LJ toner + typewriter impressions (carbon)	yes	yes	partial	yes	yes
17	LJ toner + typewriter impressions (fabric)	yes	yes	no	yes	yes
18	LJ toner + indented writing	yes	yes	partial	yes	yes
19	LJ toner + correction fluid over toner	yes	yes	partial	yes	yes
20	LJ toner, watermark paper	yes	no	yes	n/a	yes
21	LJ toner + rubber stamp impressions	yes	yes	partial	yes	yes
22	LJ toner + dry seal impressions	yes	yes	partial	yes	yes
23	PC toner, transparency	n/a	n/a	no	no	n/a
24	PC toner + ball point inks	yes	yes	yes	n/a	yes
25	PC toner + roller ball inks	yes	yes	partial	yes	yes
26	PC toner + gel inks	yes	yes	partial	yes	yes
27	PC toner + felt tip inks	yes	yes	partial	yes	yes
28	Ball point inks over PC toner	yes	yes	partial	yes	yes
29	PC toner over ball point inks	yes	yes	partial	yes	yes
30	PC toner + pencil	yes	yes	partial	yes	yes
31	PC toner + typewriter impressions (carbon)	yes	yes	no	yes	yes
32	PC toner + typewriter impressions (fabric)	yes	yes	partial	yes	yes
33	PC toner + indented writing	yes	yes	partial	yes	yes
34	PC toner + correction fluid over toner	yes	yes	partial	yes	yes
35	PC toner, watermark paper	yes	no	partial	yes	yes
36	PC toner + rubber stamp impressions	yes	yes	partial	yes	yes
37	PC toner + dry seal impressions	yes	yes	partial	yes	yes
38	PC toner, double sided	yes	yes	partial	yes	yes
39	Color inkjet printer	yes	yes	yes	n/a	yes

* LJ toner specimens originated from a HP LaserJet printer with a Lexmark print toner cartridge.
Fax toner specimens originated from a Panafax UF facsimile with 744 toner.
PC toner specimens originated from an Oce 3155 photocopier with Oce photocopy toner.
Specimens #5 and #39 don't contain toner (ink jet).
† Paper fiber disturbance was compared to a nondecopied sheet of paper, variation was presence among DeCopied Specimens.
‡ Under visual examination, a noted change in the appearance of the additional application (not the toner).
§ Presence of toner and readable text on specimen (Specimens #5 and #39 contain ink text).
‖ Residue or "shadow" of original toner text remaining on specimen in white light, variation in the legibility of the text was present.
¶ Paper texture change was compared to a nondecopied sheet of paper.

or completely removed by the DeCopying process left carriers in the paper that were visible under ultraviolet and infrared light sources.

Color Inkjet and Color Laser Applications

Specimens 5 through 7 and 39 contained color inkjet and color laser applications. These specimens were not significantly affected by the DeCopying Solution. The color ink and color toner faded slightly but not to the same extent as the black toner and other applications.

Watermark

Specimens 20 and 35 contained toner entries on paper with a physical watermark. As expected, no change in the visual appearance of the watermark was observed after DeCopying. The watermark was the only application which did not appear to be affected by the DeCopying process.

Texture

The texture of all the paper specimens was easily distinguishable from that of new paper. If the samples had been machine dried and calendared, this characteristic may not have been as readily identifiable.

Odor

All the paper specimens maintained a distinct chemical odor, even months after they had been DeCopied.

DeCopier Technologies, Inc. Samples

Samples that contained successfully tested toner where provided by the company. Under magnification, toner particles

were still visible on the paper. These toner particles were randomly dispersed and did not allow the removed text to be deciphered.

There was also a slight but perceivable change in the paper texture and hue. The appearance of paper fiber disturbance was significantly less in these samples than in the experiment specimens.

DeCopier Technologies, Inc. also demonstrated partial DeCopying of their samples. They were able to DeCopy selected portions of text on a page leaving the remaining text intact.

Conclusions

Currently, DeCopier Technologies Inc.'s ability to successfully remove toner from paper is limited to a few types of commercial toner. As a result of this preliminary assessment, the toner appearing on the transparency specimens was successfully removed. However, the toner on the paper specimens was removed to varying degrees due to a component that remained in the text areas of the paper. The information on these paper specimens was not successfully removed.

The DeCopying marketing literature claims that a DeCopied document cannot be distinguished from new paper. From the experimentation and observations conducted, Specimens 1 through 7, 9 through 22, and 24 through 39 were distinguishable from new paper. However, the textural and physical observations of the DeCopied documents that were provided from the company were more difficult to distinguish from new paper.

Specimens 8 and 23 (transparencies) were indistinguishable in texture from new transparencies.

The DeCopying process affected all the additional applications, except watermarks, but did not completely remove any of them. The extent to which the additional applications were affected varied.

Impact on Document Examination

The use of the DeCopier technology by government, business, and criminal organizations could greatly impact the work of the forensic document examiner. Document examiners see document alteration utilizing computers, photocopiers, cut and paste manipulation, chemical washing, obliteration, and additions. The DeCopier is potentially a "new tool" for more successful document alteration. If the process is perfected and successfully marketed, documentary evidence could be easily altered or destroyed. Additionally, the capability to partially DeCopy documents could significantly impact the alteration of documents.

If DeCopier technology is used to alter or destroy a document, the document examiner may not have the ability to restore the lost information, nor be able to conclude that a document has been altered. Forensic document examiners should be aware of the work of DeCopier Technologies, Inc. and keep abreast of any advances they make in the future. If DeCopying becomes a common office practice, its effect on documentary evidence will surely be felt in the forensic community.

Suggestions for Future Research

Further research into the effects of the DeCopying process on documentary evidence will be necessary particularly if the DeCopier becomes available to the public. Possible research topics include the following: an assessment of toners and their ability/inability to be DeCopied, an assessment of the effects of the DeCopying process on latent fingerprints present on documents, and an assessment of the changes in paper structure as a result of the DeCopying process.

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