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### Erasable Inks in Document Fraud: A Systematic Review of Forensic Detection Methods

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**Abstract.** A variety of crucial and legitimate documents, including negotiable instruments like demand drafts, fixed deposit receipts, and cheques, can be used as tools for criminal activity to perpetrate document fraud by erasing text and changing it. Despite the many forms of research that have already been conducted over the years, there is a need to gather the fragmented knowledge that has been available regarding document fraud through erasure and erasable writing instrument ink. As a result, an effort is made in this review to examine literature that has represented its legal values and validate it in light of existing literature and published research studies to shed light on the procedures and methods used to remove the original writing from the forensic questioned document. This will aid in the detection, investigation, and prevention of document fraud by banks, insurance companies, and law enforcement agencies, as well as increase public awareness.

**Keywords:** Erasure in document fraud; White-collar crime; Magic erasable ink; Questioned document; Forensic science.

## 1. Introduction

The execution of fraudulent signatures or writings, additions, substitutions, modifications, counterfeiting, interpolation, and/or use of identity documents and other fraudulent documents to evade immigration restrictions are all considered forms of document fraud commonly referred to as identity fraud<sup>1-3</sup>. A variety of necessary documents and negotiable instruments, including demand drafts, fixed deposit receipts, cheques, and so on, can be used as tools for criminal activity to perpetrate document fraud by erasing the ink and using it<sup>4</sup>. Furthermore, a variety of erasing techniques and inks are employed fraudulently to falsify documents without leaving any apparent traces of suspicion or secret writing, respectively<sup>5</sup>. These days, a variety of erasable inks are sold in stores and online markets that may be completely removed from surfaces by subjecting them to CO<sub>2</sub><sup>6</sup>, source of the heat, friction, certain chemicals, and other environmental factors<sup>7</sup>. Additionally, it has been reported that disappearing inks are water-based acid-base indicators (pH indicators) that, when exposed to atmospheric CO<sub>2</sub> present in the air, transform from a colourful to a colourless solution<sup>8</sup>. Digital technologies are also developing quickly. Certain computer-based programs, such as editing software, Adobe Photo shop®, MAC®, Windows®, and Paint®, have erased capabilities<sup>9</sup>. The largest difficulty facing forensic document experts in forensic laboratories and law enforcement agencies investigating forensic document science in the digital age is cut-and-paste forgery<sup>10-12</sup>.

Thus, the current review endeavors to examine the literature that provides evidence of its legal characteristics and corroborates them in the context of existing literature and published research investigations. To examine a forensic document for fraud, forensic scientist must gather information, record a statement, review the evidence, aid in the investigation, compile a report, and present the case to the Honorable Court for natural justice<sup>13</sup>. Fraud is defined as any action by which one person intends to gain a dishonest advantage over another<sup>14, 15</sup>. Aside from this; the quick-rich syndrome is causing the crime graph to rapidly worsen. In addition, the quick-rich syndrome, the shortcut to success, and the ease of access to instruments (such as erasable writing instruments, various chemical and physical erasures, and electronic devices like printers, scanners, cameras, and computer software) are all factors that contribute to the crime rate's sharp rise<sup>16-17</sup>. The use of a range of methods by contemporary criminals is evidence of document fraud, a financially

motivated, non-violent crime. Modern criminals' employment of a variety of techniques is proof of document fraud, a financially driven, non-violent crime. Fraudsters always try to produce an exact copy of the genuine writings and signatures from the original documents<sup>18</sup>.

Forgery is defined as "the act of forging something, especially the unlawful act of counterfeiting a document or object for fraud or deception" in the questioned document science. It can be further classified as digital/cut and paste forgery, disguise, freehand forgery, traced forgery, and simulated forgery<sup>19-20</sup>. We recently published a new category of forgery christened "Hybrid Forgery" in the questioned documents science<sup>21</sup>. Meanwhile, fraudsters additionally utilize other strategies including additions, deletions, substitutions, obliterations and alterations to interpolate crucial documents for their nefarious purposes and deceive innocent people for their personal gain by utilizing erasures<sup>22-25</sup>. Identity fraud includes several misleading actions, including unauthorized use or change of identifying documents. False signatures, unauthorized additions, substitutions, alterations, counterfeiting, and interpolation are common forms of fraud. Fraudsters generally modify or create documents to avoid legal or institutional examination, especially in immigration control, financial transactions, and government benefits. Criminals are increasingly using erasable inks, particularly thermal ones, thymolphthalein (blue) ink, and other erasable inks to deceive. Heat, friction, other environmental conditions, and special ink erasure can remove these inks, making it possible to alter counterfeit documents. Forgers can use these inks, along with different *modus operandi*, to fabricate documents that appear authentic. A document may be produced using erasable ink, submitted for approval or verification, and subsequently updated to include a false name, date of birth, or visa expiration date. Identity fraudsters use erasable inks to alter official documents.

For most document examiners, ink analysis is one of the most frequent tasks. A crucial aspect of forensic document examination is determining whether a handwritten signature on a disputed document is genuine. The first step in this process is to establish whether writing ink was used to produce the signature. Finding a signature's identity or demonstrating its authenticity has been a major point of contention in numerous court cases<sup>26-33</sup>. Despite the several forms of research that have already been conducted on this subject over the previous few decades, there is a need to compile the scattered knowledge that examines document fraud.

Consequently, an effort is made in this review to carefully examine literary works that have conveyed its legal values and to validate them in the context of existing literature and published research investigations.

This work can also aid in identifying future research directions that aim to address real-world case problems. While every attempt has been made to include all advancements regarding document examination in this assessment, it is possible that some information has been left out.

## **2. Materials and Methods**

A Google Scholar search yielded 121 results with information about document frauds in disputed document science; additionally, published articles, literature, and a few review articles with cross-references were gathered. For the review, published materials on new advances in forensic document fraud research were examined, including original publications in PubMed, Scope-med, PubMed Central Databases, Research Gate, Google Scholar and other related databases. Erasures, erasable inks, writing instruments, and scientific studies using destructive and non-destructive methods within the forensic community were the only items that met the search parameters. For the current Systematic review work, reported data were examined and presented as figures and tables. It is significant to notice that two distinct categories of publications generalist and forensic-questioned document science are cited in this systematic review. Exclusively forensic publications and renowned published book references are also discussed for this work; all other publications are just presented as background. Due to the wide range of analysis areas related to the questioned documents, the findings of the bibliographic research were grouped around several key topics: the classification of pencils and erasures; the classification of writing instruments' inks; the classification of printers' inks and toners; the types of erasable magic writing instruments and the composition of their ink; and the examination of erasures using non-distractive and distractive techniques.

The article is divided into several sections. These include the history of the ink, erasures and how to classify them, types of erasable magic writing instruments and how their ink acts as an erasure, how to identify erasures and other magic-erasable writing instruments, and other scientific instruments and methods for testing erasable ink. This manuscript provides information regarding the surface-level details

about the ink's history in this review. This article also discusses pencils and how, over the past few years, pencil classification has expanded significantly. Writing instrument inks are not very new, but as they are a forensics-related topic, this review should nonetheless include them. Information on the categorization of toner and ink meant specifically for printers is also included in this publication. This review also provides information on the erasure classification in the forensic science of the questioned documents. The main objective of this review is to show how magic-erasable writing instruments are used and how they work as erasures to remove unwanted data from the writing surfaces. Since erasable writing strokes are the primary means by which latent handwritten impressions are revealed, the final section of this article on forensic handwriting analysis discusses scientific equipment and procedures.

### **3. Results and discussion**

#### **3.1 History of ink**

Ink has a long history dating back to antiquity. Carbon was one of the first materials utilized, producing extremely persistent ink. It is still used today in some drawing inks, also known as Indian inks. Artists around the world, including those in the Far East, continue to use this type of ink extensively. In its most basic form, carbon ink is made of amorphous carbon solidified using glue. Grinding the cake and dispersing the particles in a water–glue mixture converts it into a liquid suitable for writing.

To enhance the hue, colored dyes are occasionally added. Liquid carbon inks, which maintain the carbon in suspension, are also available. In these formulations, animal glue is replaced with borax and shellac, and a wetting agent is added to improve the interaction between carbon and shellac. Carbon inks are highly stable and cannot be degraded by light, air, moisture, or microorganisms. They are insoluble in water and can only be removed from paper by abrasion, meaning that the ink persists as long as the paper itself. Although not typically recommended for use in fountain pens, they are widely used for printing and drawing purposes<sup>34-37</sup>.

Iron gall ink was developed during the Middle Ages. Writing produced with iron gall ink is characterized by oxidation and gradual browning from its original black color. Due to its corrosive properties, it can degrade the paper on which it is applied, a phenomenon observed in many historical manuscripts. Over time, it was refined

into blue-black ink, which remained widely used until the emergence of the ballpoint pen as the dominant writing instrument.

The first colored inks were produced using natural dyes. These were eventually replaced by synthetic dyes such as aniline (1856) and synthetic indigo (1861)<sup>38</sup>. This transition occurred primarily in the late 19th and early 20th centuries. During the 1930s, strong alkaline solutions began to be used in place of mild acidic ones for dye production, although these newer inks were not well received in the market. Until this period, water had been the primary solvent in ink formulations.

A significant change occurred with the development of the ballpoint pen in the mid-1940s<sup>39</sup>. Unlike earlier inks, ballpoint ink is a viscous, paste-like substance composed of organic solvents rather than water<sup>40</sup>. While it shares some similarities with inks used in printing and typewriter ribbons, it has distinct properties that differentiate it from previous formulations.

Since the 1970s, water-based fluid inks have regained popularity, initially in fiber-tip (porous-tip) pens and later in rollerball pens<sup>41-42</sup>. The fiber-tip pen evolved from felt-tip markers, which used non-water-based inks for specific applications. Today, most inks are colored using synthetic dyes and pigments<sup>43</sup>.

Rollerball pens are generally classified into two main types: liquid ink and gel ink. Liquid-ink rollerball pens combine the smooth writing experience of fountain pens with the convenience of ballpoint pens, using an ink delivery system similar to that of fountain pens. This type of pen was first developed by the Japanese company Ohto in 1963<sup>44-45</sup>. Gel-ink rollerball pens, introduced later and patented by Sakura Colour Products in 1982, use aqueous gel-based ink<sup>46</sup>.

Gel inks typically contain pigments, whereas liquid inks are generally dye-based, since pigments in liquid formulations tend to settle (sedimentation). The use of pigments in gel inks allows for a broader range of brighter and more opaque colors, including pastel, metallic, and glitter effects. The higher viscosity of gel inks enables better suspension of particles but may also result in occasional "skipping" during writing. In contrast, liquid inks, with lower viscosity, provide more consistent flow and reduced skipping<sup>47</sup>.

Both rollerball and gel pens operate using a rotating metal ball that transfers ink to the paper. Early versions used opaque, high-viscosity pigment inks that minimized bleeding compared to water-based or porous-tip inks. Currently, black gel

inks are available in both pigment-based and dye-based formulations, and a wide variety of ink colors is commercially available<sup>48-52</sup>.

The survey results and literature related to the chronological development of writing instruments are summarized in Table 1.

**Table 1.** Chronology of the evolution of writing instruments<sup>60</sup>.

Sr. Nos.	Years in AD/BC	Peripheral literatures
1.	In 54 BC	In the Mediterranean region, quills from geese were used to make pens. Pen is shorthand for Penna, the Latin word for feather, which was used to refer to writing instruments.
2.	In 50 BC	From this time until 1650 AD, the quill or reed pen was used for the majority of writing. According to legend, monks in the Middle Ages wrote manuscripts using quill pens for small writing and reed pens for normal writing. A metal pen was occasionally used in the Roman and later European eras. There was gold, silver, iron, steel, and bronze. Steel and bronze were durable enough to be utilized for the pen's point and stem. A valuable stone was carved to a point when a craftsman created an instrument out of iron, silver, or gold in order to give a pen tip that was durable enough for writing.
3.	In 1650 AD	Books from the seventeenth century reported pens with an ink reservoir in an attached well, or "fountain." This is when the term "fountain pen" was originally used. A trading card of a British bookshop dated approximately 1714, listed "ink horns, fountain pens, wax wafers without elaborating on the writing implement.
4.	In 1748 AD	Johann Jansen was the initial person who produced individual steel nibs in France. They were pricey, rigid, and unyielding.
5.	In 1803 AD	In London, steel pens were produced and marketed and they were produced by hand.
6.	In 1809 AD	Quill pen manufacturers started producing distinct tips that were meant to be placed inside the quill stem.
7.	In 1818 AD	Charles Watt inserted gold tips to quills to increase their durability.
8.	In 1820 AD	Steel slip pens were first mass-produced in England by Joseph Gillott. Gil Mitchell also automated the process of producing nibs, which his brother-in-law John Mitchell had initiated.
9.	In 1828 AD	A craftsman named James Perry and an inventor named Joseph Mason enhanced Mitchell's invention's machinery

		and started producing nibs with an ink hole and central slit that provided more flexibility.
10.	In 1839 AD	The hot vulcanization technique for rubber was discovered by Charles Goodyear of New Haven, Connecticut. This foreshadowed the production of rubber tubes used as fountain pen inkwells.
11.	1851 AD	Initially, an alloy known as iridium was mixed with gold to create a robust and durable pen point. The pen market was starting to take off.
12.	1858 AD	Originally, to make a strong and long-lasting pen point, gold was combined with an alloy called iridium. The market for pens was just getting started.
13.	1884 AD	Lewis Edson Waterman, an American businessman, invented the fountain pen, which is regarded as the first useful tool of its kind. He nearly lost a sale because the dip pen he was using splattered ink all over the contract. A dropper was used to fill the barrel of Waterman's pen with ink, and a feed was used to regulate the flow of ink to the nib. These pens were initially made by hand, but later on Waterman-designed machinery. Today's fountain pens still use the same fundamental components that he created.
14.	1888 AD	American inventor John Loud was granted a patent for a ball-point pen. Unfortunately, the ink needed to create the pen commercially could not be developed.
15.	1895 AD	Castor oil and lampblack were used to create the ink for a ballpoint pen that G. A. Werner and A. W. Askew manufactured and marketed.
16.	1903 AD	Pump-style filler with a rubber sac that drew in ink when squeezed was created by L. E. Waterman. The Conklin pen, which depressed the sac by passing a coin through a slot in the barrel, appeared subsequently.
17.	1908 AD	The lever-fill principle was developed by Iowa jeweler W. A. Sheaffer, ending a protracted quest to create a workable and satisfactory self-filling pen.
18.	1913 AD	Lever-fill pen production was started when the W. A. Sheaffer Pen Company was founded.
19.	1916 AD	Van Vechten Riesbery receives a patent for a ballpoint pen writing instrument; nonetheless, his invention meets the same demise as Louds'.
20.	1922 AD	The Sheaffer Pen Company developed the first fountain pen nonsediment ink, called Skrip.
21.	1935 AD	The ball-point pen was invented by Paul V. Eisen and Wenzel Klimes, but production was halted two years later due to World War II.
22.	1943 AD	Ladislav Biro, a Hungarian living in Argentina, invented the ball-point pen. It was produced and sold in South America before being brought to the United States by American

		travelers (in a very restricted sense).
23.	1945 AD	An American public lacking in creativity was presented with "the pen that will write under water" by Chicagoan entrepreneur Milton Reynolds. The first ball point pen was created by businessman Milton Reynolds, whose 32nd Street store hosted the pen's initial New York debut on October 29, 1945 starting with the release of its renowned 045 writing pen in 1945.
24.	1947 AD	Poor-quality ink with particles that clogged the writing ball, rusted the cartridge, damaged the tip, and continued to leak in the owner's pocket when not in use caused the ball-point pen bubble to burst.
25.	1949 AD	A Hungarian chemist named Fran Seec, who now resides in America, creates an ink that turns the ballpoint pen into a useful device.
26.	1950 AD	Patrick Frawley, Jr. presents the first retractable ball point pen, known as the Paper Mate, which comes with non-smear ink.
27.	1960s AD	When the porous tip marker joined other writing tools as a reliable writing aid in the early 1960s, a second "new" wave of writing technology emerged. The marker has had quick and efficient improvements since it was first designed as an industrial marking tool with a felt tip that resembled a wick and could write on any surface by painting on the writing fluid. The creation of new, durable tip materials that could be made at any level of fineness was one such advancement.
28.	1968 AD	The rolling ball pen is introduced to the US market by Japanese companies Uni-Pen and Pentel.
29.	1969 AD	Paul Fisher used chewing gum-consistency ink to build the pressurized cartridge. In order to push the ink ahead and get it to liquefy and flow smoothly when applied to a surface, Fisher employed nitrogen pressure. Everyone refers to this kind of ball pen as the "Space Pen" because it was utilized in the American Space Program.
30.	1970s AD	Erasable inks' ultimate invention turned out to be the single most important advancement for the writing industry. Following adjustments, these inks were stored in ball-point pen systems. Henry Peper Jr. and Doctor Phillip Dawson share credit for the invention of erasable inks.
31.	1973 AD	Another chap turned out to be interested in the concept of erasable ink. Similar theories about erasable inks were developed by Dr. Phillip Daugherty, Director of Chemical Research at Anja Engineering Company, a division of Scripta, Inc. In addition to publishing works on the subject of ball pen ink composition, Dr. Daugherty has acknowledged that he came up with the concept for an erasable ink as early as 1963. Regarding this topic, the first US patent is

		4/1/75 and is titled "Erasable Writing Medium Suitable for Use in Ball Point Pens" According to the listing, the inventors are Thomas E. Palmer and Phillip M. Daugherty, both of Atlanta, Georgia's Scripta, Inc.
32.	1979 AD	The Frawley Pen Company's Paper Mate Eraser mate, which employs specialized rubberized ink and its eraser to remove the ink. Now since the ink has been eliminated, the writer is able to come back and correct the mistakes you made.
32.	1987 AD	An erasable ballpoint pen ink is the subject of a patent application with number US4687791A, titled "Erasable ballpoint pen ink." More precisely, it refers to an ink that works well with ballpoint pens, especially those that allow for the writing of small text and leave behind ink traces that can be removed with a rubber eraser after a set amount of time, all while offering superior writing performance.
33.	2006 AD	In Japan, the Pilot corporation unveils to the world their ground-breaking FriXion range of erasable ink pens. The development of this writing equipment is based on thermal erasable ink.

### 3.2 Erasures

In order to counterfeit papers and change their worth for their own benefit, forgers also employ a variety of erasing techniques. It is much simpler to make minor changes to an already-existing valid document than it is for someone to try to create entirely fraudulent documents, which are therefore extremely uncommon. A forger typically has to eliminate information that might identify them or take up space needed for the fraudulent addition, yet occasionally all it takes to commit a fraud is the addition of words or numbers. This is why erasure sites are present on most fraudulently altered papers; if these are discovered, the document will be highly condemned, especially if it is possible to read or recover all of the erased material. Forgers can use rubber, sharp object such as knife blades, needle, sand paper, solvents, and chemical bleaches as erase instruments. However, the relatively recent introduction of new reagents for detecting traces of iron into analytical chemistry and improvements in photographic materials have increased the possibility that the document examiner will be able to show the erasure process and decode or reconstruct the deleted entries. The next behaviour has extended the meaning of the term 'erasure' to include the removal of a part or even a whole sheet of a multilayer text.

Safety sheets that are intended to make certain types of erasing more difficult are also offered as a technique to limit the harm caused by the forger in an attempt to encourage greater adoption of these unique items. Photography is a distinct field and has a major role in both locating erasures and interpreting the erased matter, therefore details about cameras, lenses, negative materials, and processing have been limited. Erasures can be categorized into the following groups based on survey data and published works. Erasing out information that is unwanted one or more of the following four techniques can be used to fraudulently delete unwanted material from a document:

- (1) The paper containing the unwanted data is eliminated.
- (2) Paper abrasion on the surface.
- (3) Washing with the proper solvent.
- (4) Chemical processing of the unwanted data to produce molecules that are colourless or soluble<sup>53-58</sup>.

The survey results and literature pertaining to classification of erasures' are listed in Table 2 form below.

**Table 2.** Classification of Erasures.

<b>Nos.</b>	<b>Types</b>	<b>Examples</b>
1	Chemical	Benzene, toluene, chlorine water, bromine water, acetone, sulphurous acid etc <sup>59</sup> .
2	Detergent	Liquid detergents and shampoos etc <sup>60-61</sup> . <i>Sapindus Mukorossi</i> ; Family: Sapindeae named as <i>Aritha</i> in India.
3	Mechanical	Rubber erasures, a scratch-knife, a sharp blade, a sharp needle etc <sup>62</sup> .

Ever since the beginning of human civilization, forensic science has produced clues for fighting fraud. It is evident from reading the literature on erasure use in questioned document fraud that a variety of erasure techniques have been employed, including the employment of erasures to alter currently popular inks in order to perpetrate crimes. The Greek and Latin words papuros and papyrus are the origin of the words paper, which is papier, and papel, which were the first writing materials used before paper<sup>63</sup>. Paper is divided into two kinds in the modern era: glossy and matte<sup>64</sup>. Compared to Matte Paper, the glossy paper has a much smoother surface<sup>65</sup>. The discolouration of writing strokes varies depending on the type of ink, chemical erasures, and paper used. The process by which chemical

erasures work is that they decolourize the colouring material of dye-based ink strokes, rendering them colourless.

Forensic scientists who investigate documents have observed that solvent, chemical, and detergent erasures produce a yellow bleeding effect or ink colour bleeding effect. This is because dye-based ink is soluble in these erasures and internal paper chemicals like cellulose and whiteners react with all of the aforementioned erasures to produce ink bleeding effects that are readily visible to the unaided eye and to ultraviolet light. From a preventive perspective, bank cheques in India have one really secure security element<sup>66-68</sup>. Therefore, it is argued that whereas pigment-based ink cannot be removed by any of the aforementioned erasure methods, dye-based ink can be removed by solvent-, chemical-, or liquid detergent-based erasure methods. It has been discovered that in mechanical erasures, scratches on paper's surface can be seen because the fibers on it have been harmed by the scratching and can be seen by keeping the document in question under a high-resolution microscope<sup>69</sup>.

### **3.2.1 The chemistry behind the erasing process for writing instruments**

Since paper is naturally porous and pencil lead made of graphite is composed entirely of graphite and not dye or colour, the soft rubber may remove it with ease. This method cannot be used to erase coloured pencil writing. Usually, the rubber erasers leave a smudge around the deleted region after assimilating some of the graphite and distributing the remaining material across the paper. Liquid writing inks consist of synthetic pigments or dyes, fast-drying agents, lubricants (such as ethylene glycol, castor oil, or linseed oil), resins, surface-active agents, stabilizers, adhesives, and other compounds. Colourful dyes and pigments can be natural or synthetic; when hard rubber is used to remove ink from paper, the paper fibers get disrupted and are readily distinguishable through microscopic and physical inspection<sup>70-71</sup>.

### **3.3 Types of erasable magic writing instruments and its ink composition**

The literature, review and published data suggest that the "Otto Tachen" (Hippocrates Chemicus) explained in 1666 that the development of ink was caused by an alkali found in the "galls" (anomalous, strange excrescences that grow on the branches, shoots, and leaves of plants and trees, especially oak trees). This alkali

neutralized the acidity of the vitriol and produced a black colouring material. He demonstrated how written contents disappeared when exposed to acid and reappeared when an alkali was added<sup>72</sup>.

The most recent advancements in the history of writing media are the invention of erasable ink and its development for use in writing instruments. The primary component used to make paper is wood pulp. The Earth's green cover is under risk because of the destruction of forests for the manufacture of paper. Writing instrument firms produced erasable inks and writing instruments as green technologies to preserve trees and the environment.

These innovations allowed paper to be reused for various purposes such as correction, secret writing, and magic drawing. Meanwhile, businesses have mostly brought three types of erasable inks into the writing tool market. These writing implements serve as both erasures and hidden writings, which are tabulated below as Table 3.

**Table 3.** Types of writing instruments, which can act as erasure and secret writings

Sr Nos	Types of writing instruments	Manufactures
i.	Thymolphthalein (blue) based erasable ink	KGB® ink pen and some Chinese brands
ii.	Thermal erasable ink	Luxor®, Papermate Eraser Mate®, Reynolds® Paper Mate Replay Max®, Hauser® Rite & Eraser and some Chinese brands
iii.	Double side felt tip erasable ink	Re-write®, G.M. Pens International Pvt. Ltd., Exclusive licensee of Reynolds®, India and some Chinese brands <sup>35</sup> .

### 3.3.1 Classification of erasable writing instruments

According to the survey and literature, there are currently three (3) different types of erasable writing instruments available on the market that can be used as an erasing to remove writing strokes:

**i. Thymolphthalein (blue) ink.** These pens use a unique acid-base indicator-based ink composed of thymolphthalein (blue)<sup>73</sup>. This type of ink has a tendency to vanish completely after a while when exposed to CO<sub>2</sub> in the atmosphere or in another way.

The majority of these erasable inks are water-based acid-base indicator inks that go from coloured to colourless strokes<sup>74</sup>. Terrorist groups utilize this kind of ink to transmit messages, plans, and classified texts. Due to the existence of fine security printing, which is in liquid-sensitive ink but invisible on white paper, such ink can be identified on bank cheques via UV analysis<sup>75</sup>. Such erasable and secret writings on plain white paper can be investigated using chemical fuming techniques and heating procedures to recover the erased writings<sup>76-79</sup>.

**ii. Thermal erasable ink.** There are pens on the market with a special kind of thermal ink that reacts quite strongly to heat or temperature. This kind of ink has a tendency to cause the writing on the questioned document to vanish and become invisible to the unaided eye when heat is applied to it<sup>82</sup>. The market and online retailers are selling these kinds of heat-sensitive erasable magic ink pens under the names Pilot Frixon®, produced by Luxor®, Papermate® Eraser Mate, Reynolds®, Paper Mate Replay Max®, Hauser®, Rite & Eraser®, and a few Chinese brands. Thermal inks come in two kinds. There are two types: irreversible and reversible. Irreversible ink types vanish irreversibly and cannot be recovered by cooling when heat sources close to 200°C are used<sup>81</sup>. Fraudsters utilize a different kind of ink called reversible thermal ink with the express purpose of deceiving people. These pens come with gel-based ink that uses ballpoint technology, which writes with very little pressure. One of these pens was released and came with a soft rubber cap that could be replaced. Friction causes the temperature to rise when this rubber is rubbed over the ink-filled lettering. When the temperature rises above 60 °C, the ink vanishes and it resurfaces when cooled to between 0°C and -10°C. This is because ink is less stable at higher temperatures than it is at lower ones. The materials known as thermochromic polymers, which can be further divided into numerous subcategories, are used to make reversible thermal inks.

One such category to start with would be "thermochromic polymers themselves." The liquid crystalline polymer with the helical superstructure is one example of this type. When the helical structure satisfies "Bragg's" criterion by reflecting incident light, <sup>82</sup> the helical structure changes in tandem with temperature changes, and concurrently, colour changes occur. The second component of potential thermochromic polymers is the "thermochromic polymer-additive interaction." Polymers doped with thermochromic additives<sup>83-84</sup> are among the other

types of thermochromic polymers. The method depends on the additional component's varying absorption level at different temperatures. Conjugated polymers, inorganic pigments, and Leuco dye-developer-solvent complexes are examples of such potential additives<sup>85</sup>. The only solvent system utilized in thermal erasable inks is Leuco dye developer. Encased in a polymer shield, the thermochromic pigment is a Leuco dye-developer-solvent system. A three-component formulation that involves the interaction of a colour former (Leuco dye), a developer, and a solvent-developer interaction causes colour change<sup>86</sup>. A spiro-lactone molecule could be the colour former. Such a combination turns from coloured to colourless when heated over the melting point of its constituent parts. It is considered that the phase separation incident plays a crucial role in this procedure. The developer and colour former dissolve in the solvent during the melting process<sup>87</sup>.

The environment becomes comparatively non-polar during the heating process, which causes the colour to change on the ring-closed colourless side. The developer and the colour former split out from the solution phase during the chilling process<sup>88</sup>. With the aid of particular UV ranges (312 nm and 365 nm spectrum) and a spotlight under the extremely advanced scientific instrument VSC-6000/HS, such ghost-writing or hidden writings can be identified. The refrigerator technique, often known as the cooling method, is used to extract the extant ghost-writing or hidden writings. As of right now, there is just one known way to use cooling to retrieve erasable writings and secret writing from thermal erasable ink pens, which is to do so below 0°C to -10°C<sup>89-90</sup>.

**iii. Double-sided felt-tip erasable ink.** Writing instruments on the market include Re-write®, G.M. Pens International PVT. Ltd., the exclusive licensee of Reynolds®, India, and a few Chinese brands. These companies offer a unique variety of writing instruments, including double-sided felt-tip pens with two distinct chambers in the barrel that each function as a stand-alone pen. One side of this pen features a thin felt tip for writing. A special ink that is used for writing is given to the sponge inside the barrel of the pen on this side. Pen with a thick felt tip in the shape of a cone on the opposite side.

This pen's thick felt tip is attached to a sponge that is housed inside the barrel on this side, along with a unique liquid chemical eraser. Writing created using

this pen's thin felt tip is erased and disappears when the thick felt tip is placed; no marks or traces are visible to the unaided eye. With the aid of particular UV ranges (312 nm and 365 nm spectrum) and a spotlight under the very advanced scientific apparatus VSC-6000/HS, such ghost writings and secret writings are apparent<sup>91</sup>.

### 3.4 Identification of erasures and other magic erasable writings instruments

Identification of different types of erasures and magic erasable writing instruments are examined with VSC-6000/HS® and other documents instruments like Docucenter Nirvis®, Docubox Dragan-HD®, and Questioned Document Examination Analyzer® etc. with multiple functions and features are as Table 4.

**Table 4.** Functions of erasures.

Sr. No.	Erasures	Methodologies (Destructive and Non-destructive)	Description	Forensic implications
1.	Chemical and Detergent erasures	Lighting functions (UV, IR, spot light and visible light spectrums) in highly sophisticated scientific instruments (Non-destructive techniques)	The scientific instrument VSC-6000/HS and other incredibly complex scientific instruments and tools with various features of the spot light bulb and visible light spectrum are very beneficial for the investigation of chemical and detergent erasures. At the moment, they are progressively being used for document examination <sup>92-95</sup> .	This method facilitates the identification of modifications without compromising the original document, thereby maintaining its evidentiary integrity in legal processes. It enables the detection of chemical adulteration and assists in the restoration of the original composition.
2.	Chemical and detergent erasures	Chemical action (Destructive techniques)	Employing certain substances, such as hydrogen sulphide, sodium bicarbonate, ammonium sulphide, hydrogen sulphide cyanide, etc., to recover the tampering <sup>96</sup> .	This approach is efficacious for retrieving altered information, notwithstanding its damaging characteristics. Use it when non-destructive techniques fail. This method could potentially lead to partial destruction, which is why thorough documentation is

				crucial.
3.	Mechanical	Lighting functions in highly sophisticated scientific instruments (Non-destructive)	Examining physical characteristics such as length, width, and thickness of the document in questioned—all of which are checked on all sides and contrasted with the unaltered section—can help identify mechanical erasure <sup>97</sup> .	This instrument offers significant insights on physical disruptions, including surface abrasion. It can aid in detecting efforts to eliminate content and ascertaining if the document has experienced mechanical modification. This procedure guarantees the document's integrity.
4.	Erasable Writing instruments	Ultraviolet, Infra-Red rays (Non-destructive)	At varying UV light wavelengths, ghost, existing, and/or buried writings can be seen <sup>98</sup> .	UV/IR illumination exposes invisible inks or erased material, offering compelling visual proof of alteration. It is essential for detecting ghostwriting or altered text.
5.	Thymolphthalein (Blue) and Thermal erasable inks-based pens are available as ball point technology.	Electro Static Detection Apparatus (ESDA) manufactured by Foster + Freeman, UK. (Non-destructive)	The writing indentations created by the pressure imprints on paper and the friction of the ball point pens were created by the ESDA <sup>99-102</sup> .	Despite the removal of ink, ESDA uncovers concealed writing and pressure impressions. Such evidence is essential for revealing underlying content, confirming authorship, and authenticating document history.
6.	Thymolphthalein (blue)	Application of the chemical solvents and the source of the heating (Destructive)	By using several chemical reagents and a heat source, one can make these letters resurface and preserve the original writing's brushstrokes.	Utilized to reinstate obliterated text through chemical methods. This method allows for the retrieval of crucial evidence, but it also modifies the text. Due to its intrusive characteristics, people often view

				this approach as a last resort.
7.	Thermal erasable	Solvents and cooling (Destructive/Non-destructive)	Employing procedures such as chilling, cooling, and iodine fuming, you can retrieve the ghost strokes or concealed messages <sup>89</sup> .	It reveals phantom impressions from thermochromic inks. It can investigate the erasures. Significant forgeries or frauds utilize it.
8.	Double side felt tip erasable ink	Solvents (Destructive)	Utilizing methods such as heating and iodine fuming, recover the ghost strokes or concealed/hidden letters <sup>91</sup> .	This tool helps identify deleted or replaced content with high visibility. Such behavior frequently corroborates the concept of deliberate alteration. Nevertheless, it modifies the document's structure.
9.	Thymolphthalein (blue), Thermal erasable and Double side felt tip erasable ink	UV and IR Photography (Non-destructive)	The position of erasures and sometimes the original letters can be seen in photography when contrast film and transmitted light are used. The original texts are often visible when photographed under UV light. Infrared photography can be useful when printing on materials that were created using IR opaque inks <sup>73-79</sup> .	This technique facilitates photographic evidence of deletions and original texts. This technique provides unequivocal and admissible visual evidence of forgery or tampering for legal applications.
10.	All types of erasable writing instruments and erasures	Video Spectral Comparator/VSC @-6000/HS®, Docu-Box Dragan® and Docu-center NIRVIS® and Questioned Document Examination Analyzer® (Non-destructive)	The vanished erasable writing is discernible using the following tools: Questioned Document Examination Analyzer®, manufactured by Projectina®; Docu-Box Dragan-HD; UV, IR, fluorescence spot light, transmitted angular lights, and other multiple features to identify erasures in questioned documents; Foster+Freeman, London, UK; and Docu-Box Dragan-HD. These documents are frequently the subject of investigations by document scientists in forensic science labs <sup>73-89, 91-102</sup> .	A thorough examination employing sophisticated technologies improves precision in identifying different forms of erasures. Such accuracy is essential for the verification of documents in both forensic and legal contexts.

11.	Digital erasure processing	Image processing software	The presence of dots, irregularities in the word and letter spacing and sizes, differences in the pixel colors of the altered words and letters, and the presence of a unique set of dots encircling every letter or word that has been inserted <sup>103-106</sup> .	This technology identifies digital forgery and alterations in scanned or electronic documents. It is essential in cybercrime investigations, identity theft, and the authentication of digital documents.
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### 3.5 Other scientific instruments and techniques for erasable ink examinations

Forensic document scientists examine ink and toner formulations and typically use both destructive and non-destructive techniques to complete their investigations. According to surveys and literature, these scientists occasionally employ a variety of methods, including paper electrophoresis, luminescence, thin-layer chromatography, high-performance liquid chromatography, and diffuse reflectance. Dichroic filters, laser excitation and spectroscopy, capillary electrophoresis, Fourier transform infrared, micro spectrometry, luminescence photography, ALSs (Alternate Light Source Analysis), and apparatus to monitor the ink's response to infrared absorption, reflectance, and luminescence.

Several forensic document scientists have been looking into and testing different ways to look at and tell the difference between different types of ink. They use tools like Fourier transform infrared spectroscopy (FTIR), scanning electron microscope/X-ray fluorescence spectroscopy, surface-enhanced resonance, and Raman scattering spectroscopy with a microscope attachment. Table 5 includes a list of techniques.

**Table 5.** Instruments and techniques for investigation of erasable ink.

Sr No	Instruments and techniques	Description	Forensic implications
1.	Chromatography (Thin-layer chromatography, High-performance liquid chromatography)	These methods are analytical tests; ink and dye analysis can be done with planar chromatography. Chromatography methods are one approach that, at the very least, acts as a presumptive test for this. Such analytical procedures may be necessary to determine whether two	Distinguishes ink formulas; aids in identifying shared or distinct ink origins in disputed documents.

		ink formulations are the same or not <sup>107-109</sup> .	
2.	Micro spectrometry	To examine the pigments, dyes, and additives in inks and papers, a microspectrophotometer is utilized. This device examines the paper, pigments, dyes, and various security elements found in these kinds of papers. Microspectrophotometers have the benefit of being able to examine even the tiniest security and microprinting details. Such equipment is particularly helpful for investigating the interpolation of erasures, from forensic research to formulating ink and paper <sup>110-112</sup> .	Facilitates the examination of minute ink and paper characteristics; essential for identifying modifications and counterfeit entries.
3.	Luminescence photography	Reflected infrared photography is essentially nothing new and is analogous to colour filter photography. Just cover the optical lens with a filter of the desired colour, and the recording results will show only the wavelengths that the filter permits to pass through, causing tonal changes or relationships within the scene. To put it briefly, a red filter appears red because it only lets through red wavelengths. Similarly, this is the name given to an infrared filter that allows only infrared light to pass through while blocking all other light. As a result, it appears opaque. similar to how there are "complementary" filters for the infrared filters and an identical filter for the first red, green, and blue filters (Cyan, Magenta, and Yellow). The filter is frequently referred to as a "hot mirror" due to its ability to reflect back infrared photons; alternatively, it may be referred to as an infrared blocking or absorbing filter. Since it transmits light or wavelengths between 400 and 700 nm but blocks everything else, it would be referred to as a "light" filter. The eyes appear blue-green in colour <sup>112-114</sup> .	It improves the discernibility of concealed or modified writing and aids in uncovering erased or rewritten material.
4.	Laser excitation and spectroscopy and the surface-enhanced Raman spectrometry (SERS)	Commercially available ballpoint writing devices in the color's red, pink, purple, and green were subjected to dye mixture detection using Raman spectroscopy and	It accurately identifies ink constituents and is effective in associating or distinguishing writing devices, even

		<p>SERS. Every writing device ink was examined as colored patches on store-bought paper. Using laser excitation wavelengths at about 514, 532, and 785 nm made it possible to identify the primary dyes for all writing devices using Raman analysis. The main benefit of Raman spectroscopy is that it is non-invasive. Nevertheless, SERS was able to accomplish more accurate identification by applying Ag nano paste to colored paper. It was generally not necessary to use several illumination lines because enhanced Raman signals were obtained for each chosen illumination wavelength. The characterization of red, pink, and purple inks—whose Raman spectra were characterized by strong fluorescence backgrounds—were very successful with the application of SERS. The intrusive aspect of SERS, which is linked to the deposition of nano paste on the analytical surface, is its main disadvantage. This frequently makes it impossible to apply SERS directly to artwork. However, this work demonstrates that SERS can be a useful method for analyzing micro-extracted materials and other creative mediums, such as felt-tip and ballpoint writing utensils<sup>110, 115-116</sup>.</p>	with limited samples.
5.	Luminescence	<p>When stimulating radiation in the visible or near visible waveband is absorbed by chemical molecules, part of the energy is re-emitted at a longer wavelength, a phenomenon known as luminescence. Ultraviolet fluorescence is the term for a phenomenon when energy is emitted into the visible spectrum after an excitation occurs in the ultraviolet portion of the spectrum. Known as infrared luminescence, energy can be emitted in the far-red and infrared areas if the stimulating radiations are in the visible spectrum. Since there is experimental proof that these phenomena involve both fluorescence and phosphorescent</p>	Identifies ink discrepancies and concealed entries; essential for analyzing obliterations and interpolations.

		<p>qualities, the term "infrared luminescence" has been employed. Initially, this novel method was successfully used to examine a variety of questioned document difficulties utilizing blue-green glass and gelatin filters. However, it has been discovered that a 5–10% copper sulphate (CuSO<sub>4</sub>) solution functions as a superior filter. Ellen, Creer, and Shaneyfelt have recently employed this solution to analyze the infrared luminescence of ink inscriptions. Because the resulting brightness can be directly photographed and captured on an infrared film, the procedure is essentially straightforward. In actuality, there might not be a difference visible with the infrared viewer (image converter), infrared photography, or both; but, infrared luminescence might be able to pick up on a slight variation in inks. The procedure should be regularly used, especially in cases when other approaches have not produced desired outcomes. As a result, it has significantly increased the likelihood of interpreting interpolations and obliterations, including erasures<sup>117-121</sup>.</p>	
6.	Thermofax Examination	<p>Thermofax technique is a straightforward and distinct method of replicating documents. It uses powerful filament light sources in conjunction with heat-sensitive emulsion-coated paper. Only the carbon or metallic components of the writing block light radiation. As a result, the reproduction is limited to writings that are created using carbon-based inks or that contain iron and other metallic salts. In replication, ballpoint inks and other dye-based inks are not used. Although it might not be appropriate in every situation, this straightforward method proved helpful in routine reviews of documents pertaining to interpolation and erasures<sup>1-12, 71-72, 122</sup>.</p>	Discloses carbon-based inks and aids in identifying erasures or modifications to specific document types.
7.	ALS (Alternate Light Source Analysis)	At the scene of the crime, alternate light sources (ALS) are employed to	Distinguishes inks according to their

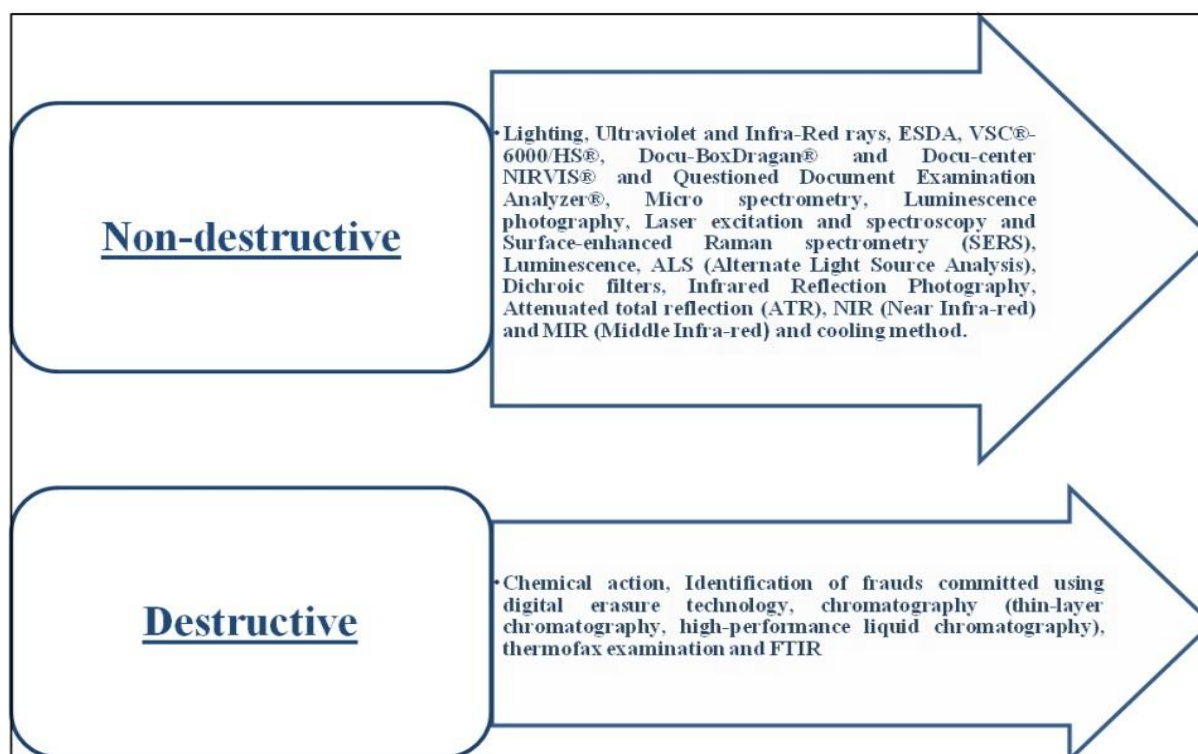
		search for and locate various types of evidence. Using a UV light source with different frequencies, you can tell the difference between thermal erasable ink, thymolphthalein-based (blue) ink, and double-sided felt tip erasable ink <sup>123</sup> .	luminous properties; beneficial for detecting erasable inks at crime scenes.
8.	Dichroic filters	Dichroic filters essentially transmit an excessive amount of the red portion of the color spectrum together with a relatively modest quantity of the blue-green region. They are made of a mixture of glass and gelatine filters <sup>124</sup> . Ink handwriting can display a red or purple image when exposed to red-rich light and viewed via certain dichroic filters, all while leaving the background completely unaltered. When huge volumes of red radiation are reflected from ink letters that do undergo this alteration, they seem subdued to the unaided sight along with their original hue. Through a dichroic filter, red light is primarily transmitted, while a significant quantity of light in the blue-green area is muted. This easy method could be helpfully used for an initial assessment. Godown, Packard and Dick <sup>125</sup> , have researched and suggested a number of well-applied combinations, including blue-green or green and yellow-orange filters. Even though it's a basic procedure, there are some practical restrictions. For example, each type of ink will require a wide range of dichroic filters, and individual visual reactions may vary as well. The resulting technique frequently proves useful in detecting fakes.	Facilitates the preliminary identification of ink modifications or additions without compromising the integrity of the document.
9.	Infrared Reflection Photography	The colour of the material in visible light has no bearing on the absorption or reflection of infrared energy. Certain writing instruments, such as ballpoint or fluid, are transparent to infrared radiation because they reflect all forms of infrared light. On the other hand, different ballpoint and blue-black (iron-based) inks absorb and reflect these radiations to different degrees.	Reveal concealed or modified texts; be proficient in detecting counterfeit inscriptions utilizing various inks.

		When using an infrared-sensitive film for photography and a potent infrared radiation source for lighting, the final image is proportional to the amount of infrared radiation that the ink absorbs. When identifying forgeries, the resulting photographic evidence is frequently useful <sup>126</sup> .	
10.	Fourier transform infrared spectroscopy (FTIR)	Fourier-transform infrared (FT-IR) spectroscopy was a powerful analytical tool used in the investigation for figuring out the chemical "fingerprint" of different ink formulations. It has been demonstrated that the FTIR spectroscopy method can assess writing instrument inks with reasonable accuracy. With this special approach, writing tool ink samples are exposed to light in order to produce a particular FTIR spectrum. This FTIR spectrum serves as the ink samples' "molecular fingerprints," enabling direct visual comparison. Finding the ink's chemical composition and morphological structure can frequently be accomplished with the use of the resulting spectra <sup>127-128</sup> .	It offers a molecular signature of inks and is valuable for validating or dismissing typical ink origins.
11.	Attenuated total reflection (ATR)	When paired with contemporary attenuated total reflectance accessories, sample processing has become incredibly simple and fast while still yielding accurate findings. It is very desirable to have the evidence or samples preserved when employing a non-destructive approach like FT-IR-attenuated total reflectance (ATR) for document analysis and many other applications. With the use of this procedure, a novel and non-destructive approach to the systematic investigation of ink on a disputed document will be possible. Micro-ATR-FTIR spectroscopy was used to study ink samples in situ on the paper substrate. A variety of multivariate chemometrics were used to interpret and assess the data that was collected. Cluster examination (CA) and principal component examination	Non-invasive ink analysis is essential for the in situ assessment of documents without the need for sampling.

		(PCA) were both used to process absorbance values from wavenumbers ranging from 2000 to 675 cm <sup>-1</sup> in order to create a collection of new variables. The variable set was then applied to identification, differentiation, and classification. In summary, it was determined that this technique for removing and generating a new variable set from the infrared spectrum would work well for systematically analyzing inks using their infrared spectra <sup>129-131</sup> .	
12.	NIR (Near Infra-red) and MIR (Middle Infra-red)	Near-infrared spectroscopy (NIRs) and middle infrared spectroscopy (MIR) along with chemometrics were looked at for the first time to see how useful they are as a new way to look at black toners, stamp inks, typewriter inks, and writing instrument inks in forensically questioned document cases. These techniques involved comparing and maintaining spectra from several toner producers to identify distinct types of toners. A multivariate statistical analysis model of toner comparison in the questioned papers was tested using principal component analysis (PCA). The results demonstrated that the NIR/Chemometrics technique could accurately identify toners even when printed on different types of paper and was unaffected by the printing process. These methods demonstrate that NIRs and MIRs are practical, quick, and non-destructive instruments for characterizing toners and compositions of writing instrument ink <sup>132</sup> .	Identify toner and ink types and suppliers; facilitate comparisons across various paper types. This technology recognizes toner and ink types and suppliers, enabling comparisons among different paper types.

### 3.6 Methodologies (destructive and non-destructive) of erasures

Under natural light, the questioned documents are examined from various perspectives. Spotlights, UV light, transmitted light, and grazing light are helpful in identifying the original erased writing.



**Figure 1.** Destructive and Non-destructive Erasures.

In most cases, erased documents reveal ghost images of the original writing. Variations in fluorescence are commonly used to identify chemical erasures and erasable writing inks. Ultraviolet (UV) examination is one of the most widely applied techniques in the analysis of security and important documents, allowing the detection of solvent-based erasures and interpolations.

Secret writings that may have been thermally erased can be restored within temperature ranges between 4°C and -10°C. Additionally, heating the material or applying fuming techniques can reveal inks such as thymolphthalein (blue ink). In such cases, the erased writing reacts with alcohol vapors, enabling the latent content to reappear. Another important method for producing erasable writing involves organic reagents such as tannic acid, which react with iron to form colored compounds.

Infrared (IR) radiation cannot penetrate carbon-based inks or certain permanent inks. However, it can assist in reconstructing original writings and identifying the locations of erasures. Erasures made using some double-sided felt-tip pens can be detected under UV light within a wavelength range of 312–365 nm, particularly when examined using specialized equipment such as the VSC-6000/HS.

Forensic document examiners rely on instruments like VSC-6000/HS, as well as other advanced systems such as Docu-Box Dragan® and Docu-Center Nirvis®, to analyze these types of inks<sup>133-135</sup>.

These erasable or “magic” inks are commercially available due to technological advancements in writing instruments. However, in the 21st century, the rapid expansion of computer use, along with associated software applications, has led to a significant increase in digital document fraud, particularly in white-collar crimes.

Many software applications, including Windows® Paint®, incorporate erasure tools that allow users to modify or remove content from digital documents and images. In such fraudulent practices, a genuine document is first converted into a digital format through scanning or photography. The resulting file (soft copy) is then edited using image manipulation software to remove or alter specific information. After modification, the document can be reprinted, giving the appearance of authenticity.

These types of alterations are particularly concerning when digital images are used as a legal evidence or when scanned financial documents are processed by banking institutions. Documents such as wills, deeds, certificates, and financial instruments (e.g., cheques, demand drafts, and deposit receipts) are often produced using various printing technologies and subsequently altered using digital tools, with the intent to deceive.

Detection of digitally manipulated documents relies on several indicators, including the presence of unique dot patterns around inserted text, surface disturbances, irregularities in pixel distribution, inconsistencies in word or letter size and spacing, and color variations in modified regions. Advanced image processing software is capable of identifying these anomalies, supporting forensic analysis of altered documents.

### **3.7 Identified deficiencies in forensic analysis of erasures and erasable inks**

Even with improvements in forensic document inspection methods, there are still major problems, especially when it comes to finding erasures and studying erasable inks in fake documents. These constraints significantly affect the reliability, accessibility, and reproducibility of forensic findings in legal and investigative

situations. The subsequent critical research deficiencies necessitate systematic focus:

### **3.7.1 Necessity for economical, accessible detection methods**

Modern forensic tools like the VSC-6000/HS®, Docu-Box Dragan®, and Electrostatic Detection Apparatus (ESDA) work well but are very expensive, making them mostly available to wealthy forensic labs. This engenders a discrepancy in investigative capabilities between resource-abundant and resource-constrained institutions.

Future Direction: Development of economical, portable detection devices utilizing streamlined UV/IR lighting arrays, smartphone imaging, and open-source image processing techniques. Introduction of chemical field kits intended for the preliminary assessment of document tampering, specifically for application in developing regions or remote crime scenes.

### **3.7.2 Absence of Inter-Laboratory Validation and Standardization**

Not having standard testing methods and studies comparing different labs results in inconsistent detection outcomes, especially with complex or new erasable inks. This diversity diminishes the evidential robustness of forensic reports submitted in court.

Future Direction: Conducting joint studies between different labs to test erasable, thermal, and magic inks using different detection methods (like UV/IR, iodine fuming, and ESDA). Implementation of standardized forensic techniques, encompassing calibration benchmarks and repeatability standards for ink erasure analysis. The team also established a consolidated reference database that documents the types of erasable ink, their chemical compositions, spectral responses, and recovery profiles.

### **3.7.3 Inadequate scientific characterization of novel erasable inks**

Innovative ink technologies—such as thermal erasable, double-sided felt tip, and chemically reactive inks—pose a distinct challenge. Numerous inks display characteristics that elude identification by standard non-destructive methods and are inadequately documented in forensic literature.

Future Direction: Systematic chemical, physical, and spectrographic analyses of commercially available erasable inks. The research will focus on examining the characteristics of ink deterioration, its resilience to environmental

conditions, and its interactions with various solvents and light sources. Investigation of recovery strategies for ghost strokes, especially under fluctuating temperature and chemical environments.

#### **3.7.4 Restricted incorporation of digital forensics in erasure analysis**

The rise in document forgeries, which have both digital changes and human edits, requires combining digital forensic methods with traditional checking techniques.

Future Direction: Creating systems that combine UV/IR spectral analysis with machine learning to detect different types of images. This includes making training datasets and AI models that can spot small differences and unusual changes in text in scanned or digitally printed documents. Creation of training datasets and AI models proficient at detecting pixel-level discrepancies and anomalous text alteration patterns in scanned or digitally printed documents.

The forensic science community must prioritize the establishment of standardized, accessible, and scientifically verified methods for detecting erasures and erasable inks. Addressing these research deficiencies will markedly improve the precision, dependability, and fairness of document assessment methods globally. Working together on research, teaming up across different fields, and having helpful policies are crucial for closing these gaps and achieving strong forensic results in both traditional and digital settings.

### **3.8 Precautions**

It is believed that the most susceptible organizations for scams involving erasable ink pens are banks. Customers of banks have a responsibility to participate with the banking system while also exercising caution. The authors advise bank clients and banks to take the following safety measures in order to ascertain the frequency of these kinds of frauds:

1. It could be suggested to customers that they write and sign the bank instrument and other important documents using a pen of their own.
2. Manufacturers could create useful and practical illumination devices for bank workers.

#### 4. Final remarks

This review article highlights the need to alert financial institutions such as banks and insurance companies, as well as law enforcement agencies, vigilance and surveillance departments, and forensic scientists, about fraudulent techniques used to erase original writings and alter document values.

A wide range of non-destructive scientific instruments is employed in forensic document examinations. These include lighting techniques, ultraviolet (UV) and infrared (IR) radiation, ESDA®, VSC®-6000/HS®, Docu-Box Dragan®, Docu-Center NIRVIS®, Questioned Document Examination Analyzer®, luminescence photography, laser excitation and spectroscopy, surface-enhanced Raman spectrometry (SERS), alternate light source analysis (ALS), dichroic filters, infrared reflection photography, attenuated total reflection (ATR), near-infrared (NIR), and mid-infrared (MIR) techniques.

In addition, specific analytical tools are used to identify interpolations and to characterize the morphological structure and chemical composition of inks, toners, and paper. These include chemical reagents, digital erasure detection techniques, chromatography methods such as thin-layer chromatography (TLC) and high-performance liquid chromatography (HPLC), thermofax examination, and Fourier-transform infrared spectroscopy (FTIR).

Highly advanced instruments such as ESDA®, VSC-6000/HS®, Docu-Center NIRVIS®, and Docu-Box Dragan-HD®, along with selected UV wavelength ranges, are particularly effective for detecting ghost strokes and concealed handwriting. However, the identification process varies because manufacturers frequently modify ink formulations to maintain proprietary advantages.

Most erasable writings can be revealed using chemical fumes, heating, or different light sources. Notably, thermal erasable inks may also reveal ghost strokes when exposed to cooling temperatures between 0 °C and -10 °C. In contrast, erased writing produced using thymolphthalein blue-based ink on white printer or ruled paper is particularly difficult to detect under UV light.

However, when using fluorescence spotlights within a UV range of 312–365 nm, ghost strokes can be observed on documents such as bank cheques or demand drafts containing thymolphthalein-based inks. In some cases, ESDA®, angular lighting in VSC®, or other indentation-revealing techniques are required to detect underlying impressions.

Among available methods, VSC systems equipped with UV and fluorescence enhancement capabilities are particularly effective for detecting erased handwriting produced by thermal erasable inks and double-sided felt-tip pens. These tools provide forensic document examiners with advanced capabilities that may surpass conventional techniques.

This review underscores the critical need for standardized forensic procedures, improved access to advanced analytical tools, and interdisciplinary collaboration to enhance the detection and interpretation of document tampering. Furthermore, training and capacity building in forensic institutions, law enforcement agencies, and financial sectors are essential to mitigate the impact of such fraud.

Future research should focus on the characterization of different erasable inks, the development of detection methods applicable to real-world scenarios, and the validation of forensic techniques to ensure reliability and admissibility in court. Strengthening the understanding of erasure-based document fraud and institutional responses will ultimately help preserve the integrity of written documents and support the administration of justice.

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