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Spectroscopic and Chromaticity Examination of Disappearing Ink

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Abstract:

The increasing prevalence of disappearing ink pens in forgery cases has posed significant challenges to forensic document examiners. This study investigates disappearing ink's spectroscopic and chromaticity characteristics to establish a reliable method for determining the relative age of writing. Using a Video Spectral Comparator (VSC-6000/hs), the absorbance, reflectance, and fluorescence spectra of disappearing ink were analyzed over time. Chromaticity values were evaluated within the CIE L*a*b* color space to quantify changes in the ink's optical properties as it faded. Results demonstrate that the L* value, representing luminance, showed a strong correlation with time in absorbance and reflectance spectra (R^2 = 0.82 and 0.81, respectively). Statistical analysis confirmed the linearity of L* values, making it a significant indicator for estimating the time elapsed since writing. The study concludes that absorbance and reflectance measurements are more effective than fluorescence for analyzing disappearing ink. This research provides forensic experts with a sensitive, non-destructive, and reproducible method to analyze disappearing inks and estimate the relative time of writing, offering a valuable tool for addressing forgery-related challenges.

Keywords: Disappearing ink, forensic document examination, spectroscopic analysis, chromaticity values, CIE Lab* color space, Video Spectral Comparator

1. INTRODUCTION:

Last decade commercial market was flooded with many innovative ink technologies like erasable inks, magic pens, and even inkless pens. [1] [2] [3] [4]. Many of the time forgers and fraudsters use these types of pens to commit forgeries for wrongful gains. [5] [6]. In this category magic pens are the most potential threats and challenges before questioned document examiners as the writing content becomes invisible after a short period. Many early researchers have reported different means by which the hidden content can be made visible. [7] [8] [9]. Here in this study, a systematic examination of magic pen ink is carried out and an attempt is made to establish the relation between chromaticity value and spectroscopic findings concerning time.

1.1. Chromaticity measurements in Tristimulus colorimeter

From time to time various systems have been developed to express the perception of the color of the human eye in numbers. To measure the color of ink/ toner from the surface colorimetry technique is used which comes under the category of destructive techniques because it sample is

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removed from the surface. Chromaticity coordinated provides a mathematical formulation of color, determined from the spectral graph in a Video Spectral Comparator. From time to time different color measurement systems are reported like XYZ, xy, uv, CYMK, RGB, and L*a*b* by CIE (Commission International de l'Eclairage).

CIE L*a*b* is considered one of the best systems for the mathematical formulation of color perception when compared to the human eye. Therefore, its application in forensic science [10] Is widely increased from the aspects of aging by studying the age in color. The study has been reported on the application of CIE L*a*b* for document examination to determine the age of inkjet and laser-printed documents. In the present study, to determine the chromaticity values of the disappearing ink color system of CIE it was proposed in 1976. Sometimes this is also called L*a*b* or CIELAB color space. From the absorbance, Reflectance, and Fluorescence spectra in the Video spectral comparator chromaticity measurements were obtained. The obtained chromaticity values are subjected to statistical evaluation and implemented to determine changes in L*a*b* values for evaluating the changes in the disappearing ink concerning time and to establish the chronological changes to obtain the time elapsed after writing with the disappearing ink on the paper surface. It's a non-destructive phenomenon to determine the relative age of writing by disappearing ink pen. In the CIE L*a*b* system, L* denotes relative Luminescence, and the values of L* range from 0 to 100. Where value 0 denotes/represents total black and value 100 denotes/represents total white. Hence L* represents a range from total Black to total white. The* denotes color quality in red to green channel/ coordination. Where -a* values denote/represents color quality as green and +a* denotes/ represents color as red. And, The b* denotes color quality in blue to yellow channel/ coordination. Where -b* values denote/represents color quality as blue and +b* denotes/ represents color as yellow [11]. The main objectives of the present study are to find the applicability of chromaticity values for the examination of disappearing ink and to determine, which is most prominently applicable for revealing disappeared ink out of absorption, reflectance, and fluorescence spectra.

2 METHODOLOGY
2.1 Sample preparation:
The samples are prepared on A4 size 80gsm copy power paper. The disappearing ink pen (magic pen) is purchased from the local market in Ahmedabad, India. While preparing samples, precaution is taken that there should not be a time gap between writing on paper and analysis. The entire examination is conducted in a time-bound process without

changing the ambient condition of the vicinity. This minimizes the atmospheric effect on the fading of ink. The entire examination is carried out with the help of VSC-6000/hs by Foster & Freeman UK. VSC is an instrument fitted with various light sources with different bandpass filters, hyperspectral analysis through microspectrophotometer, in spectroscopic analysis by microphotometer, reflectance and fluorescence of a selected in ink line is measured in a form graphical representation whereas chromaticity values l, a, and b were measured under the influence of different illuminator.

2.2 By using a spectrophotometer
In VSC-6000/hs the sample was placed under visible light (flood light), and- a photometer was used to measure absorbance, reflectance, and Fluorescence of the disappearing ink at different time intervals, to measure the absorbance, and reflectance, thus the sample was placed under visible light (flood light). Magnification was adjusted accordingly, and a white balance reference was obtained by placing the blank paper under the cross-section for analysis. After the white reference is obtained, the sample is placed under a cross-section of a microspectro photometer to measure absorbance and subsequently reflectance of the ink. The entire process is replicated with the interval of 20 minutes, till the entire sample/ink disappears from the paper surface. The aforementioned whole process gets completed in 140 minutes along with absorbance and reflectance, out of different chromaticity values L*, a*, and b* color space is considered for examination as it is the latest method given in CIE.

2.2.1 Fluorescence spectra
To obtain fluorescence spectra, the sample was placed under spot fluorescence in a video spectral comparator. Again, the magnification was adjusted accordingly. Black reference was recorded and the sample was placed under cross section to obtain Fluorescence spectra.
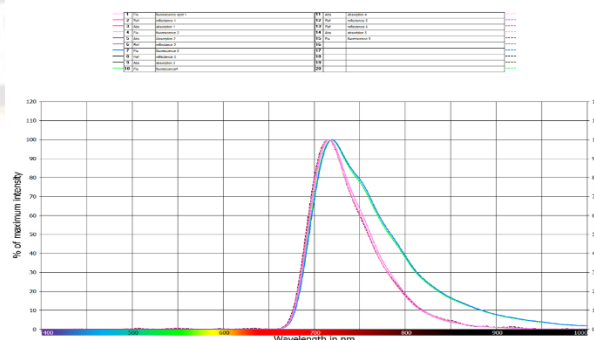
2.3. Result and Discussion

Figure 1Showing the fluorescence at a different wavelength

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The prominent Fluorescence peak was obtained at 720 nm, and the percentage of maximum intensity remained the same during this entire period that is from the execution of the stroke till the ink disappears and the stroke becomes invisible. As intensity does not change the Fluorescence light can be the best parameter to reveal the disappeared ink content and make it legible. The graph obtained illustrates the constant decrease in the percentage of maximum intensity concerning increasing time intervals up to 60 minutes. After 60 minutes, the ink starts to disappear prominently. The graph obtained after 20 minutes shows variations concerning the previous one indicating significant change in the chemical structure of the ink.

2.4 Reflectance spectra

The Reflectance spectra obtained illustrate the constant decrease in % of maximum intensity concerning time intervals up to 60 minutes. After 60 minutes, the ink starts to disappear prominently. The spectra obtained after 20 minutes show variations concerning the previous one indicating a significant change in the chemical structure of the ink.

Figure 2 shows the absorbance at different intervals of time.

2.5 Absorbance Spectra

The absorbance spectra obtained illustrate the constant decrease in % of maximum intensity concerning time intervals up to 60 minutes. After 60 minutes, the ink starts to disappear prominently. The spectra obtained after 20 minutes show variations concerning the previous one indicating a significant change in the chemical structure of the ink.
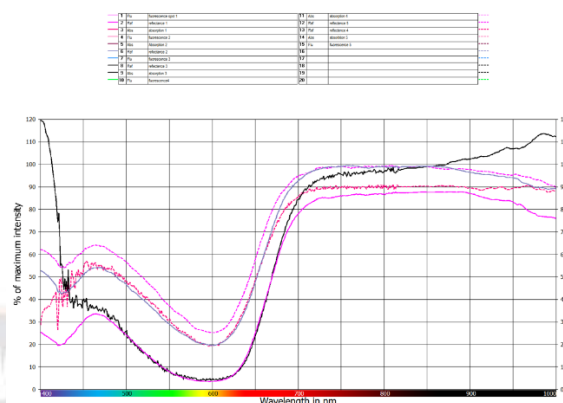
2.6 Chromaticity Values

On spectral analysis of ink i.e. absorbance, reflectance, and fluorescence, the different chromaticity values were also measured according to CIE color space. The results obtained are as follows-

Time	Test	X	Y	Z	x	y	u	v	L*	a*	b*
1min	Abs	0.114	0.108	0.275	0.229	0.218	0.177	0.253	39.3	3.9	-34.7
20min	Abs	0.309	0.313	0.501	0.275	0.279	0.19	0.289	62.7	-1.5	-23.1
40min	Abs	0.12	0.102	0.319	0.222	0.188	0.184	0.235	38.2	13.1	-43.2
60min	Abs	0.291	0.269	0.62	0.247	0.228	0.188	0.261	58.9	8.4	-41.4
80min	Abs	0.368	0.373	0.58	0.278	0.283	0.191	0.291	67.5	-1.9	-22.8
100min	Abs	0.645	0.662	0.742	0.315	0.323	0.201	0.31	85.1	-3.8	-6.7

Table 1, Shows chromaticity values of disappearing ink in absorbance spectra

Time	Test	X	Y	Z	x	y	u	v	L*	a*	b*
1min	Flu	0.003	0.002	0	0.593	0.36	0.386	0.352	1.6	4.3	2.3
20min	Flu	0.003	0.002	0	0.63	0.34	0.434	0.35	1.5	5.5	2.3
40min	Flu	0.003	0.002	0	0.619	0.367	0.402	0.357	1.5	4.4	2.5
60min	Flu	0.002	0.001	0	0.627	0.302	0.466	0.338	1.1	5	1.4
80min	Flu	0.004	0.003	0	0.543	0.4	0.324	0.357	2.9	4.4	4.3
100min	Flu	0.004	0.002	0.001	0.567	0.3	0.415	0.33	2	7.8	2

Table 2, Showing chromaticity values of disappearing ink in fluorescence spectra

Time	Test	X	Y	Z	x	y	u	v	L*	a*	b*
1min	Ref	0.112	0.106	0.274	0.227	0.215	0.177	0.252	38.9	4.3	-35.3

17

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20min	Ref	0.301	0.304	0.487	0.276	0.279	0.19	0.289	62	-1.3	-22.8
40min	Ref	0.141	0.11	0.41	0.214	0.166	0.187	0.218	39.5	21	-52.8
60min	Ref	0.376	0.383	0.591	0.279	0.283	0.191	0.291	68.2	-2.1	-22.7
80min	Ref	0.306	0.315	0.495	0.274	0.282	0.188	0.29	62.9	-3.1	-22.1
100min	Ref	0.645	0.661	0.746	0.314	0.322	0.201	0.31	85	-3.6	-7.1

Table 3, Showing chromaticity values of disappearing ink in reflectance spectra

Statistical analysis of chromaticity values obtained as shown in Table 4, illustrates the correlation coefficient of L*, a*, and b* concerning time interval. The R^2 values were obtained from regression analysis of obtained data. From the statistical analysis, it is evident that the correlation coefficient of value L* concerning time in absorbance as well as in reflectance is the best (0.82). Change in L* value with time shows linearity as compared to values of a* and b*. Values of a* and b* are not that significant and less beneficial in estimating the relative time of writing in disappearable ink.

Table 4 Statistical analysis of chromaticity values.

Chromaticity values	L*		a*		b*		ΔE
	Correlation coefficient	R^2	Correlation coefficient	R^2	Correlation coefficient	R^2	
Absorbance	0.82	0.67	-0.40	0.16	0.62	0.39	54.23
Reflectance	0.81	0.62	-0.39	0.15	0.62	0.41	54.61
Fluorescence	0.46	0.21	0.68	0.47	0.11	0.013	3.53

To determine the time passed the writing till the examination carried out can be best governed by the L* chromaticity values. The total energy change at time 1 minute to that of time 120 minutes

he i.e. E= foula $\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$

The ΔE, for absorbance, reflectance, and fluorescence are 54.23, 54.16 & 3.53 respectively. ΔE is best shown in absorbance in reflectance and absorbance.

3 Conclusion:

Disappearing ink pen, forming the widely used tool in forgeries reported in recent times is becoming terrible for many law agencies and financial institutions. It also creates challenges for forensic document examiners for retrieving the written content. Though many earlier researchers had reported numerous methods for the same. But one question that is asked by many law agencies is when it was written i.e. relative age of writing or time of writing. As in document examination, destructive methods are more relied upon. The spectral analysis and chromaticity values serve the purpose of examination under VSC's most potent instrument in questioned document division. The present study clearly illustrates that the chromaticity values obtained from L* have a significant role in estimating the relative age of writing. In spectroscopic analysis, the absorbance and reflectance give more steadfast results compared to fluorescence. The developed method will help question document examiner to detect, analyze, and calculate the relative time of writing. It opens new doors in the forensic examination of disappearing inks by simple, sensitive, and trustworthy methods.

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