Characterisation and Comparison of Thermal Papers of Various Sources Using X-Ray Diffraction Technique: A Forensic Aspect

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Abstract

Thermal papers play a crucial role in various industries, offering a unique combination of convenience and efficiency. Unlike traditional papers, thermal papers are specially coated to react to heat, producing text and images without the need for ink. In the realm of forensic science, recovery of any thermal papers receipt from suspect or victim whether legible or faded can emerge as a valuable tool by providing investigators with idea about where a person has travelled or visited. A non-destructive methodology based on X-ray diffraction technique (XRD) is proposed in this research for characterisation and discrimination of thermal papers obtained from different sources. Qualitative interpretation of the XRD data of thermal papers has been done to obtain high discriminating power analyzing diffraction peaks and determining the crystalline structure of the sample. Thermal paper samples used in study were bus tickets of different states and U.T's, retail centres bills, ATM slips etc. The diverse XRD patterns found in collected samples from various industries show how difference in thermal sheets with varying compositions and structures employed in different situations. The similarity in thermal samples of one entity points towards the industry standards for their individualisation. Due the variability, the thermal paper samples showed marked differences in their composition taken from different sources that is related to the quality of the paper. The study outcomes were quite encouraging or the forensic document experts in analysing and comparing the thermal papers samples using X-ray diffraction technique.

Keywords: Thermal paper, Forensic , Questioned Documents, X-RD, ATM slips, Bus tickets.

INTRODUCTION

In the realm of forensic science, the analysis of fingerprint and trace evidence stands as an indispensable cornerstone, offering crucial insights into criminal investigations. Fingerprint evidence, long revered as one of the most reliable forms of forensic identification, not only serves to establish the presence of an individual at a crime scene but also aids in linking suspects to specific criminal activities with unparalleled precision. Concurrently, trace evidence, encompassing a myriad of microscopic materials such as fibers, hair, and glass fragments, plays an equally pivotal role, often providing invaluable clues that can elucidate the circumstances surrounding a crime. Moreover, diatoms, microscopic algae ubiquitous in aquatic environments, have emerged as an intriguing frontier in forensic research. Their presence in various substrates, including thermal paper, holds the promise of offering unique signatures that can be leveraged for forensic analyses. As such, this paper delves into the intricate realm of thermal paper examination, shedding light on its significance in modern forensic investigations while exploring the nuanced interplay between fingerprint and trace evidence, alongside the burgeoning potential of diatom analysis [1-4]. Due to extensive usage and application, thermal papers have become a common piece of forensic evidence found either in the pocket or wallet of the victim/suspect and sometimes even on the crime scene. A thermal paper receipt can establish the connection of a site to which the suspect or victim has traveled or been to as they carry information like date, name of the person, place, etc.

Thermal printers have revolutionized the printing market due to their edge over other printing machines like being lightweight, inexpensive, providing fast output, and low noise working conditions [5-6]. The use of thermal papers has increased immensely in the last decade. Their application can largely be seen in enormous places including supermarkets, grocery stores, bills in restaurants, fuel stations, modes of public transport, fax, ATM transaction slips, and many more [7-8].

A thermal paper consists of a heat-sensitive color-forming layer with a combination of acid-sensitive leuco dye and a color developer along with other constituents like additives, co-reactants, fillers, etc. . are also added to the paper to aid the color developing process and to sustain its property. On the application of heat through a thermal printer head, the reactant components in the paper get activated. This in turn develops an image that is the same as the heating pattern generated by the thermal head [9-10].

Many successful studies reported to retrieve faded or artificially removed latent texts on thermal paper with the use of the iodine fuming method, VSC 6000/HS and an image enhancement software tool [5-6]. Relative age of thermal papers were attempt by FTIR spectroscopy and by measuring the grey values of printed strokes using Adobe Photoshop CS 8.1 software [5]. Characterization of inorganic constituents whilst the organic ingredients to differentiate thermal papers of different manufacturers using Attenuated Total Reflection Fourier Transform Infrared (ATR-FTIR) spectroscopy, Raman microscopy, and Scanning Electron Microscope coupled with Energy Dispersive Spectroscopy (SEM-EDS) were attempted that did not gave encouraging results [11].

The present study has been aimed to characterize, identify, and discriminate different samples of thermal paper obtained from various sources by exploring the use of X-Ray diffraction. This study offers higher discrimination ability and also encompasses the application of X-Ray diffraction technique in identification and comparison of thermal papers. Moreover, no study has been reported on the discrimination of thermal papers using X-Ray diffraction technique.

MATERIALS AND METHODS

Thermal papers samples for analyses and comparison by using X Ray techniques were collected from different sources (Table 1). A set of ten samples of thermal paper in similar original conditions were procured from each source. Each thermal papers belonging either to the same source of procurements or different were labelled.

Table no.1 showing samples of collected thermal papers for the study.

S.No.	Source of sample	No. Of samples	Sample number
1.	Chandigarh transport Union	4	1

2.	Haryana road ways	3	2
3.	D-mart	1	3
4.	ATM slip	2	4

XRD Conditions

The X-ray diffraction (XRD) experiment was conducted under specific measurement conditions to analyse the crystal structure of materials in the different thermal papers. The X-ray generator operated at 40 kV with a current of 15 mA, providing the incident X-ray beam for the analysis. The experiment followed a 1D scan mode with a scan speed of 10.00 °/min. A MiniFlex 300/600 goniometer with a standard sample stage and a step width of 0.01 ° was employed, and the scan-axis was set to θ/2θ geometry. No specific filter was utilised during the experiment, and the scan range covered 3 to 90 °. Divergence slit (DS) was set at 1.25°, and the incident beam horizontal slit (IHS) had a width of 10 mm. The detector used was a D/teX Ultra2 SS (Solid State), and no specific optics attribute was specified. The receiving slit (RS) was open. These measurement conditions, including the X-ray generator settings, scan parameters, goniometer details, and slit specifications, collectively defined the experimental setup, influencing the quality and precision of the XRD analysis results.

RESULTS AND DISCUSSION

The study aimed to analyze the XRD patterns of thermal paper samples collected from different sources, including Chandigarh transport Union (CTU), Haryana Roadways, bank statements, and Dmart. The investigation sought to explore the potential variations in thermal paper composition across different business sectors. XRD analysis results for the samples were obtained with various parameters, including 2θ, d-spacing (Å), peak height (cps), full width at half maximum (FWHM, °), integrated intensity (Int. I., cps), intensity width (Int. W., °), asymmetry, and decay parameters (ηL/mL and ηH/mH). To determine whether the samples are different or the same, we need to compare their XRD patterns.

Sample 1, represents CTU, exhibited peaks at 7.016°, 7.601°, 10°, 15.85°, and others. Notably, all CTU Samples shared common peaks, suggesting a consistent XRD pattern among these CTU samples [Figure 1-2]. This consistency indicates uniformity in the thermal paper composition used by the Chandigarh transport Union. Sample 2, representing bank statements, demonstrated peaks at 16.57°, 23.25°, 76°, and 78°, which did not align with the patterns observed in either CTU or Haryana Roadways samples. All Sample 2 did not align with either CTU or Haryana Roadways patterns, indicating the use of thermal paper with unique characteristics, possibly specific to the financial sector [Figure 3]. Sample 3, representing Haryana Roadways, displayed distinct peaks differing from those in CTU samples, suggesting a unique XRD pattern for thermal paper used in Haryana roadways [Figure 4]. The peak at 23.25° (2θ) and 3.823Å (d-spacing) set it apart, indicating a specific composition of thermal paper used in Haryana roadways. The characteristic peaks at 27214 cps (peak height), 2.53° (FWHM), and 2.15° (Int. W.) contribute to the identification of this distinct pattern. Sample 4, associated with Dmart, displayed an XRD pattern that did not match any of the previously examined samples [Figure 5]. The peaks at 13.98° (2θ) and 6.329Å (d-spacing) are unique, suggesting a thermal paper composition distinct from both CTU and Haryana roadways samples. The peak characteristics, including 749 cps (peak height), 2.8° (FWHM), and 0.76° (Int. W.), contribute to the identification of this unique thermal paper composition.

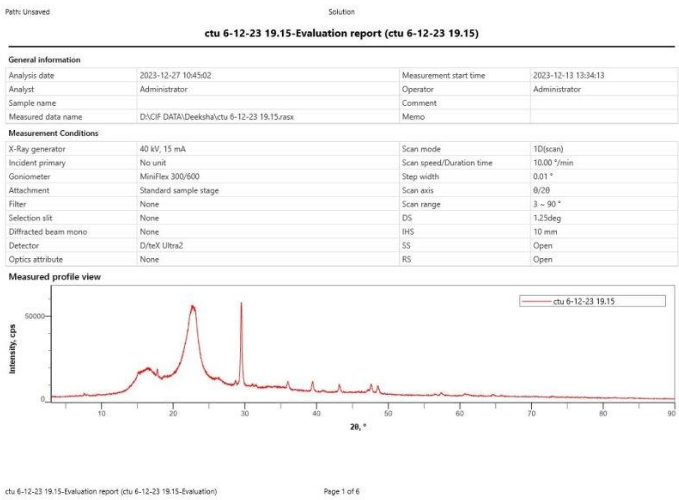
This emphasizes notable diversity in the thermal paper employed by the retail sector, possibly for receipt printing. The distinct XRD patterns observed among samples from different business sectors highlight the unique compositions and structures of thermal papers used in various contexts. The uniformity among CTU samples suggests standardized practices within this sector. Meanwhile, the variability observed in Haryana roadways, ATM slips, and Dmart samples emphasizes the importance of considering XRD analysis in document verification processes [Figure -4].

The characterization of inorganic constituents thermal paper samples has been attempted by using Attenuated Total Reflection Fourier Transform Infrared (ATR-FTIR) spectroscopy, Raman microscopy, and Scanning Electron Microscope coupled with Energy Dispersive Spectroscopy (SEM-EDS) [8].No work has been reported on analysis of thermal paper using X ray diffraction technique. The technique is completely non-destructive. A certain amount of the information obtained by XRD can also be obtained by elemental analysis. However XRD supplies information not obtainable by other methods.

CONCLUSION

The present study explores the methods for the forensic examination of thermal paper using X-ray diffraction. The methodology used is based on a non-destructive approach that retains the integrity of the thermal paper samples. The findings from the concluded that XRD analysis of thermal paper can potentially serve as a reliable method for verifying the authenticity of documents. The distinct patterns associated with different business sectors indicate that variations in thermal paper composition can be indicative of the document's source. This underscores the significance of employing advanced analytical techniques in examining thermal paper to ensure the accuracy and integrity of received documents, especially in sectors where document verification is critical, such as finance and transportation. The study can further be extended by adding the dimensions of assessing the effect of storing conditions such as sunlight, wallet, room light, and dark on the thermal paper. The study successfully demonstrates the potential of X ray diffraction technique to characterize, identify, discriminate, and decipher different samples of thermal papers in forensic casework. The findings are expected to impact a wide community of forensic scientists and active researchers for the examination of thermal paper as evidence.

Figure & legends


Path: Unsaved Solution

ctu 6-12-23 19.15-Evaluation report (ctu 6-12-23 19.15)

General information

Analysis date	2023-12-27 10:45:02	Measurement start time	2023-12-13 13:34:13
Analyst	Administrator	Operator	Administrator
Sample name		Comment	
Measured data name	D:\CIF DATA\Deeksha\ctu 6-12-23 19.15.rasx	Memo	

Measurement Conditions

X-Ray generator	40 kV, 15 mA	Scan mode	1D(scan)
Incident primary	No unit	Scan speed/Duration time	10.00 °/min
Goniometer	MiniFlex 300/600	Step width	0.01 °
Attachment	Standard sample stage	Scan axis	θ/2θ
Filter	None	Scan range	3 ~ 90 °
Selection slit	None	DS	1.25deg
Diffracted beam mono	None	IHS	10 mm
Detector	D/teX Ultra2	SS	Open
Optics attribute	None	RS	Open

Measured profile view

ctu 6-12-23 19.15-Evaluation report (ctu 6-12-23 19.15-Evaluation) Page 1 of 6

Figure no.1: showing X Ray diffraction analysis of CTU ticket.

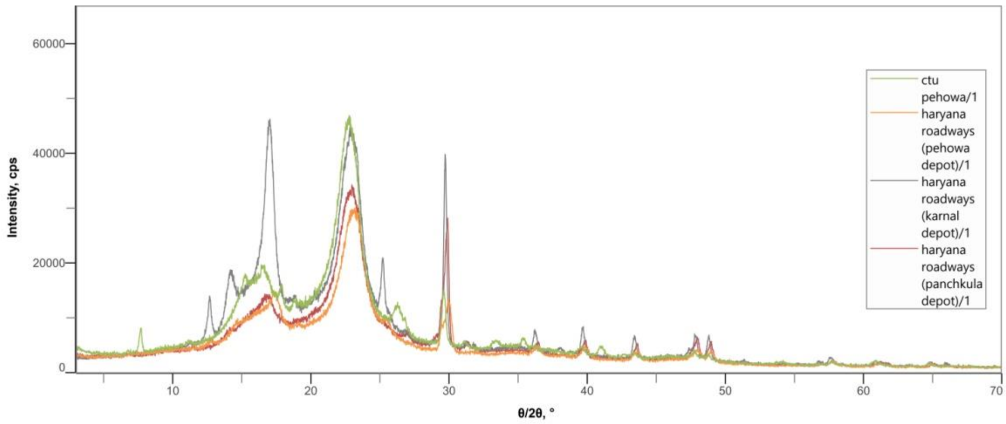


Figure no. 2: showing X Ray diffraction analysis of all samples of CTU.

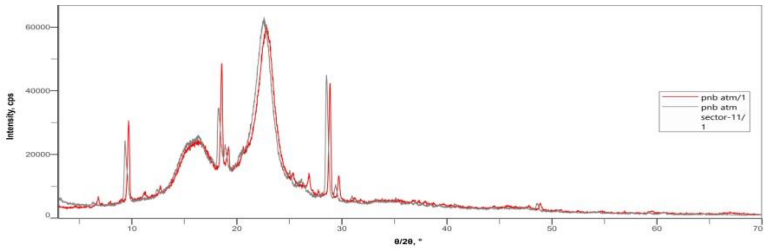


Figure no. 3: showing X Ray diffraction analysis of ATM slips with CTU and haryana roadways tickets.

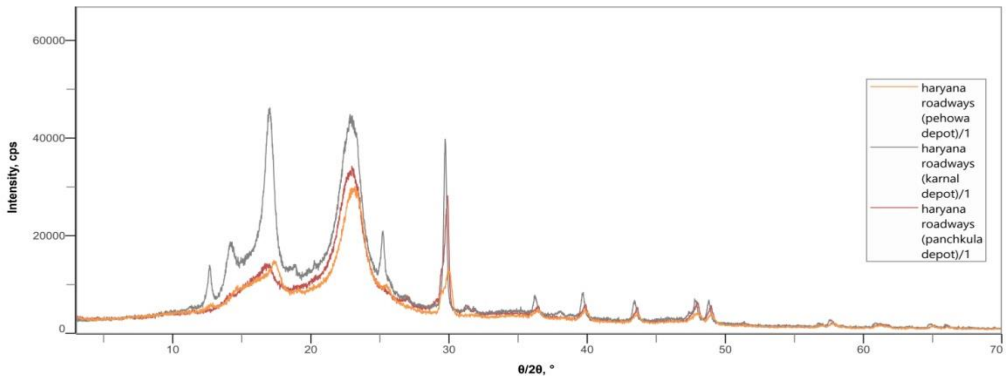


Figure no. 4: showing X Ray diffraction analysis of all samples of Haryana roadways ticket.

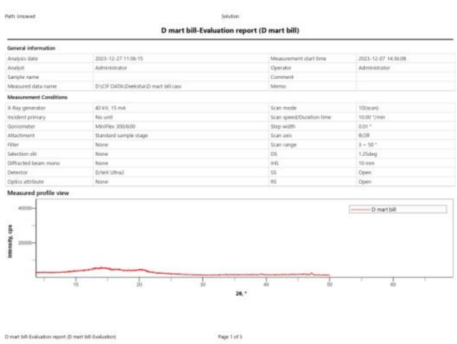


Figure no. 5: showing combined X Ray diffraction analysis of D mart samples with bus tickets.

REFERENCE

1. Singh GK, Kaur R. Forensic examination of vermilion (Sindoor) sample using ATR-FTIR spectroscopy. Materials Today: Proceedings. 2022 Jan 1;68:664-8.
2. Singh GK, Kaur R, Singh C, Singh P. Elemental analysis and characterization of vermilion and lipstick sample using SEM-EDS. Materials Today: Proceedings. 2023 Jan 3.
3. Kaur R, Sharma RK, Goswami M, Verma P. Study demonstrating pattern of suicidal poisoning deaths in Shaheed Bhagat Singh Nagar (Nawanshahar) of Punjab. International Journal of Medical Toxicology & Legal Medicine. 2017;20(3and4):61-7.
4. Kaur K, Sharma T, Kaur R. Development of submerged latent fingerprints on non porous substrates with activated charcoal based small partical reagant. Indian Journal of Forensic Medicine & Toxicology. 2020 Jul 30;14(3):388-94.
5. M. Forina *et al.*Clustering with dendrograms on interpretation variables Anal. Chim. Acta(2002)
6. C.S. Silva *et al.*Chemometric approaches for document dating: Handling paper variabilityAnal. Chim. Acta(2018)
7. T. Geens *et al.*Levels of bisphenol-A in thermal paper receipts from Belgium and estimation of human exposure Sci. Total Environ.(2012)
8. S. Yao *et al.*Geographic identification of Boletus mushrooms by data fusion of FT-IR and UV spectroscopies combined with multivariate statistical analysis Spectrochimica Acta- Part A: Mol. Biomol. Spectrosc.(2018)
9. M. Broda *et al.*Natural decay of archaeological oak wood versus artificial degradation processes- An FT-IR spectroscopy and X-ray diffraction studySpectrochimica Acta - Part A: Mol. Biomol. Spectrosc.(2019)
10. I. Fierascu *et al.*Chemical and mineral characterization of Romanian book paper materials (XVII–XIXth century)Microchem. J.(2020)
11. K. Kumar, P. Sharma, A. Sen, S.K. Menon, A new non-destructive method for retrieval of completely removed printed text...
12. B. Li Studies on the differentiation of thermal papers and estimation of the printing age of thermal paper documents Aust. J. Forensic Sci.

Conflict of interest statement

The authors declare that there is no conflict of interest regarding the publication of this research article, "Characterization and Comparison of Thermal Papers of Various Sources using X-Ray Diffraction Technique: A Forensic Aspect," in the Journal Science and Justice.

We affirm that we have no financial or personal relationships with individuals or organizations that could inappropriately influence the content or interpretation of our research. This research was conducted with integrity and without bias, and the findings presented in this article are based on objective analysis and interpretation of the data.

Novelty statement

The novelty of our research lies in the innovative application of X-Ray Diffraction (XRD) technique to the forensic investigation of thermal papers. While thermal papers are ubiquitous in everyday life, our study is the first to systematically characterize and compare papers from various sources using XRD, providing a unique insight into their crystalline structures. The forensic aspect of our investigation introduces a novel dimension to the field, demonstrating the potential of XRD as a tool for differentiating and identifying thermal papers, thus opening new avenues for document authentication and forensic analysis. This pioneering approach enhances our understanding of the materials commonly used in document production, offering valuable applications in forensic science.