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Raman Spectroscopic Analysis of Inkjet and Laser Printed Documents to Find the Source of Printing

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ABSTRACT

This work investigates the use of Raman spectroscopy as a non-destructive tool for analysing inkjet and laser printed counterfeits. The primary goal of the study was to determine if Raman spectroscopy is an acceptable tool for demonstrating the link between various specimens of counterfeits suspected of being printed with the same toner on the same machine. Specimens of several kinds of toners printed on various types of paper are studied using a Raman spectroscopy apparatus with an excitation line at 514.5 nm. Cyan, magenta, yellow, and black toners are examined independently for each specimen. The Raman spectra of the cyan and yellow toners were the most distinguishable. The findings reveal that Raman spectroscopy may be used effectively to analyse colour toner printed document counterfeiting, such as banknotes and papers, in order to create linkages between more or less varied specimens of counterfeits by evaluating the characteristics of a colour toner.

Keywords : Forgery, Toner, Raman spectroscopy, inkjet, Laser, Forensic documentation

I. INTRODUCTION

In situations of deceitful papers and forgery banknotes, the pharmacological makeup of inks offers crucial corroborating evidence. Fabrication and falsification of papers and currencies is now done using inkjet printers. Because to the great accuracy of contemporary computer media and the excellent quality of inkjet printer inks, vouchers, receipts, prescriptions, banknotes, and other documents generated in this manner have a high likeness to the originals. Inks used in the inkjet printing process have a complicated composition that differs greatly from typical pen inks. Given the available specialised publications, digital forensics examiners are well aware of the features and discriminatory power of several methods, such as ultraviolet-visible spectrophotometry (UV-vis), Fourier transform infrared spectroscopy (FTIR) [1,2], thin layer chromatography (TLC) [1,2], Raman spectroscopy [3,4], X-ray fluorescence (XRF) [4,] mass spectrometry (MS) [5-8], high performance liquid The primary method of evaluating inkjet printed documents is to evaluate questioned and specimen printing for class and machine specific features, and then compare and contrast them [9-11]. Several of the features under consideration - paper handling markings, black image, dot size and shape, print direction, print head size, colour printing sequence - are related to the fundamental functioning of inkjet printers [12, 13]. Yet, one of the most important aspects of this inquiry is ink analysis [14].

It is critical to note the ageing of printer inks from a forensic standpoint [15]. This procedure has the potential to significantly alter the findings of an ink comparison [16, 17]. According to the literature [18,19] and the authors' prior study [20], the deterioration of ink on printouts is impacted not only by time but also by light. It was also shown that humidity may influence the pace of ageing. As a result, the optimal circumstances for document preservation are in a dark and dry atmosphere. The research compares the discriminating power of Raman spectroscopy methods on the investigation of four inkjet and four laser printers with 32 inks. This inquiry is the first step towards creating a database of inkjet inks, which is critical for forensic scientists' work.

II. MATERIALS AND METHODS

Sample preparation

Table 1 lists the eight printer inks tested in the current study. All of the inks tested were from various manufacturers or batches from the same manufacturer. The test sheet for each of the printers mentioned in Table 1 was produced in a rectangle rainbow design with three colours (yellow, magenta, and cyan). All printouts were kept in a dark, dry place at room temperature [20].

METHODOLOGY

All specimen characteristics were taken in such a manner that each colour toner, cyan, magenta, and yellow, was tested independently. We looked to see whether the Raman bands from the paper showed in the spectra of the toner printed on paper. When the spectra of the toner powder, the paper, and the toner printed on paper are compared (Fig. 1), the bands of the paper may be seen in the spectrum of the toner printed on paper. To counteract the effect of the paper on the measured spectrum, the spectra of the tested toners were derived by removing the wavelength of the paper from the spectral range obtained on the printed specimen. Each paper's Raman spectrum is obtained on a non-printed region on the same side of the paper as the toners were produced.

Specimen no.	Manufacturer	Model	Paper size	Type of ink
1	Cannon	PIXMA G2000	A4	Cartridge
2	Hp	ENVY 6255	A4	Cartridge
3	Epson	L360	A4	Cartridge
4	Epson	Eco L15150	A4	Cartridge
5	Konica	C226i	A4	Toner
6	Konica	C224e	A4	Toner
7	Hp	477dw	A4	Toner
8	Toshiba	2309A	A4	Toner

Nstrumentation

The Confocal Raman Spectroscopy/Imaging Alpha300R was used for Raman spectroscopy (WITec, GmbH, Germany). The Argon Ion laser emitted the excitation line at 514.5 nm (Coherent, Innova 400, Santa Clara, CA). Neutral filters have been used to reduce laser power on specimens in order to minimise specimen damage at the focus of a laser beam. The laser beam's power was carefully tuned based on the colour of the specimen, therefore the laser power employed was 2 or 7 mW. The Raman spectra were obtained in the 200-1700 cm-1 range, with integration times ranging from 1 to 10 s and 4 scans. Some of the spectra were adjusted for baseline using Lab Spec software.

III. RESULTS

Cyan toners/inks

Laser

After the removal of the spectra from the papers, all Raman spectra for the cyan toners representing the unique spectrum for the toner printed on the specimens were compared (Figure. 2). The investigation reveals that the Raman spectra of the cyan toners were shows Hp 477dw and Toshiba 2309A spectrum shows same spectra (1562 cm^{-1}), Konica C226i, Konica C224e, revealed different spectrums (1272 and 2095 cm^{-1}).

Inkjet

The investigation reveals that the Raman spectra of the cyan toners were not same, regardless of whether the cyan toners were manufactured by the same or different manufacturers (Figure. 3). The obtained different spectra include Epson L360 (3047 cm^{-1}), Epson Eco L15150 (404 cm^{-1}), Cannon PIXMA G2000 (457 cm^{-1}), and Hp ENVY 6255 (523 cm^{-1}).

Magenta toners/inks

Laser

The distinctive Raman spectra of magenta toners produced on paper were compared. After subtracting the spectra from the papers, all of the spectra are represented. The study of the spectra in figure. 4 revealed that the Raman spectra of magenta toners from various manufacturers significantly same (Fig. 6). The most noticeable change was with the Hp 477dw (1837 cm^{-1}) toner.

Inkjet

The distinctive Raman spectra of magenta toners produced on paper were compared. After subtracting the spectra from the publications, all of the spectra are represented. The study of the spectra revealed that the Raman spectra of magenta toners from various manufacturers differed significantly (figure. 5). The most noticeable difference includes Epson L360 (1705 cm^{-1}), Epson Eco L15150 (1721 cm^{-1}), Cannon PIXMA G2000 (3450 cm^{-1}), and Hp ENVY 6255 (1961 cm^{-1}).

Yellow toners/inks

Laser

The Raman spectra of yellow toners printed on paper were compared. Since the spectra of the paper are eliminated, the spectra indicate the unique portrayal of the toner. The Raman spectra research revealed that yellow toners from a certain manufacturer had a same and distinct Raman spectrum were obtained when compared between them in figure 6. The yellow toners may be distinguished from one another based on the locations of the Raman bands as well as the relative strength and sharpness of the Raman bands. The obtained results include Konica C226i, Konica C224e toners were same (692 cm^{-1}) and Hp 477dw and Toshiba 2309A toners shows different spectrum (773 and 1227 cm^{-1})

Inkjet

The Raman spectra of yellow inks printed on paper were compared. Since the spectra of the paper are eliminated, the spectra indicate the unique portrayal of the toner. The Raman spectra research revealed that yellow inks from an inkjet certain manufacturer had a same and distinct Raman spectrum (Figure. 7). Epson L360, Cannon PIXMA G2000 shows same spectra (2923 cm^{-1}) and Epson Eco L15150 (2200 cm^{-1}), Hp ENVY 6255 (3108cm^{-1}) shows different spectrum compared to other two.

Black toners/inks

Laser

The Raman spectra of selected laser printer black toners were analysed and it shows the same spectra of all the different type of manufacturer and different company (Figure. 8). The resultant spectra include Konica C226i, Konica C224e, Hp 477dw, and Toshiba 2309A toners (1900 cm^{-1})

Inkjet

The Raman spectra of selected inkjet printer inks were analysed and it shows the same spectra of same company printers includes Epson Eco L15150 and

Epson L360 (3125 cm^{-1}) and the different printer black inks also shows similar spectrum as follows Cannon PIXMA G2000 and Hp ENVY 6255 (3314 cm^{-1}) respectively (Figure. 9).

Discussion

There aren't many research publications on the use of Raman spectroscopy in the forensic investigation of colour toners. One of the earliest articles on the topic details the Surface Enhanced Resonance Raman Scattering (SERRS) examination of toners using a He Ne laser at 632.8 nm and a laser diode at 784.8 nm [17]. In one recent study, 30 yellow powder toner specimens were examined using a monochromatic light with an excitation wavelength of 785 nm. Toners from two distinct cartridges from the same brand and for the same printer were tested, and their Raman spectra were found to be identical [18]. Raman spectroscopy is used in this investigation using a laser excitation line at 514.5 nm. The measurement circumstances were altered based on the colour of the toner. Yellow and cyan toners produced excellent quality Raman spectra in the majority of experiments, however magenta toners produced excessive luminosity and had to be baseline adjusted before comparison. Following prior study that shown that papers had distinct Raman spectra [11] and that various kinds of paper had distinct Raman spectra [19-20], the Raman spectrum of the specimen's papers was taken into account in each measurement. Moreover, Raman spectroscopy of the paper was always done on the unprinted region of the same side of the paper as toner measurements were taken in order to prevent conflicting findings when using one side coated papers. Since liquid toners are partly absorbed in the paper fibres, concentrating the laser beam deeper within the paper was necessary, while spectra collecting for powder toners was done on the paper's surface. When the Raman spectra of each colour toner were compared, it was discovered that yellow toners were considerably more readily differentiated from magenta toners.

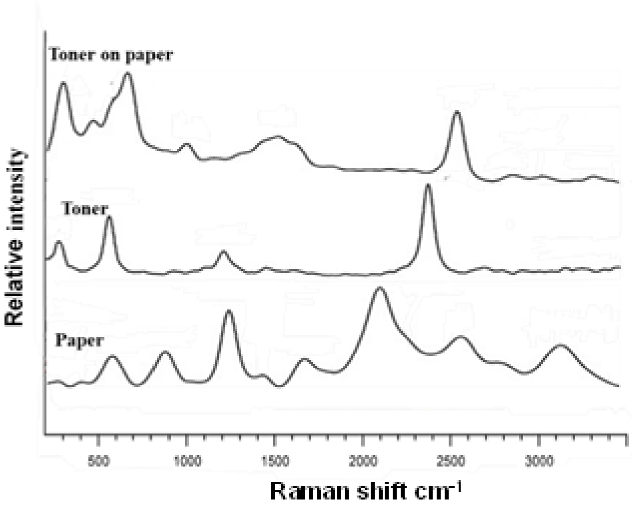

Figure 1. Raman spectra of overall selected toners printed on paper

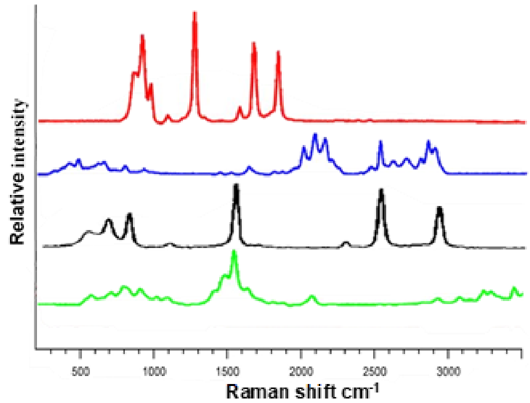

Figure 2. Raman spectra of Cyan toner of the laser printer

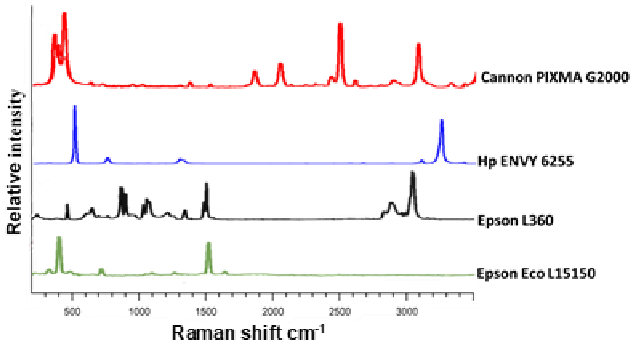

Figure 3. Raman spectra of Cyan inks of the Inkjet printers

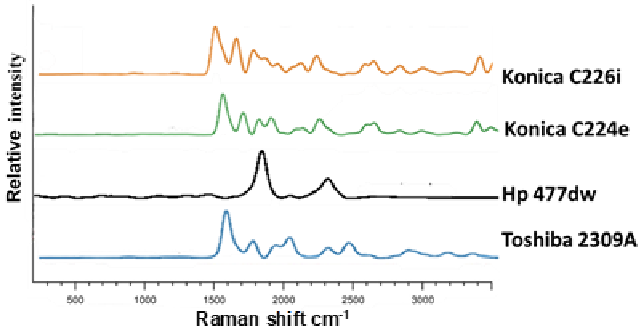

Figure 4. Raman spectra of Majenta of the laser printers

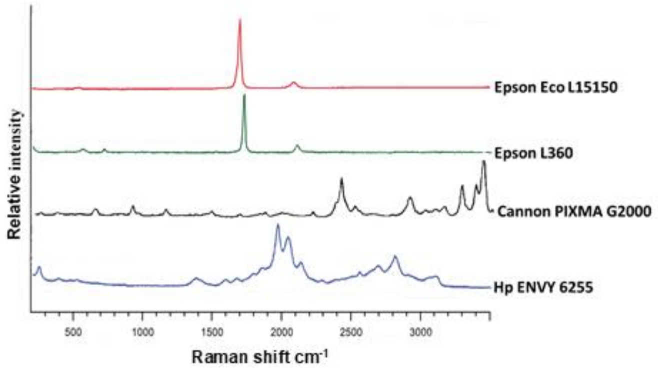

Figure 5. Raman spectra of Magenta inks of the inkjet printers

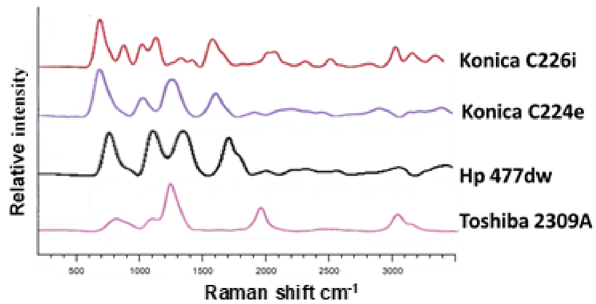

Figure 6. Rama spectra of Yellow toner of the Laser printers

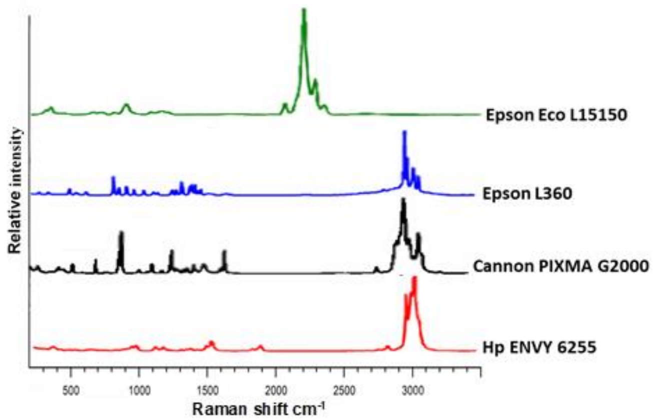

Figure 7. Rama spectra of Yellow inks of the Inkjet printers

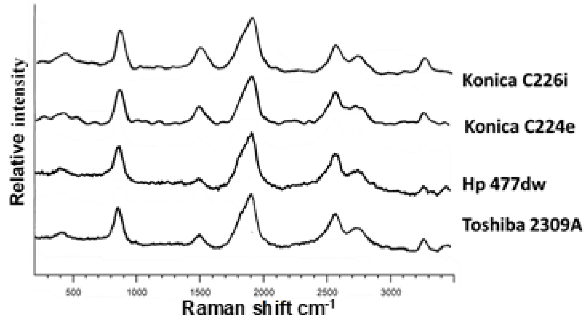

Figure 8. Raman spectra of Black toner of the laser printers

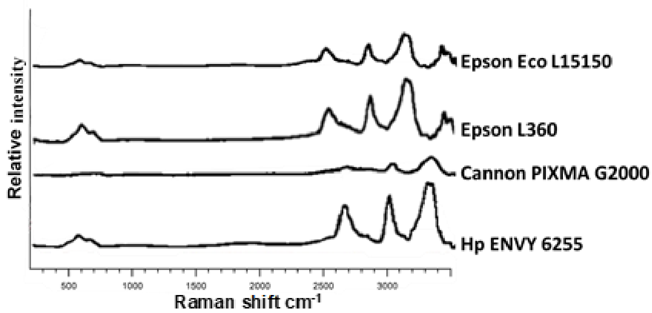

Figure 9. Raman spectra of Black inks of the Inkjet printers

IV. CONCLUSION

The Raman spectra of all black inks of inkjet and laser printers were identical, independent of origin or kind of toner. Different Raman spectra were detected for toners of the same hue in the situations of cyan, magenta, and yellow inks from the same and separate manufacturers of both the inkjet and laser printers. Additionally, distinct Raman spectra were detected in all instances of yellow toners for toners of the same hue from various manufacturers as well as from the same manufacturer. This leads us to the conclusion that the yellow toners studied in this study have the most different Raman spectra and can be recognised from one another using Raman spectroscopy. To fully establish this claim, more study based on Raman spectroscopy of yellow inks and toner of both printers should be undertaken on a considerably larger collection of toner specimens from various manufacturers and printer types. Such extensive research might pave the way for the creation of a spectral library of yellow toners as a tool for recognising a toner maker based on the distinctive spectra of that toner. Based on the findings of this study's analysis, we can deduce that each yellow toner has a distinct Raman spectrum. Similar Raman spectra of two or more yellow toners on separate specimens of investigated counterfeits lead to the conclusion that the counterfeits were produced with the same toner or, at the very least, with printers manufactured by the same company. The ultimate result is that spectroscopy may be effectively employed as a method for recognising a toner's distinctive spectrum in the investigation of colour toner printed counterfeit banknotes. This examination might reveal the shared origin of physically distinct counterfeit specimens suspected of coming from the same source. Just the study of the yellow toners is regarded necessary for reaching a final judgement on the case in order to get accurate information.

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