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A Comparative Study between Spectroscopic and Physical Techniques for Discrimination of The Counterfeited Computer-Generated Documents (A Case Study)

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THE discrimination between counterfeited computer-generated documents has been one of the most challenging missions for forensic purposes. Forensic document examiners usually prefer using non-destructive techniques than a destructive one, but sometimes the latter technique can be the last decision for them. Our forensic laboratory has recently received a case involving many counterfeit one hundred Egyptian pounds 100 L.E produced using color laser printing machines, two of them having the same serial number and date of issue. The public Prosecution request the source of two counterfeited notes are they from the same source or not? We applied two approaches to answer this question, one of them spectroscopic techniques which include Fourier-Transform Infrared Spectroscopy (FTIR) as qualitative analysis combined with Scanning Electron Microscopy -Energy Dispersive X-Ray Spectroscopy (SEM-EDX) as quantitative analysis. We used the Video Spectral Comparator device (Regula 4307) as a physical technique. The result showed that the physical approach was superior for the classification and discrimination of color laser printing machines which encoding serial numbers to its brand source regardless of the toner type and the spectroscopic techniques were useful in discrimination of the color laser printing machines which not encoding serial number.

Keywords: Computer-generated documents, Forensic purposes, Color laser printing machines, FTIR, SEM-EDX, Regula 4307.

Introduction

Every day in forensic document examiner life there are some repeated routine working questions such as asking about the authenticity of documents (banknotes, contracts, receipt) Are they genuine or forged/counterfeited? And if it forged or counterfeited. The main question in a forged document, especially in multiple pages document like contracts, bride home constituents list and passports are all pages printed on the same printer or not? On the other hand, counterfeited documents especially in banknotes the same question required, but there is an important request to link the documents to a certain printer. Answering to those questions required a scheme for ink/toner profile which used to produce these documents. Laser printing machines as a non-impact printing technique can be classified into monochrome and colour which can be used as printer, copier and multifunction. A significant increase in these machines have been noted and make it possible to use it as a counterfeiting tools. The Raw material of laser printing machines is a toner. Toner is a mixture of colorant, binding agent (polymer resin) and additives.

Scheme begins with non-destructive techniques which called physical examinations using lenses and microscope to discover and identify stroke morphology is it Laser jet or

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inkjet print out? Then Optical examinations ended by chemical examinations. there are different methods to compare toner or ink mentioned in the literature reviews such as thin-layer chromatography (TLC) [1,6], gas chromatography-mass spectrometry (GC-MS), various types of fourier transform infrared spectrometry (FTIR) [2-10], Trzcinska (2006) recommended that the comparison should begin with examination through IR spectroscopy as a qualitative technique because it's efficiency to classify samples based on polymer composition followed by XRF as a quantitative technique for further identification of laser toners [4]. C.L Gilmour 1994 used FTIR combined with SEM-EDX to compare between laser and copier printout [5]. Trzcinsks 1997 used also FTIR combined with SEM-EDX to identify photocopy toners, he concluded that it is possible to differentiate among the toners and that the differentiation is suitable for forensic purposes and identification can be made regardless the quantity of the sample [3].

Limited articles [11-15] have been written on classification of color laser printing machines using unique counterfeit protection system code dotted pattern as a non-destructive technique. The US next generation currency committee mentioned two strategies to combat counterfeiting using digital printing one of them Currency Recognition System & the other Copier/Printer Identification System. we reviewed the previous works of ("Chi-Keung Li and Sze-Chung Leung, 1998", "Janis S. Tweedy,2001","Chi-Keung Li, Wai-Chung, Yua-Sang Cheng, and Sze-Chung Leung.2003","Komal Saini "" Jiang-Chun Li", Beusekum for tracking color laser printer & copier we found that some of them depend on the shape & number of micro-dots which barely appear on the entire surface of the printout and the other depends on viewing & measurement of the horizontal & vertical pattern separation distance between two repeated groups. We applied Janis S. Tweedy technique on the submitted case studies.

The current study focused on the utility of different analytical methods FTIR Spectroscopy combined with SEM-EDX Spectroscopy and unique counterfeit protection system code dotted pattern as a new approach which can be used separately or combined to differentiate & classify laser printing machines print out for forensic purposes.

Materials and Methods

Spectroscopic Techniques

Sample Preparation

Toner particles were removed or scrapped from the two questioned counterfeiting 100 EGP (labeled as Q_1 and Q_2) using a scalpel under an optical microscope to avoid contaminations

Fourier Transform Infrared Spectroscopy

The measurements were performed in the transmission mode. The infrared spectra of two questioned scrapped toner samples (Q_1, Q_2) were obtained in the 4000–400 cm^{-1} region by using Bruker tensor 27 IR with KBr discs at faculty of Science, Suez Canal University, Ismailia, Egypt.

X-ray Microanalysis Examinations

$Q_1$and Q_2 samples were examined under X-ray microanalyzer (module oxford 6587 INCA x-sight) attached to JEOL JSM-5500 LV scanning electron microscopy at 20KV after gold coating using SPI-Module sputter coater at the Regional Center of Mycology and Biotechnology, Cairo, Egypt.

Physical Technique

Optical device: Video Spectral comparator Regula model 4307 supported with a set of light sources of visible, infrared, ultraviolet spectral ranges and imaging filters used for carrying out forensic examinations.

Trinocular Stereo Microscope Regula 5003: Color camera, frame size, pixels — 2592×1944, objective magnification with 30x eyepieces — 24x to 420x.

Unique Counterfeit Protection System codes dotted pattern

We used Janis Tweedy methodology and classification according vertical pattern separation (VPS) distance between two adjacent repeated units as shown below: 0.16-inch, 0.32-inch regular pattern, 0.32-inch diffuse pattern, 0.48 inch, 0.50 inch, 0.64 inch RICOH type, 0.64 inch Xerox type, 0.69 inch, 0.96 inch, 1.20 inch,1.28 inch.

The measurements for both VPS and HPS distance applied on Hewlett-Packard (HP®) and of Ricoh® brands

Results and Discussion

Characterizations of Toner from Printouts by Spectroscopic Techniques

FTIR spectroscopy

The FTIR spectra of the scrapped toners for both two samples denoted with (Q_1, Q_2) are given in figures 1 and 2, respectively.

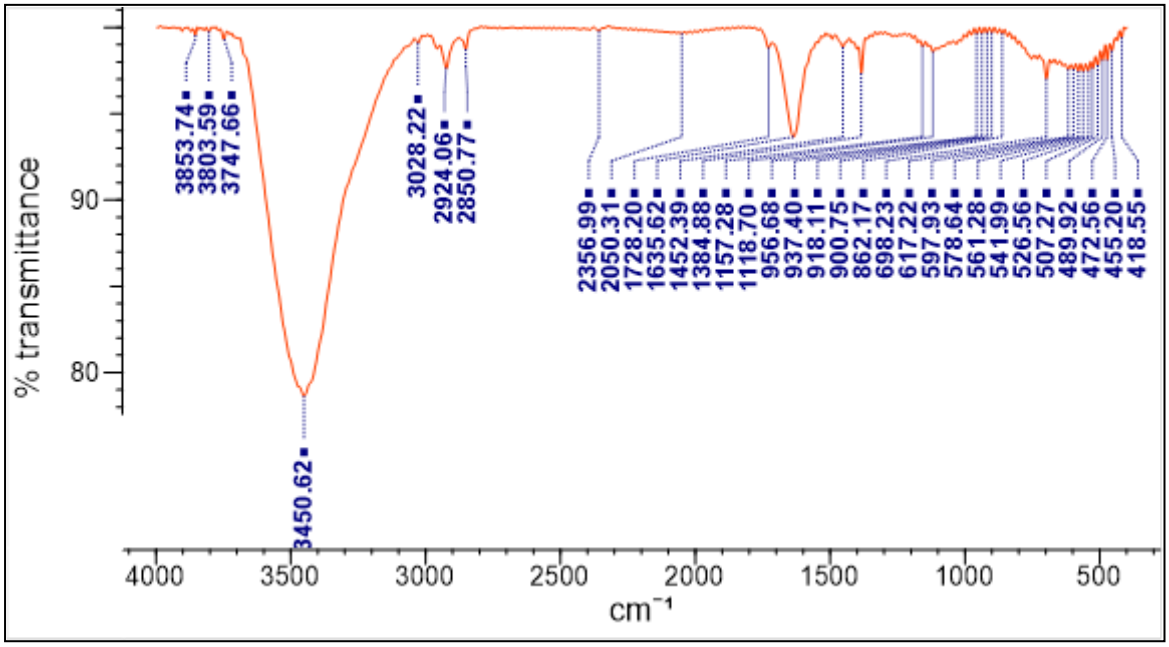

Fig.1. Infrared spectra of sample Q_1 .

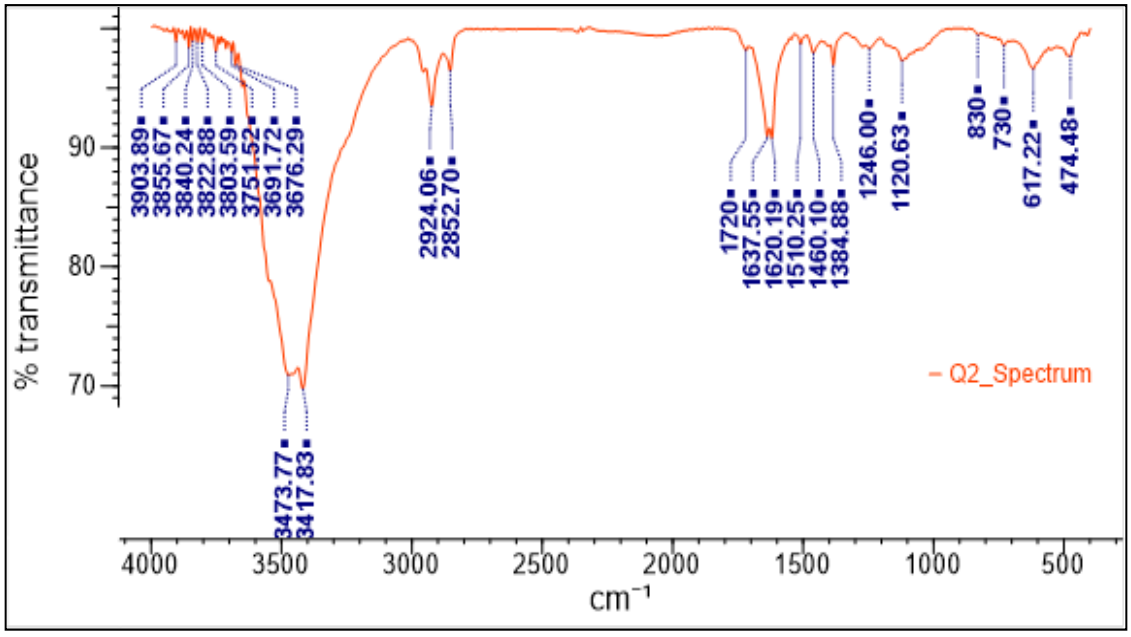

Fig.2. Infrared spectra of sample Q_2 .

According to band intensity and position for two samples, we could investigate the main components for each sample. Hence, among different constituents of toner, approximately 75% percent represented resins. In addition to minor components such as flow, charge agents and waxes. So, the IR spectra exhibited lots of information about the main constituents for each toner.

The spectra observed for Q_1 sample exhibits Bands at 3450.62, 2924.06, 2850.77, 1728, 1636,1384, 1119,753 and 698 and cm^{-1}. these bands can be attributed to the presence of polymeric association of (O-H) group at 3450.62 cm^{-1}, Cycloalkanes of (C-H) groups at 2924.06 cm^{-1}, methyl acrylate stretching vibration of (CH_3) group at 1728 cm^{-1}, Dialkyl ketone (C=O) group at 1636 cm^{-1}, Aryl tertiary amine (C-N) group

at 1384 cm^{-1}, Nitrosamine(N-N) group at 1119 cm^{-1}, Styrene (Benzen ring) group at 698 cm^{-1}, respectively. therefore, the data analysis from the above IR spectra indicated the presence of the main polymer resin in the sample (Q_1) belongs to styrene-co-acrylate resins class.

The spectra observed for Q_2 sample exhibits Bands at 3473.77, 2924.06, 2852.70, 1720, 1637,1460, 1384,1120, 830, 730, 617.22 and 474.48 and cm^{-1}. these bands can be attributed to the presence of polymeric association of (O-H) group at 3473.77cm^{-1}, Cycloalkanes of (C-H) groups at 2924.06 cm-1, methyl acrylate stretching vibration of (CH3) group at 1720cm-1, Dialkyl ketone (C=O) group at 1637 cm^{-1}, Aryl tertiary amine (C-N) group at 1384 cm^{-1}, Nitrosamine(N-N) group at 1120 cm^{-1}, Bisphenol A ((Phenyl Nucleus) group at 830 ,1510 cm^{-1}, Isopthalate at 730, Sulphides & disulfides (C-S), (S-S) at 617.22 and 474.48 respectively. therefore, the data analysis from the above IR spectra indicated the presence of the main polymer resin in the sample (Q_2) belongs to polyester -terephthalate and Bisphenol A resins class which could discriminate in the fingerprint region of IR spectra.

Therefore, the FT-IR spectra observed for two unknown samples, we discriminate at first aspect the main polymeric resin in their components in a qualitative tool.

SEM- EDX spectroscopy

In a second step for elementary analysis of two samples denoted with (Q_1, Q_2) using Scanning Electron Microscopy Energy Dispersive Spectrometry technique. the obtained spectra and data are given in (Figs. 3 -5).

AS seen from the observed data of SEM-EDX for two samples, there are a little bit differences in their elemental composition such as depicted in each figure 3, 4 and 5 respectively. silicon and calcium elements are exhibited in both samples (Q_1 and Q_2) but in the second sample (Q_2) their ratio is more than exist for sample Q_1. in addition to the first sample (Q_1) has a few ratios of Iron. all these elements exist as a form of inorganic additives.

From both FT-IR and SEM-EDX techniques, we could start to distinguish between two unknown samples toner qualitatively and quantitatively for their toner composition.

Characterizations of toner from printouts by physical approaches

Two samples (Q_1& Q_2) were placed on a workspace inside Video Spectral comparator Regula model 4307 without any prior preparation of them and were activated with the spectroscopic system at a range of 400 – 460 nm (blue region).

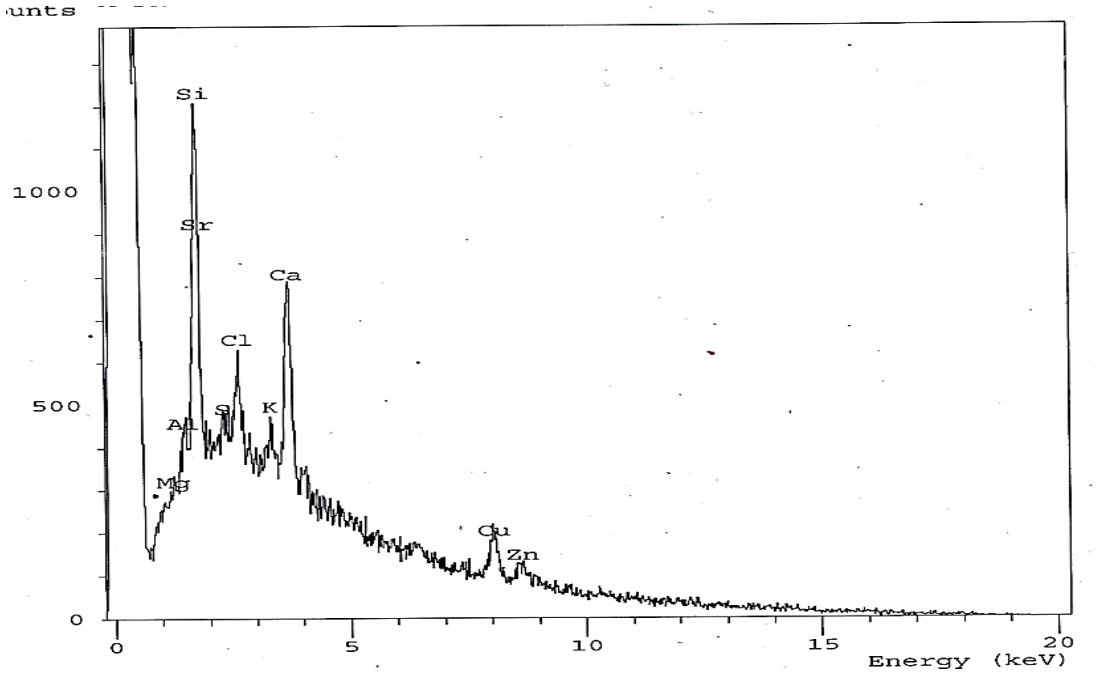

Fig.3. EDX spectra of Q_1 sample.

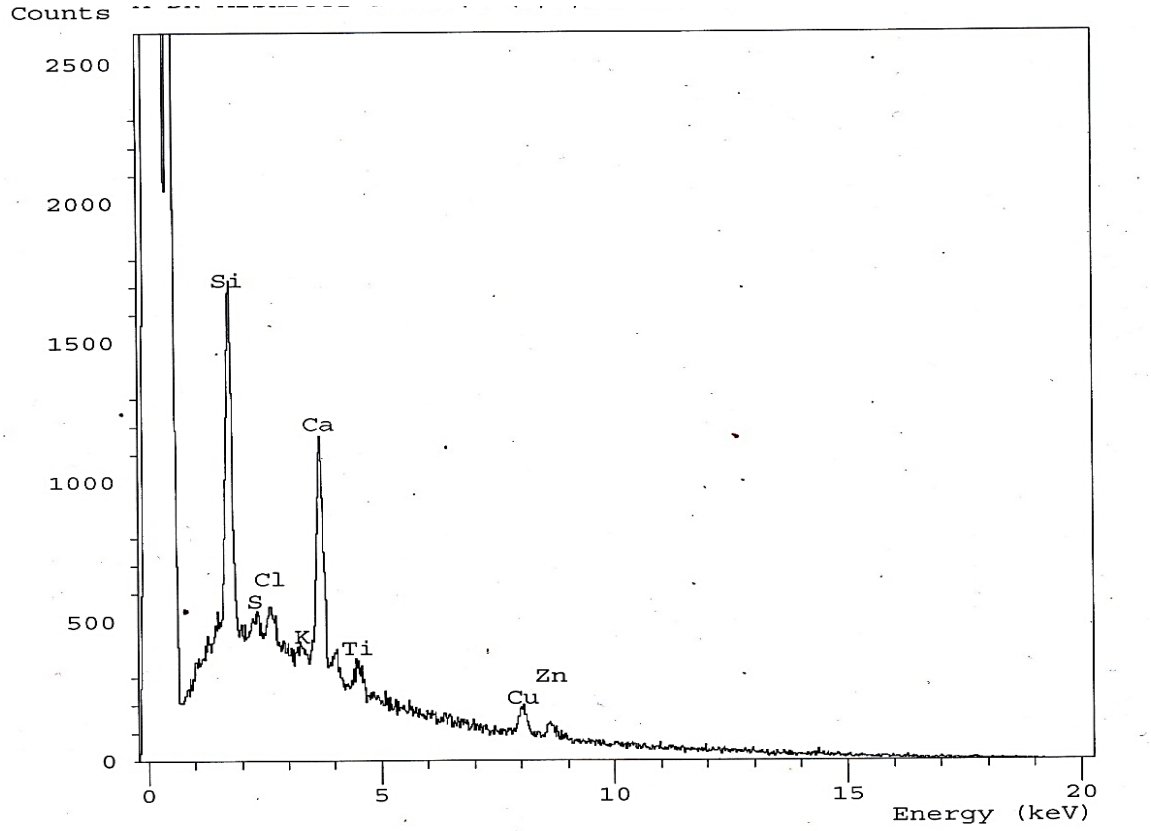

Fig.4. EDX spectra of Q_2 sample.

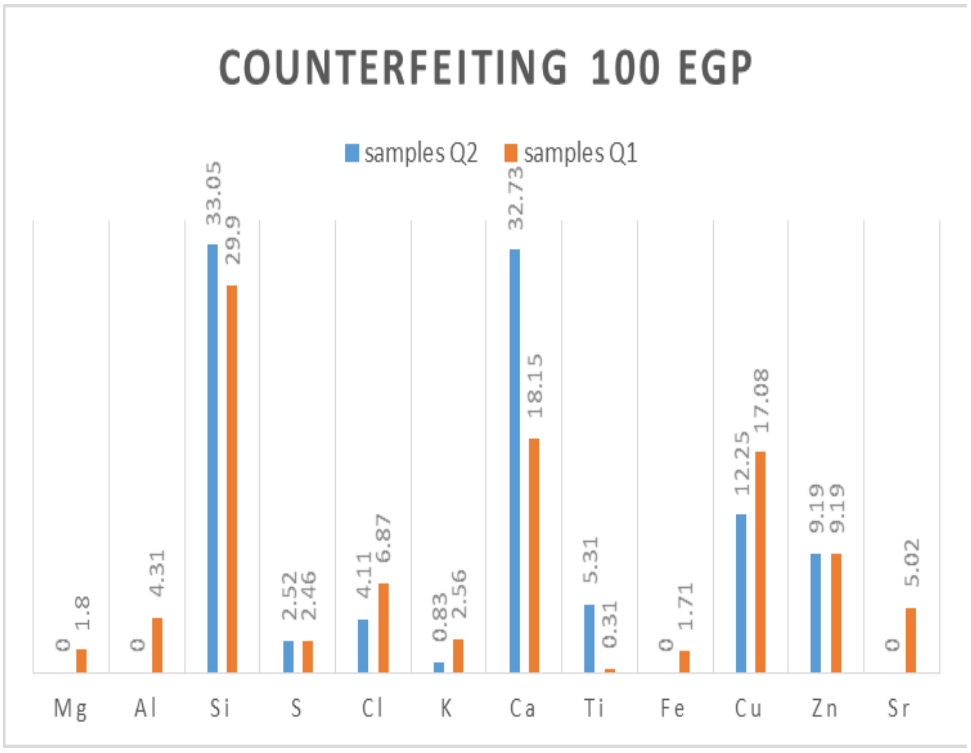

Fig.5. EDX elemental analysis of two sample (Q_1& Q_2) .

Hyperspectral analysis (HAS) feature was a candidate to extract the **CPS codes** embedded in color laser printouts of two unknown samples (Q_1 & Q_2).

Two samples (Q_1& Q_2) of counterfeiting banknotes of one Egyptian hundred pounds have the information of the banknote serial number, the number of groups and the date of issue as given in figure 6.

The two samples (Q_1 & Q_2) exhibited small black dots under activation the light source of wavelength in the blue region and the results obtained from HAS feature can be seen in figs. 7 and 8 respectively.

Moreover, the spatial distances of these CPS codes patterns were measured via a complementary indentation of VSC Regula 4307.

As seen in Figures 7 and 8 the two samples contained different patterns of coded dot-matrix spread entirely for each counterfeiting banknote.

For complete identification, we found sample Q_1 contained regular CPS codes characterized for color LaserJet printers of Hewlett-Packard (HP®) brand. on the other hand, we found sample Q_2 contained regular CPS codes for color laser printers of Ricoh® brand.

Conclusions

According to fig. (9) the flowchart there are two recommended analytical approaches for differentiating and classifying Color laser printing machines for forensic purpose. One of them is non-destructive techniques but depend on the presence of clear unique counterfeit protection system code dotted pattern then determine the repeated units and measure both VPS & HPS distance between two adjacent units. Sometimes the unique counterfeit protection system code dotted pattern is faint or not present, the FDES should use the qualitative method such as FTIR followed by SEM-EDX as a quantitative method to give high discrimination power.

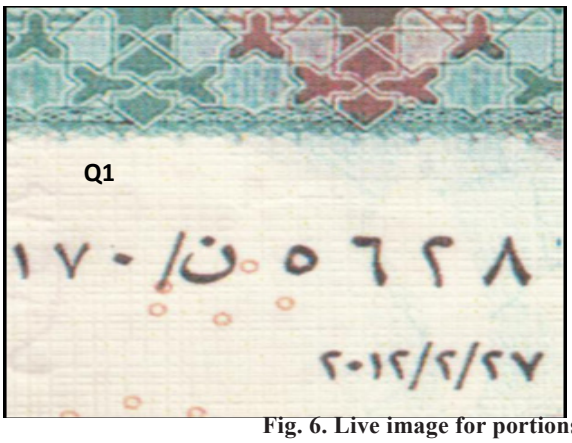

Fig. 6. Live image for portions of samples (Q_1at left Q_2 at right) .

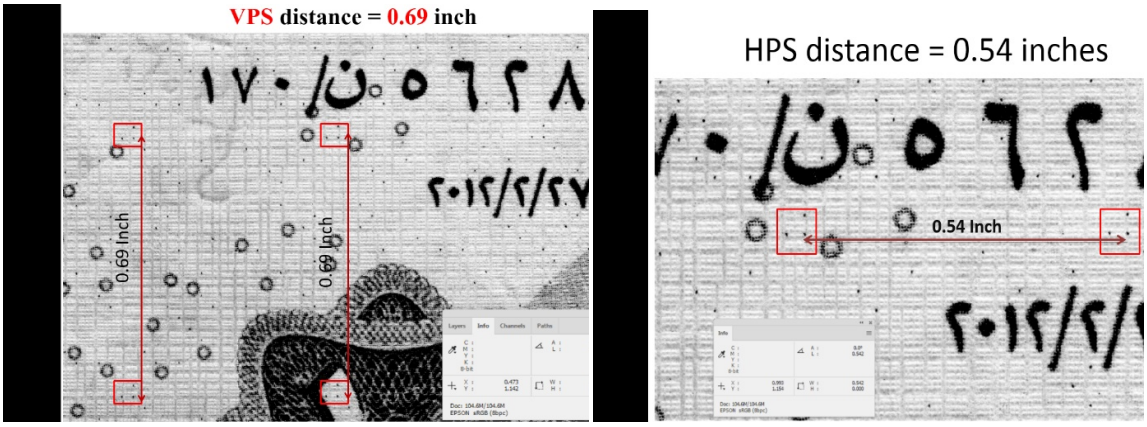

Fig. 7.

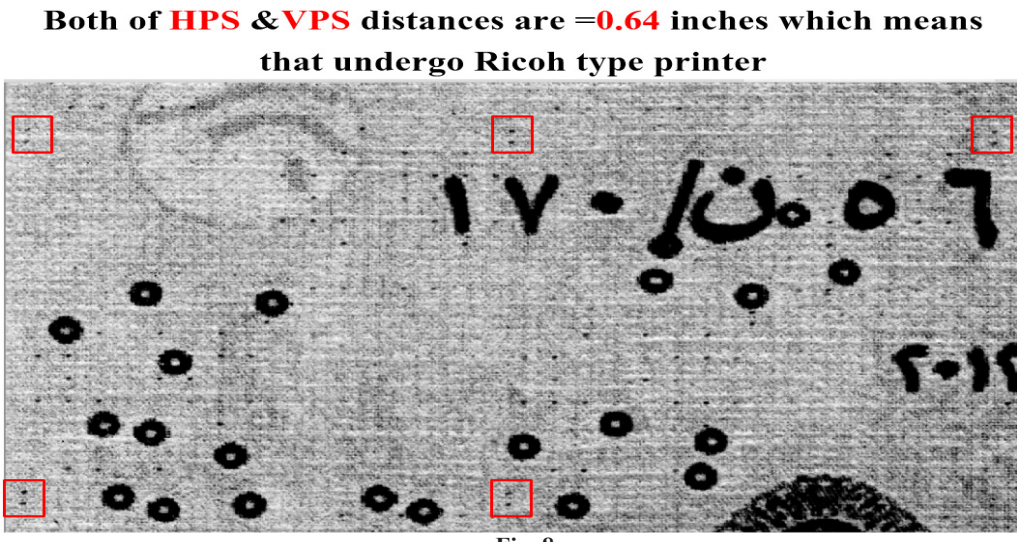

Fig. 8.

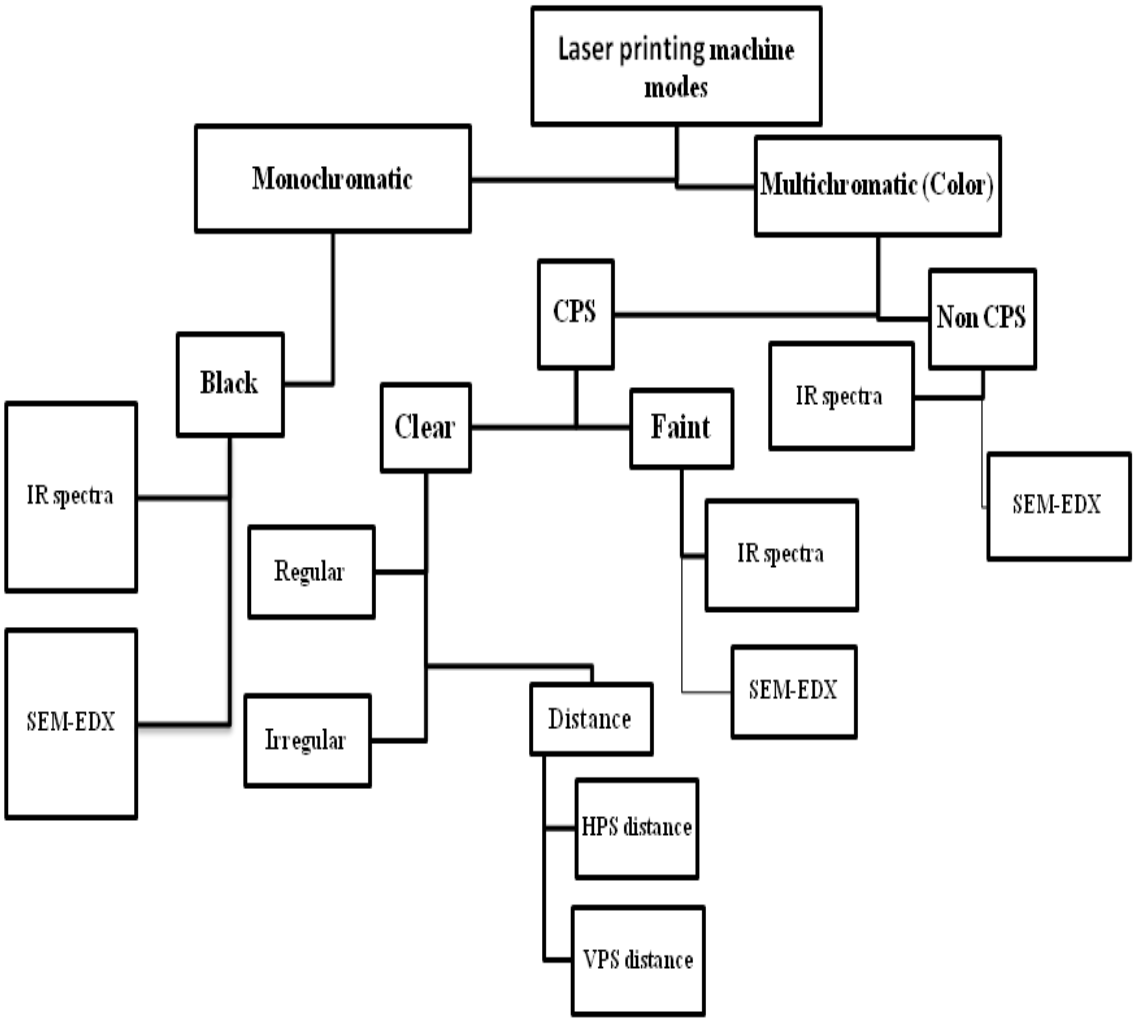

Fig .9. The flowchart of analytical scheme of laser printing machines.

We applied those two approaches for the Q_1 & Q_2 seized counterfeited 100 EGP with the same serial numbers and found we can conclude that there are differences between Q_1& Q_2 seized counterfeited 100 EGP notes in:-

1. The polymer composition and in the elemental composition. Q_1, Q_2 were differentiated based on their FT-IR and SEM-EDX spectra, respectively and classified using the unique dotted pattern of CPS codes.
2. The binding agents in toners are copolymers produced from (Styrene/acrylate) in Q_1 and (Polyester/terephthalate and Bisphenol A) in Q_2.
3. Using two analytical methods (FT-IR and SEM-EDX) allowed for further differentiation of toners.
4. We used a unique dotted pattern of counterfeit protection system code as a non-destructive technique in differentiating & discriminating between Q_1 & Q_2
5. Determining & extracting (unique dotted pattern) of counterfeit protection system code of Q_1 & Q_2 help in identifying the class characteristics of Color laser printing machines which were used to produce them.
6. The Q_1 with VPS distance 0.69 inches and HPS distance 0.54 corresponding for different brands within them assigned for Hewlett-Packard (HP®) brand patterns class characteristic.
7. The Q_2 with both VPS distance and HPS distance 0.64 corresponding for different brands within them assigned for the Ricoh® brand pattern class characteristic.

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دراسة مقارنة بين الطرق التقنية الطيفية والفيزيائية لتمييز الوثائق المقلدة (دراسة حالة)

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يعد تمييز أصل الوثائق المقلدة باستخدام الطابعات الكمبيوترية الرقمية الحديثة من أحد المعوقات الحالية التي تواجه المعامل الشرعية العالمية بشكل كبير.

ويعمل خبراء أبحاث التزييف والتزوير والمهتمين بهذا الصدد الي الوصول الي الحل الأمثل والمحافظة على أصل هذه المستندات المقلدة هو القصد والغاية المنشودة لإقامة الدليل الفني لذا يلجأ كافة الخبراء بكافة القطاعات الي الطرق الغير متلفة للوصول الي ادق النتائج اللازمة للفحص الفني المطلوب. وفي بعض من الحالات البحثية يلجأ الخبراء الي استخدام الطرق التحليل الكيميائية التي تعد وسيلة قاطعة للوصول الي التركيب الكيميائي لتلك المكونات التي يتم دراستها الا انها تكون من الطرق المتلفة بشكل عام الا انه مع التقدم في الوسائل المستخدمة تم استخدام عينات متناهية الصغر وها ما يسمي بالحجوم النانومترين والتي تصلح للتحاليل المخصصة لذلك.

ويهدف عملنا في هذا البحث الي استخدام طريقتين مختلفتين في الأسلوب والطريقة العامة للوصول الي هوية الاحبار المستخدمة في انتاج العملتين المقلدتين المرشحتين لهذا التطبيق (عملة مالية ورقية فئة المائة جنية مصري).

تم استخدام الطرق الكيميائية المتمثلة في مطياف الرمان والمسح الالكتروني باستخدام الاشعة السينية كوسائل كمية للوصول الي التركيب الكيميائي المتواجد بتلك الاحبار.

مع استخدام جهاز الفيديو الطيفي المقارن كوسيلة دقيقة غير متلفة للوصول الي الفحص الدقيق لهوية الاحبار المستخدمة في تقليد العملات المرشحة لهذا التطبيق بشكل متخصص وبالغ في الدقة.

واسفرت تلك الدراسة عن الوصول على اغلب المركبات الكيميائية والعناصر المشاركة في تكوين هوية تلك الاحبار الخاصة بكل عملة ورقية مالية تم استخدامها لهذه الدراسة والوصول الي هوية الطابعة التي تم استخدامها في انتاج تلك العملات الورقية المقلدة بشكل بالغ الدقة والتحديد بشكل غير مسبوق.