CHAPTER-5

SUMMARY AND CONCLUSIONS
5.1 SUMMARY

The rapid increase in the use and availability of photocopies was followed by the parallel growth of their use in criminal activities. The most common crimes associated with photocopied documents involve fraud, terrorism, passing secrets or confidential materials, anonymous letters etc., which provide great advantage to the criminals. The scenario has become worse with the introduction of coloured photocopiers in the market that provide good resolution, high output of multiple copies with automatic feed and sorting facilities which lead to the abuse of coloured photocopies in a safer and sophisticated manner. The documents, which are generally fabricated, are bank notes, currency notes, cheques, certificates, lottery tickets, stamp papers etc.

Cases of manipulated photocopies are frequently encountered due to widespread use and general acceptance of photocopies in business and legal matters which provides enough opportunity to dishonest person to do manipulation. Under these circumstances, it is necessary for the document examiner to evaluate the authenticity of photocopy and reveal evidence of manipulations if present.

The Forensic Document Examiners (FDEs) should be aware of the characteristics of photocopied process to carry out the examination of the photocopied document. The photocopied documents are examined by comparing class characteristics present followed by careful evaluation of identifying features. The classification of the photocopied document is based on the physical characteristics such as paper type, toner type, toner application, magnetic properties, defect marks and fusion methods. Scanning Electron Microscope (SEM) is also used to study the surface morphology of the toner deposits on the paper. The colour photocopies have been examined by their physical properties such as printing characteristics and counterfeit protection system code. The counterfeit protection
system code is present in the form of yellow dots on the surface of colour copies/printouts, which is not visible to the naked eye.

The toners employed in photocopies are composed of organic resins such as synthetic polymers and copolymers mixed with carbon black (in black copies) or coloured pigments (in case of colour copiers). Numbers of possible source machines are quite large, therefore any additional classification method, that is, examination of chemical properties of the toners has further improved the class characteristics. The chemical analysis of toners is carried out by using various analytical techniques such as TLC, UV-VIS Spectrophotometry, Infrared Spectroscopy and Pyrolysis Gas Chromatography.

The characteristics of contemporary photocopying processes are favorable to the manipulation of photocopied documents and examination of same has been used for the detection of fraudulent photocopies.

In India, very limited work has been done on this aspect. So, present proposal has been selected to work on this problem systematically by using various microscopic and analytical techniques. To achieve the goal, three objectives have been proposed. These are; to determine whether this is photocopied documents or not (both in black and coloured), to determine the source of photocopied documents (both in black and coloured) and to determine the authenticity of photocopied documents (both in black and coloured).

The examination of photocopied documents for determination of its nature and source has been achieved on the basis of physical and chemical analysis of the photocopy. The physical analysis includes examination of physical characteristics. The chemical examination reveals analysis of toners (both raw and processed) with analytical techniques. For this, photocopied documents were collected from sixty two photocopiers of twenty five different makes and models. Raw toners were also collected from the respective photocopiers. Raw toners of twenty eight brand names were found to be used in sixty two
photocopiers. Samples of the coloured processed toners were collected by designing two pages; one containing bars of different colours and other containing text matter in different colours. Then both pages were printed from nine colour laserjet printers and photocopied from nineteen coloured photocopiers. After the gap of one month, photocopies and printouts of both pages were again collected from the same coloured laserjet printers and photocopiers to study the variation with time. In this way, One hundred and twelve sheets of processed toners were collected from twenty eight colour photocopiers and laser printers. Ten raw toners containing all four colours i.e. yellow, cyan, magenta and black were collected. These samples include toners from original manufacturers as well as refilled toners.

Physical Examination of black photocopied samples were examined under Olympus SZX7 Stereomicroscope (4x40X) for the presence of various physical characteristics such as toner type, toner fusion, splattering effect of the toner and trash marks, images were captured with camedia-8080 Olympus camera, then transferred to the computer. Photocopies show trash marks due to glass platen, defective drum, defective fusing roller and residual toner impressions.

Physical Examination of coloured laser printed and photocopied documents were examined for their printing characteristics. The printing characteristics include counterfeit protection system code and toner deposit pattern of different colours. The counterfeit protection system code was examined under Olympus SZX7 Stereomicroscope (4x40X) and Video Spectra Comparator (VSC200/HR of Foster and Freeman Ltd). The toner deposit pattern was examined under Digital Microscope (Olympus MIC-D with magnification of 132K) with an LED (Light emitting diode) light source attached. Scanning Electron Microscopy for the surface morphology of the toner deposits on the paper surface was examined. Various colour and black photocopies and laser printouts
were studied under Scanning Electron Microscope model JSM-6100 to determine the fusion methods.

Chemical analyses of toners were done by using Thin Layer Chromatography, UV Spectroscopy and FTIR spectroscopy. The extracts of samples of processed black toners, coloured photocopies and laser printouts for chemical examination were prepared by removing them thermally by modifying the technique given by Munson, 1989 and then dissolving them in chloroform. The dyes from raw toners (black and coloured) were also extracted by using chloroform. These extracts were used to analyze all toner samples by TLC, UV and FTIR techniques.

Thin Layer Chromatography has been done on sixty two black toner (both processed and raw) samples and twenty eight processed and ten raw colour samples. Four solvent systems have been tried for the analysis of black toners and sixteen solvent systems were tried to separate the dye components of colour raw as well as processed toners. Results were interpreted on the basis of difference in number, colours and hRf values of spots under visible and UV light.

UV Spectroscopy has been performed on samples of black toner (processed as well as raw) and colour processed and raw toners by UV spectrophotometer model Perkin Elmer Lamda 45. The spectrum of solvent (chloroform) in which toners were dissolved, was taken to set value to zero. The extracts of toners of all samples were filtered by using Whatman filter paper, then filtered solution was subjected to UV spectrophotometer and its spectrum was recorded in the UV-range (200nm to 300nm).

Fourier Transform Infrared Spectroscopy has been applied on samples of black toners (both raw and processed) and coloured processed and raw toners by FTIR spectrophotometer model Perkin Elmer- Spectrum RXI FTIR System. Measurements were performed in transmission mode. Spectra obtained at 2.0 cm⁻¹ resolution with 4 scans in
range of 450-4000 cm\(^{-1}\). The extracts of black processed toners of all samples were poured on the KBr transparent pallets and kept for drying. In case of raw toners, toners of all samples were mixed with KBr powder and the pallets were prepared. Then, these pallets were subjected to FTIR analysis. Similarly, extracts of four colours bars/strokes of processed and raw colour toners along with their mixture, of all samples, were analyzed by FTIR and spectra were recorded. The FTIR spectra obtained were categorized on the basis of position of characteristics absorption peaks.

Determination of the authenticity of the photocopied documents was carried out. For this, black and coloured photocopies of the cheques, receipts, detail-marks certificate and letter pads were prepared. Alterations such as addition, deletion and transplantation were designed in the typed portion, printed portion, handwriting portion and signature portion of fifty black and twenty colour photocopies. These altered black samples were then photocopied from two black photocopiers (one of poor quality and other of good quality) upto 3\(^{rd}\) generation. Similarly, colour photocopies of twenty coloured altered photocopies were also prepared from one colour photocopier upto 3\(^{rd}\) generation. Photocopied samples of three hundred black and sixty colour photocopies were examined under Stereomicroscope (4x40X) for the detection of alteration in the documents. The black samples were also examined for the determination of the generation of the photocopied documents.

Photocopied documents were analysed for determination of their nature and source. The results of black and coloured photocopied documents by various techniques were examined and classified for their physical and chemical characteristics.

The collected sixty two processed samples were examined for various physical characteristics and defect marks present on the documents. The physical characteristics are produced on the documents during their pass through the machine. These characteristics
include toner type, toner fusion methods and splattering effect and trash marks. The photocopies have been classified on the basis of the presence of these characteristics on them.

- Sixty two samples have been divided into two classes on the basis of type of toners used i.e. wet and dry toner. Only 3 (4.8%) samples show the presence of liquid toner used for the production of photocopy, the remaining 59 (95.2%) samples show the characteristics of dry toner.

- Photocopied samples were categorized into four classes on the basis of fusion method used to produce the photocopies e.g. blotter or air dry, cold pressure, heat and pressure and radiant heat method. Blotter or air dry fusion methods which are specific to wet toner used in three (4.8%) samples. Cold pressure method was used in only one (1.6%) sample. Heat and pressure method was recorded in 8 (13%) samples, whereas, 50 (80.6%) samples reveals characteristics by radiant heat method.

- The direction of splattering effect of toner has good evidential value and used for the classification of the photocopiers. Sixty two samples have been classified into eight classes. In the first group, maximum number of samples, 28.9% show splattering of the toner around all over the stroke, Second group comprises of 27.4% samples, where splattering effect of the toner is at bottom of the stroke and third group having 22.8% samples, in which splattering effect of the toner is at the bottom and top. Rest of the groups (4-7th) include splattering effect of the toner on left side of the stroke (9.7% samples), top of the stroke (3.2% samples), left and right of the stroke (1.6% samples), left and bottom of the stroke (1.6% sample) respectively. Group eight includes three (4.8%) samples, which do not show any splattering effect of the toner.

- The photocopied documents were examined for presence of trash marks originating either from scratches present on glass platen, photosensitive drum and fusing rollers or
due to impressions of the residual toner. These marks are transferred to the copies during their production. Out of sixty two photocopied samples examined, 49 (79.1%) samples show presence of trash marks and 13 (20.9%) samples do not reveal any trash marks.

Glass platen marks have been observed in 5 (8.1%) samples, 4 (6.5%) samples show only drum defect marks and 9 (14.6%) samples display only roller defect marks present on their surface, however, both glass and drum marks, both drum and roller marks and both glass and roller marks have been observed in 20 (32.3%), 2 (3.2%) and 2 (3.2%) samples respectively whereas all three types of marks have been observed in 7 (11.2%) samples. Glass and drum defect marks help to differentiate the work of different photocopiers, whereas roller marks classify the photocopies into different classes. From the repetition of the drum defect marks, sequence of the pages has also been determined.

Out of sixty two samples, 52 (83.9%) samples have shown impressions due to residual toner on the photocopies in the form of letters, lines and spots.

- Counterfeit Protection System Code (CPS code) has been determined for twenty eight samples of coloured photocopies and laser printouts collected from the market and examined under VSC2000/HR and stereo-zoom-microscope (magnification 4x40X). The counterfeit protection system code is comprised of yellow dots, which are produced with yellow toner and are invisible to the naked eye. This pattern covers the entire surface of the document but more easily seen in areas of the document, where there is no printing. The code pattern has been decoded to identify the make, model and serial number of colour laser copier used. CPS code repeats on the paper and their number, location and arrangement is the sole basis for their uniqueness. Samples of same model but different serial number have produced different CPS code. Twenty five out of
twenty eight samples got differentiated from each other as they produced unique Counterfeit Protection System code in the form of motifs of yellow dots.

Printing Characteristics for coloured laser printed and photocopied documents have been examined under Digital microscope. Images have been captured on 5-megapixel inbuilt camera and directly transferred to the computer. Different colours of the toner particles (CYMK) arranged in a definite “Toner deposit pattern” on the surface of the laser printouts and photocopies have been observed. The number of colours of toner particles and their arrangement present in a particular coloured bar or stroke is also definite. The size of cluster and spreading/concentration of toner grains in these clusters is different on photocopies from different photocopiers. Therefore, average distribution of clusters of particular coloured toner grains present per unit area in a particular colour bar or stroke has been studied. In addition to this, voids have been detected on the surface of some of the printouts/photocopies. All twenty eight samples have been differentiated from each other on the basis of this feature.

- During the examination, a considerable variation in morphology of various fusion methods has been observed. Difference between liquid and dry toners can be made quite readily by Scanning Electron Microscope. The characteristics of fusion methods for dry toners such as radiant heat, heat and pressure and cold pressure have been observed in the samples of black and coloured processed samples. Fine discrimination between these methods is possible under Scanning Electron Microscope.

In black photocopies 50 (80.6%) samples have shown characteristics of radiant heat. In 8 (12.9%) samples, characteristics of heat and pressure have been observed. Cold pressure, and blotter or air dry process have been noted in 1 (1.6%) and 3 (4.9%) samples respectively. In coloured processed samples, 22 (78.5%) have shown heat and pressure and radiant heat have been studied in and 6 (21.5%) samples. From these
results it is inferred that particular fusion is not specific to the make. One company may use different methods in their machine to fuse the toner or different company may use the same fusion process.

- Sixty two processed as well as raw toners have been analyzed by Thin Layer Chromatography (TLC) and classified into 30 groups. Similar chromatograms have been obtained from raw and processed toners in terms of number, colour, and hRf values of spots observed in day light and ultraviolet light (at short and long UV), but the spots of the processed toner chromatograms have lesser intensity of colour than the spots of the raw toner chromatograms. From these results, it is clear that toners of the same brand names are differentiated from each other, however, some toners of different brands could not be differentiated from each other. This is due to the fact that either same type of dyes may have been used by various manufacturers during production of toners or toners may have been manufactured in bulk by one company and distributed under different brand names.

Similarly, twenty eight processed and ten raw colour toners have been classified into 19 and 6 groups respectively by TLC on the basis of numbers, colours and hRf values of spots. Out of them, thirteen samples of processed and five samples of raw toners are differentiated completely by TLC. However, some of the samples of the same brand could not be distinguished from each other. These samples were categorized into different groups due to reason that batch variations may exist in the samples and the samples which fall in the same group belong to the same batch.

- Sixty two black toners (raw as well as processed) have been analysed with UV spectrophotometer and classified into 10 groups on the basis of position of characteristics absorption peaks shown in the UV spectra of these samples. Twenty two processed and ten raw colour toners have been classified into 10 and 6 groups,
respectively on the basis of UV analysis. It is depicted that only three processed and four raw colour toners have been discriminated fully from their well defined absorption peaks. However, some of the toner samples of same brands and some of the toner samples of different brands could not be differentiated from each other, as they show absorption peaks at same positions. This might be due to the usage of same type of dye which may have been used by various manufacturers during production of toners. Another reason could be that the toner may have been manufactured in bulk by one company and distributed under different brand names. It is clear from the study that UV Spectroscopy differentiates toners but it offered less discrimination of toners than TLC.

- Sixty two samples of black toners (processed as well as raw) have been analysed with FTIR Spectrophotometer and classified them into six groups. Classification of the FTIR spectra is based upon the position of characteristics peaks. The FTIR spectra of processed toners are similar to the spectra of raw toners used to produce the processed copy, however, their spectra do reveal some differences in relative peak intensity between raw and processed toners. Similarly, twenty eight processed and ten raw colour toners have been analysed with FTIR Spectrophotometer. The comparison of the spectra obtained for 4 colours of the same toners do not reveal any marked difference. This is due to the fact that Infrared spectrum of colour toner does not depend on the actual colour of the toner but on the organic resin base, which is usually same for a particular toner. So the yellow, cyan, magenta and black toners of the same brand are classified together in the same group. The processed and raw colour toners have been classified into 6 groups each on the basis of difference of the peaks in their spectra.

- Sixty two toners (processed as well as raw) have been analyzed by TLC, UV spectroscopy and FTIR spectroscopy. They are classified into 30, 10 and 6 groups with TLC, UV and FTIR respectively. Similarly, twenty eight coloured processed and ten
raw toners have been analysed by TLC, UV spectroscopy and FTIR spectroscopy. They are classified into 19 and 6 groups with TLC, 10 and 6 groups with UV spectroscopy and 6 groups each with FTIR. TLC proves to be more informative than UV and FTIR. This is due to the fact that the dye components of toner have more variety of compounds. However, FTIR analysis depends on the basic organic components which are more or less same for all toners. There are few samples which could not be differentiated with TLC while they are differentiated in UV and FTIR spectra. Therefore, all three techniques proved to be very useful and complementary to each other in improving the classification of black toner samples.

- The examination of altered photocopied documents on the basis of characteristics present in them revealed that, alterations are detected in 37/100 (37%) black and 8/20 (40%) coloured samples. However, when the generation of photocopies are increased, the detection of the alterations becomes difficult because recopying of the altered copy hide most of the characteristics of alteration.

- All samples have shown expansion of strokes and baseline of printing in 1st, 2nd and 3rd generation photocopies in comparison to their original document. Enlargement of strokes and escapement of baseline have been observed in all samples. The range of expansion increases from 0.001%-0.201% with the increase in the generation of photocopies. This is due to the disappearance of sharp angles, appearance of discontinuity in strokes, loss of smoothness of edges of strokes in subsequent photocopies. The direction of expansion of strokes of the letter and baseline of printing in photocopies from different photocopiers is different. The changes are unidirectional in all generations of photocopies produced by one photocopier.
5.2 CONCLUSION

Rise in the use of toner technology for various criminal activities, results in the increase of the suspect documents which become common subject for forensic examination. It is also a known fact that the contemporary photocopying processes are sympathetic for manipulation to the document. Under these circumstances, it is necessary for FDEs to evaluate nature, source and authenticity of photocopy. Sixty two black toners (both raw and processed) and 28 coloured and 10 raw samples have been examined for their physical and chemical characteristics to determine the nature and source of photocopied document. Collection of samples and their examination has also been carried for the identification of alteration in typed and printed materials, handwritten material and signatures of photocopied documents. The results of the present study are quite significant and appreciable.

- Sixty two black samples have been classified into fifty two groups on the basis of physical characteristics, such as, toner type, fusion methods, splattering effect of the toner and trash marks.
- Sixty two black toners (both raw and processed) have been classified into 34 groups on the basis of their chemical properties of the toners with combination of Thin Layer Chromatography, Ultraviolet (UV) Spectroscopy and Fourier Transform Infrared (FTIR) Spectroscopy.
- Twenty eight processed coloured samples have been examined for the Counterfeit Protection System (CPS) code and Toner Deposit Patterns. Twenty five, out of twenty eight coloured processed samples have been differentiated from each other on the basis of CPS code present on the surface while three samples could not be discriminated on the basis of CPS code. These Counterfeit Protection System codes are specific to the serial number of the photocopier and laser printers. However, they have been fully
differentiated from each other from their printing characteristics that is, Toner Deposit Pattern. Different machines of the same make have also been differentiated from each other by the presence of toner deposit patterns. This type of study has been done for the first time in the field of document examination.

- Coloured samples have also been classified on the basis of their chemical analyses. Almost all the processed and raw coloured samples (except two processed and four raw colour toners) have been discriminated from each other with combination of TLC, UV and FTIR.

- One hundred black and twenty coloured samples of the altered photocopies have also been examined for the determination of alterations. Various features, such as, difference in quality of strokes, difference in brightness of the strokes, extra deposition of toner, discontinuity of background printing, difference in spacing, shape and design and difference in alignment etc. have been observed, which indicate the presence of alterations in photocopied documents. Alterations have been detected in 37/100 (37%) black and 8/20 (40%) coloured samples, when all the features are collectively considered. However, when the generation of photocopies are increased, the detection of the alterations becomes difficult because recopying of the altered copy hide most of the characteristics of alterations.

- Duplication of the trash marks and the degree (percentage) of expansion of the strokes of the letter and baseline of printing from original upto 3rd generation considered as useful characteristic in the determination of the sequence of generation of the photocopied documents. The direction and extent of expansion have also been used to differentiate photocopiers.
RESEARCH PUBLICATIONS


Saini, K. and Saroa, J.S., “Determination of generation of photocopy by image processing”, Problem of Forensic Science (Accepted for publication).

Saini, K. and Saroa, J.S., “Differentiation of Color Photocopy Toners using TLC, UV and FTIR techniques”, Journal of Forensic Identification (Accepted for publication).