Micro-Raman study of the sequence of non-intersecting lines for forged document investigation

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Introduction

In connection with investigation of fraud, counterfeiting, blackmail and anonymous letter cases, forensic experts frequently have to find out, whether the document was altered after signing. In these cases the sequence of crossing printer and pen ink line often needs to be determined in order to resolve whether any of the the printed text was printed after the signature.

If the printed text overlaps or intersects with the signature on the document, the alteration may be investigated by examining the areas of intersections. In this case a number of techniques are available to determine the order of crossing lines. They include standard optical microscopy, as well as more advanced SEM, FTIR-ATR, or AFM technique. When there are no intersecting lines between the printed text and the pen ink lines (see Figure 1 for instance), these standard techniques used for sequencing are no longer applicable.

Figure 1: Example of a fraud document where the printed text doesn't intersect with the signature

This note demonstrates the application of micro-Raman spectroscopy to investigate the chronological sequence of printed and hand-written features on the documents even if there are no intersecting lines.

This new method is based on the micron-scale features generated by the printing process of copiers and laser printers. During this electro-photographic process, dry toner particles with size 6-8 µm diameters, are melted and flattened by pressure onto the surface of the document. The polymer resin, the main component of dry printer toners creates thin surface layer a few µm thick that forms the characters. Incidently thousands of discrete toner particles contaminate the full surface of the paper. These microscopic toner spatters are randomly distributed over the whole document, with approximately 100 spatters/cm^2. As Figure 2. demonstrates, these particles can also be found in the area of the signature. As the chemical nature of these particles is the same as the toner material, they can provide information on the chronological sequence of pen ink and printed text application.

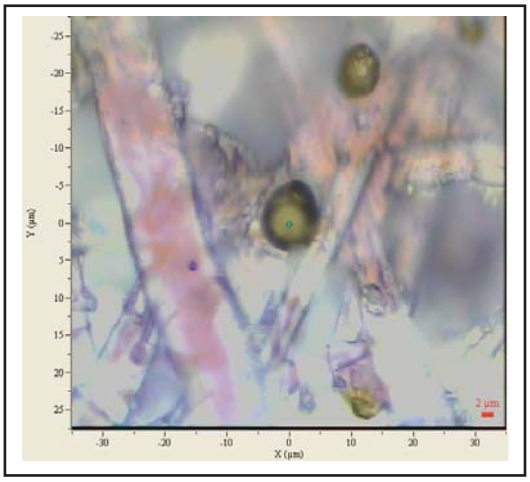

Figure 2: Optical microscopy image of toner spatters on the signature line,

Experimental method

Raman spectra were collected with a LabRAM Aramis confocal Raman microscope. The system was equipped with a 532 nm, 633 nm and 785 nm lasers excitation. Thanks to the confocal design of the system and the laser penetration depth, it is possible to discriminate different layers on the

paper surface. It is then possible to chemically analyze the surface layer only, be it very thin, without interference from the layers underneath.
Based on that principle, the chemical composition of the inks and printer toners used in a particular document was analysed in-situ on the paper. Analysis was performed for blue ink originating from a commercially available ballpoint pen and for black printer toner particles originating from the laser printer. Five blind test-documents were produced, where the ballpoint pen ink line - the signature - was randomly applied before and after printing. Naturally, the signature does not intersects with the printed text on the documents. Using the visual mode of the microscope, microscopic toner spatters were localised over the signature area and the chemical composition of the surface layer over each toner spatter was analyzed at least three times. When the upper layer shows the spectrum of black printer toner, it is concluded that the printing process contaminated the signature area and therefore that the signature was applied before printing (the document was forged).

Results and conclusion

Figure 3 shows the Raman spectrum recorded on the top layer of the toner spatters found in the signature line for the first group of the documents. As the spectrum matches the reference spectrum of black printer toner (Fig 3 inset), the first group was correctly identified as the group of the forged documents where the signature was applied before printing. Conversely, Figure 4 shows that the spectrum from the top layer matches with that of the blue pen ink. This means that the signature was applied over the toner spatters after printing. These 'original' documents hadn't been altered.

This note demonstrates that the micro-Raman technique is suitable for examining the chronological sequence of the printing and signing imprints on the documents even if there is no intersection. This method does not cause damage or impairment to the document nor does it require sample preparation. It is objective and easy to interpret. Application of this method makes the investigation of questioned documents easier and more reliable for forensic experts in criminal cases.

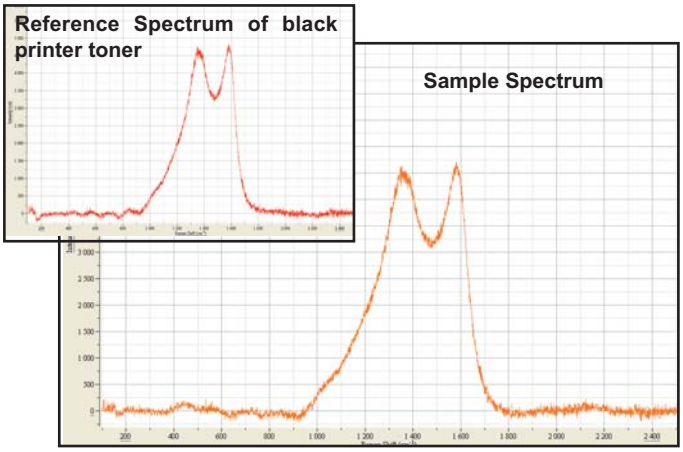

Figure 3 - Raman spectra of the upper layer on the surface of toner spatters on the signature line, when the signature was applied before printing (inset: the reference Raman spectra of black printer toner on paper)

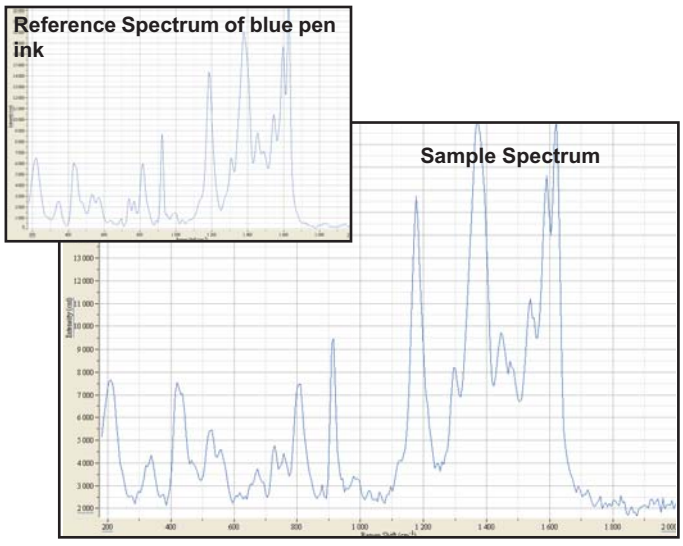

Figure 4 - Raman spectra of the upper layer on the surface of toner spatters on the signature line, when the signature was applied after printing (inset: the reference Raman spectra of blue pen ink on paper)

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