

## Seeing objects in a new light with multispectral imaging

**Keywords:** *Imaging, Anti-counterfeiting, Dermatology, Cosmetics, Forensics, Heritage*

Multispectral imaging provides valuable information on the quality and safety of a vast array of materials from pharmaceuticals to raw meat and burned biscuits. The same imaging techniques can be used to measure skin sensitivity to sticking plaster, detect counterfeit drugs and packaging and gain insight into historical artefacts such as mediaeval manuscripts and weapons. This article attempts to highlight some of the newest applications in multispectral imaging, these diverse applications converge as they all in some way have parameters measurable by the technique such as colour, texture, gloss, shape and size which when combined give previously unseen information.

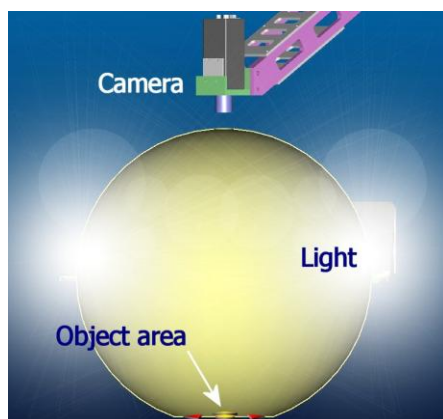
The non-destructive investigation of materials with non-uniform colour and texture can be difficult, tedious and expensive. Conventional techniques such as NIR spectroscopy only measure a single point or average over a fixed area and do not give an objective overall assessment of visual quality. Multispectral imaging can be described as a trade-off sacrificing spectral resolution to increase spatial information giving a 'snapshot' of the combined bulk properties of a sample, handling natural variation and inhomogeneity.

Traditional colour imaging uses three broad bands of colour red, green and blue and is known as RGB imaging. As a consequence of the broad bands RGB imaging has very limited spectral resolution and is unsuited to differentiating samples showing variation within a single broad band. Multispectral imaging refers to multiple wavelengths over the whole range from UV through visible to NIR (230 to 1050 nm). VideometerLab 2, a lab based multispectral imager from the Danish based company Videometer A/S, is based on a high-intensity integrating sphere illumination featuring light emitting diodes (LED) and a black and white high resolution CCD camera (2056x2056 pixels) (Figures 1 and 2). Measurements are combined at up to 20 different wavelengths into a single high resolution multispectral (2056x2056x20) image with every pixel in the image representing a spectrum.

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**Figure 1:** VideometerLab 2: Up to 20 wavelengths via LEDs, uniformly spaced around the inside of the integrating sphere are strobed successively each generating a monochrome image.



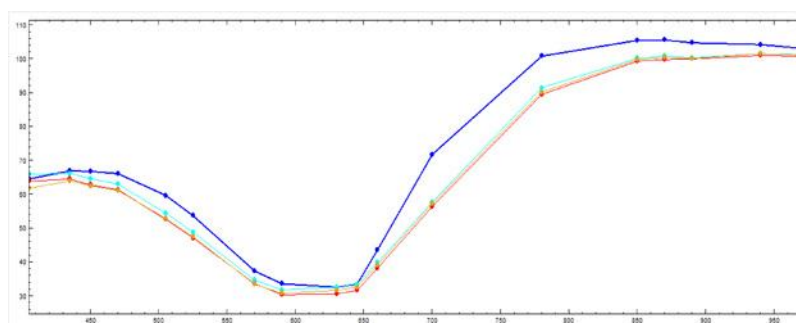


**Figure 2:** Schematic of integrating sphere: Internal reflection of the LEDs by the diffuse white inner surface of the sphere ensures diffuse homogeneous light for increased reproducibility, dynamic range, low scatter and shadow effects.

The choice of illumination wavelength ensures each application can be optimised and is not restricted to the wavelengths spanned by traditional RGB technology. Using LEDs in the UV or NIR adds information not visible to the human eye. As an example, most objects are white or transparent in the NIR region, which allows for the separation of the colour and surface properties of the measured object. Uniform and non-uniform samples alike are simply placed in the target area and custom designed PC software for data capture and analysis means results are available in less than 10 seconds; including sample handling time. A radiometric and geometric calibration procedure with NIST traceable standards is available to ensure accuracy and repeatability, and automatic diagnostic tests can be performed routinely to ensure instrument stability.

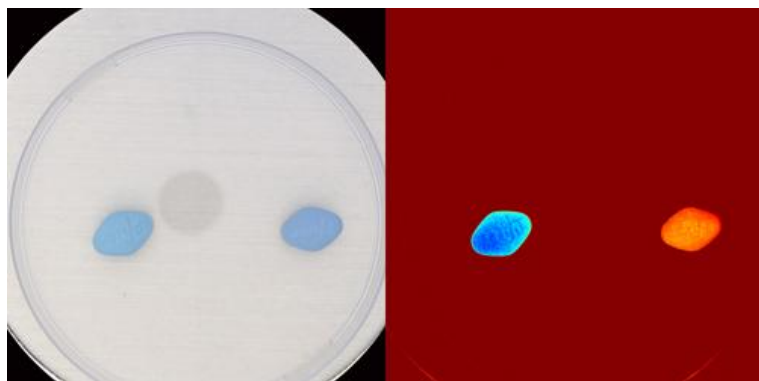
## Anti-counterfeiting

The presence of counterfeit pharmaceutical products poses an obvious hazard to human health. Counterfeits may take the form of missing or incorrect active pharmaceutical ingredient, re-packaged authentic or re-packaged expired product. Characterising incorrectly formulated counterfeit product can be achieved entirely non-destructively and in a few seconds using multispectral imaging.



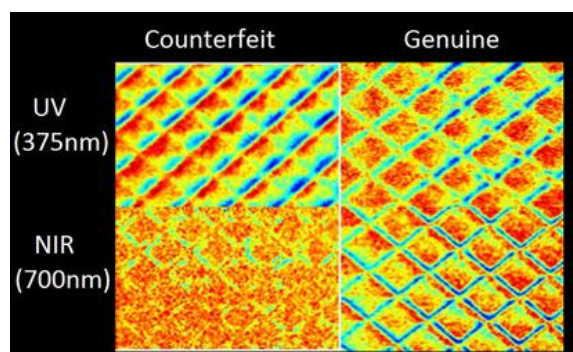
**Figure 3:** Spectra from three genuine and one counterfeit (blue) sample are shown.

The instrument response of the three genuine samples is similar across all illumination wavelengths whereas the counterfeit is clearly differentiated. Data treatments based on these differences can be applied automatically, counterfeit products are shown below as blue, genuine as orange.



**Figure 4:** Left: RGB image of counterfeit (left) and genuine tablet, visible differentiation is difficult. Right: Multispectral false colour image of the same samples, orange is genuine.

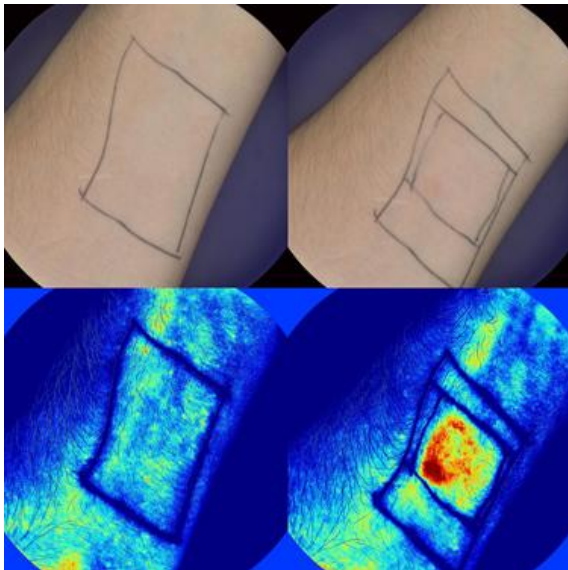
Multispectral imaging techniques can also be used to identify counterfeits through the analysis of their packaging. Although visually it may be difficult to detect counterfeit packaging it is a simple matter to automatically compare the shape and size of characters, trademarks, company names and logos on good/bad packaging, and specialised inks and texture effects on authentic packaging are simple to detect (Figure 5). Subtle changes in size, shape, colour, and markings can all be combined and used to automatically detect counterfeits often without removing the product from the original blister packaging.



**Figure 5:** Textured logo on counterfeit packaging breaks down in the NIR (bottom left area) whereas the genuine packaging remains consistent (bottom right).

## Dermatology

Colophony, a plant extract used in the manufacture of sticking plaster, can cause skin irritation. Recently, multispectral imaging has been used to detect skin irritation caused by band aids even before the 'redness' became apparent to the patient. By simply imaging skin before and after sticking plaster was applied and removed a clear 'redness' due to the removal of skin and the presence of haemoglobin was apparent (Figure 6). Expanding the study showed a clear correlation between application/removal count and irritation. This objective measure of the degree of skin irritation is useful as it allows for faster and more reliable skin testing.



**Figure 6:** Upper: visible images of skin before and after repeated application and removal of sticking plaster. Lower: VideometerLab 2 images.

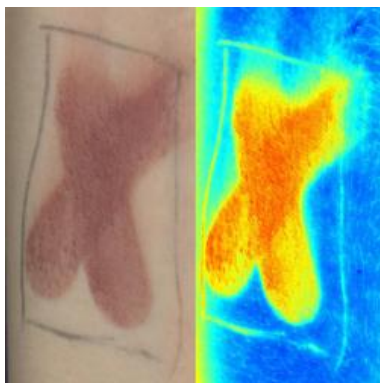
Multispectral imaging is also useful in studying skin pigmentation both in making a diagnosis and in assessing the effectiveness of treatment. Since the presence of hair can make some diagnoses difficult NIR wavelengths can be used to separate hair and skin image contributions. In the example below the hair is 'replaced' by average skin colour allowing subtle changes in skin condition to be monitored more easily.



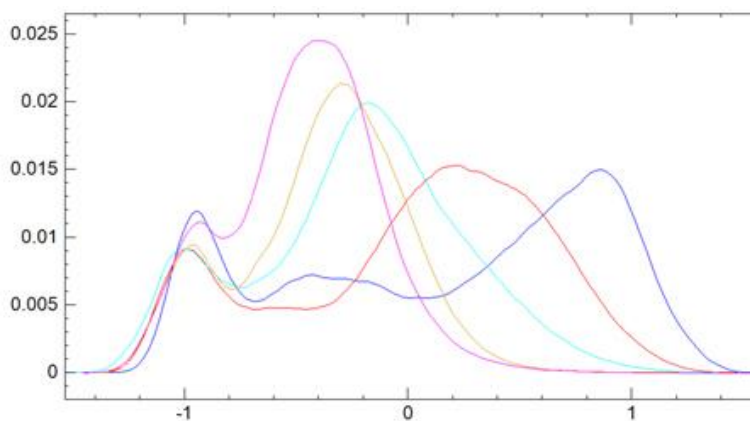
**Figure 7:** Upper image: skin + hair. Middle image: hair only. Lower image: skin with hair shown as average skin colour.

## Wear testing of cosmetics

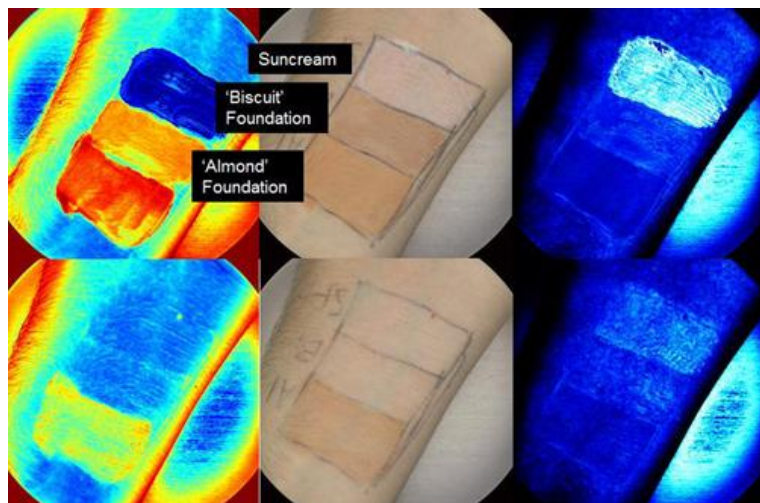
The efficacy of topical pharmaceuticals, cosmetics, skin care products and sunscreens can also be evaluated using multispectral imaging as shown in the wear testing of cosmetics example below. In summary, it is possible to objectively measure the resistance to smearing of lipsticks applied to the skin and then repeatedly wiped off. The resistance of long wearing products can be tested objectively and the point determined when the product would require re-application.



**Figure 8:** Testing the 'staying power' of lipstick.  
Lipstick on skin Left: daylight view Right: VideometerLab 2 image.



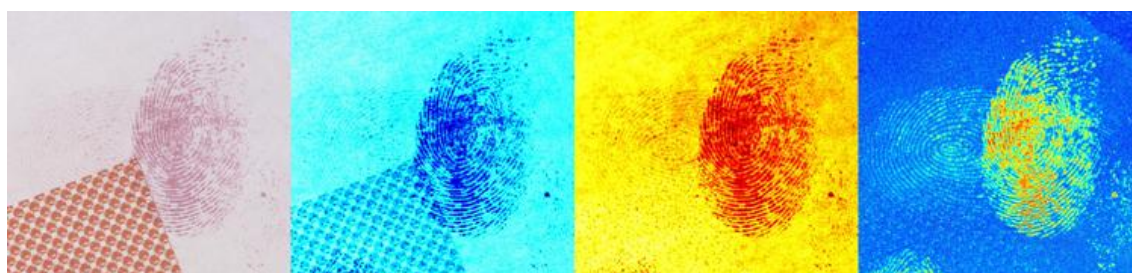
**Figure 9:** Lipstick wear study. A single application of lipstick on skin is wiped off repeatedly as multispectral images were taken. As the product is removed the band at position 1 on the x-axis is shifted towards -0.5. New applications of lipstick can be monitored (the band at position -0.5 shifts towards 1 as applications increase) not shown. It is then trivial to calculate intensity per pixel and to predict when re-application is required. Examples showing sunscreen and foundation cosmetics are shown below in figure 10.



**Figure 10:** Various sunscreen and foundations images. Upper: immediately after application. Lower: after repeated wear testing

## Forensics

The examination of fingerprints on banknotes requires a method to make prints visible before comparison; treated prints are viewed as purple in colour. Unfortunately, this is not a useful methodology for all notes since UK £20 banknotes are purple and treated prints are still not well distinguished. By employing various data treatments and noise reduction techniques the VideometerLab 2 can be used to highlight faint prints even on red/purple backgrounds (figure 11).



**Figure 11:** A single set of fingerprints shown after various data treatments. From left to right; RGB image; image at 630 nm; MNF; nCDA.

The RGB image shows a main print and a very faint secondary print to the left. This faint print starts to become visible as the contrast is enhanced using 630 nm (orange) illumination. Transforming with a Minimum Noise Fraction analysis then automatically contrasts regions of interest, and finally normalized Canonical Discriminant Analysis shows the greatest contrast.

The forensic examination of documents such as disputed wills and altered cheques for potential fraud can be achieved by careful analysis of materials such as ink and paper as well as the individual characters in handwritten, type and commercial printing.

## Historical Artefacts

In the study of historical artefacts it is essential that the analysis techniques used should be non-destructive. Multispectral imaging offers a non-invasive, non-destructive method for the investigation of artefacts such as historical parchments and engraved metal objects, a selection are shown below:



**Figure 12:** A Tudor rose emblem on a knife comes into view. A careful selection of wavelengths and false colour images will be evaluated to bring clarity. By focusing on small sections it is possible to further enhance the contrast.



**Figure 13:** Left: RGB image Right: VideometerLab 2 image.

Text from the 'Elder Westrogothic Law', the oldest complete extant manuscript in Swedish is made readable using multispectral imaging. Analysis of four partially or largely unreadable pages was possible using the VideometerLab 2.

## Conclusion

There is incredible variety in the applications of multispectral imaging using the VideometerLab 2. Developed initially to support food technologists ensure the quality and safety of processed foods it does not require highly skilled operators, results are intuitive, it is fast and very easy to use. As a result multispectral imaging can now be found in the most unlikely places such as museums and hospitals as well as forensics departments and anti-counterfeiting labs. The ability to see the unseen, and to find the important detail ensures the continued rapid uptake of multispectral imaging.