Identification of dyed jadeite using visible reflection spectra

Yan Liu, Taijin Lu, Manjun Wang, Hua Chen, Meidong Shen, Jie Ke and Beili Zhang

Abstract: Burma jadeites are often dyed to improve their colour. Most dyed jadeites are identified using a microscope or a high resolution digital imaging system. However, when dye-related microscopic features are not clear, their visible reflection spectra can be used for identifying dyed jadeite rapidly and accurately. This visible spectral method can be used to identify both dyed-only jadeite (C type) and the dyed and impregnated jadeite (B+C type), which may otherwise be difficult to distinguish.

Introduction

Low-quality jadeites are often impregnated and/or dyed to improve their transparency and colour. Polymer-impregnated jadeite is classified as B type in the gem trade and can be identified using FTIR spectroscopy (Fritsch *et al.*, 1992; Lu and Shigley, 2000).

Dyed jadeite is classified as C type, and is usually identified using visual imaging techniques with a microscope or a high resolution imaging system, since the dye is commonly visible in the pores or spaces between the inter-locking crystal fibres. Some dyed materials can be detected using X-ray fluorescence analysis (XRF) such as some metal-containing dyes. But since the major colour-inducing dyes are chromium-containing salts, it can be difficult to judge the origin of the chromium in the jadeite under test using only XRF (Zhang, 2006; Shigley, 2008). So although in most cases, 'C' jadeite can be easily identified by trained gemmologists. When high-quality colourless transparent jadeites with a fine-grained, compact and uniformly distributed texture of fibrous crystals are dyed, the characteristic microscopic features of the dyed jadeite may be unclear or hardly visible using traditional microscopy. Such pieces can be difficult to distinguish from jadeites of natural colour.

Natural green and lavender jadeites commonly display five characteristic spectral absorption lines in the visible wavelength range which are attributed to their Cr and Fe contents (see Webster, 1994; Nassau, 2001; Zhang, 2006). Although the absorption lines of some transparent jadeites can be recorded with a gemmological spectroscope (GIA, 1990; Zhang, 2006), the absorption lines of most jadeites are not easy to detect and measure.

Since the spectra of most jadeites cannot be measured using the commercially available visible spectrophotometers generally used in gemmological laboratories due to their size, shape, lack of transparency and other factors, we report here a method to identify dyed jadeite by measuring the visible reflection spectra using a TrueColor spectrometer with dual integrating spheres. By combining reflection spectra in the visible range with IR absorption spectra, dyed-only and impregnated and dyed jadeites can be accurately identified.

Measurement and samples

Although jadeites range from translucent to opaque, only a small proportion of jadeites are transparent enough to yield transmission spectra. But reflection spectra obtained from translucent or opaque stones can be measured both for colour grading by a colorimetric method and for the spectroscopic study of jadeites.

Reflection spectra of various jadeites were obtained using a new type of visible reflection spectrometer (TrueColor Spectrometer) developed by one author (Y.L.) for spectral measurement and colour grading of coloured diamonds and gemstones. This spectrometer has dual integrating spheres, one for providing illumination and spectral measurement and the other for hosting the sample, as shown in *Figure 1*. A collimating lens is installed in the measurement integrating sphere. The lens is focused on the aperture between the measurement and the sample integrating spheres. The reflected light from a measured jadeite with the transmitted light reflected back by the sample integrating sphere is collected by the lens, and then sent to the spectrometer by an optical fibre cable.

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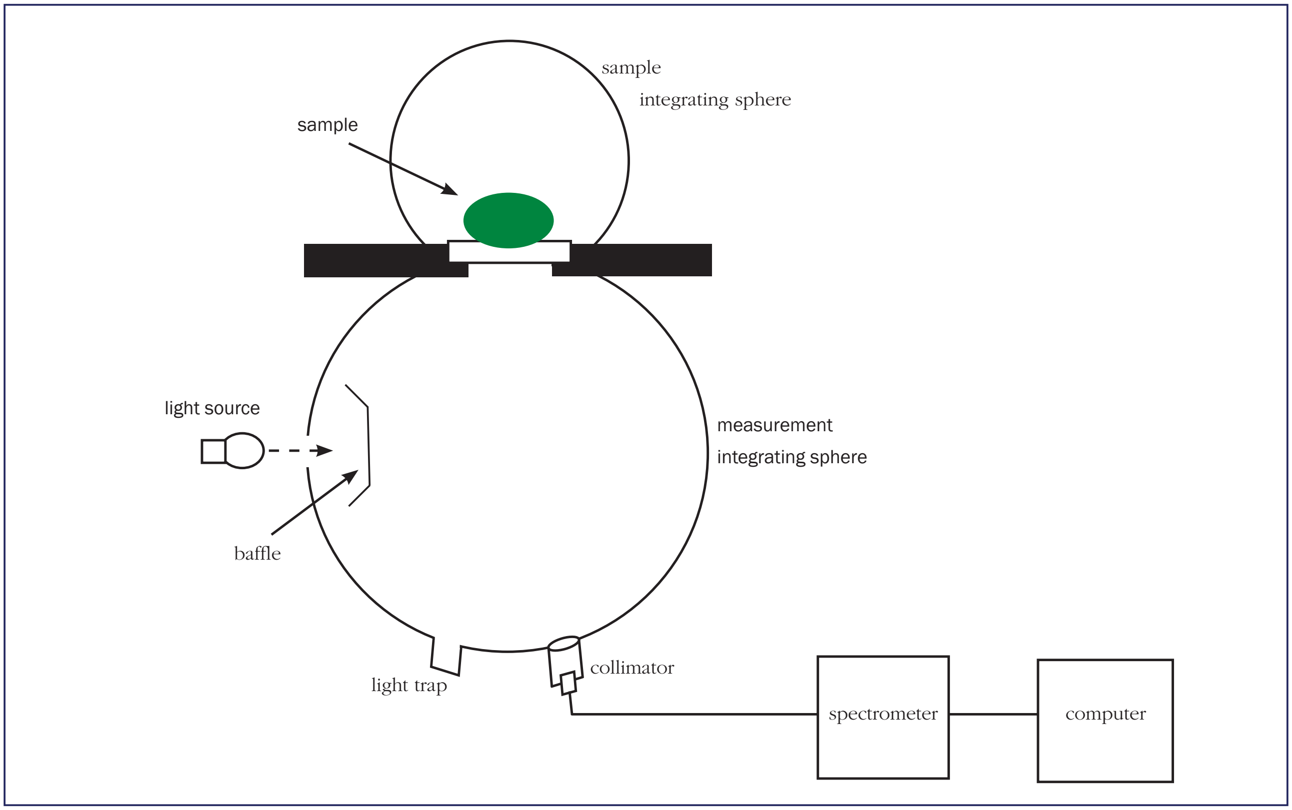

Figure 1: Schematic diagram of the TrueColor reflection spectrometer.

A diffraction grating separates the light into a spectrum on a CCD array within the spectrometer. The computer receives the electronic signals generated by the CCD and converts them to a reflection spectrum, and then calculates colour and provides colour grades.

The sample integrating sphere provides an environment similar to that for visual observation of jadeite in the trade. If a jadeite is transparent, a portion of transmitted light is reflected back by the sample integrating sphere and enters the measurement process. Consequently, the reflection spectrum of a translucent jadeite is significantly higher than that measured without an integrating sphere. More importantly, for the transparent jadeites, the measured reflection spectrum is similar to that observed on a white background in the trade.

Although visible wavelengths range only from 400 to 700 nm, the wavelength range of the spectrometer has been established at 380 to 760 nm to aim for more accurate colour measurement and grading. The extended wavelength range also makes it possible to measure the spectral features of gemstones and coloured diamonds in the 380 to 400 nm and 700 to 760 nm ranges for detailed study of such centres as GR1 at 741 nm in green diamonds.

Before taking a measurement, the spectrometer is calibrated by recording three spectra: that of a standard white tile, a standard black tile, and one without a tile. The procedure for measuring the reflection spectrum of jadeites is simple and quick: a jadeite is placed on the aperture between the measurement and

Figure 2: Three B+C type jadeite slabs typical of many hundreds examined.

Figure 4: A carved Buddha pendant of B+C type jadeite.

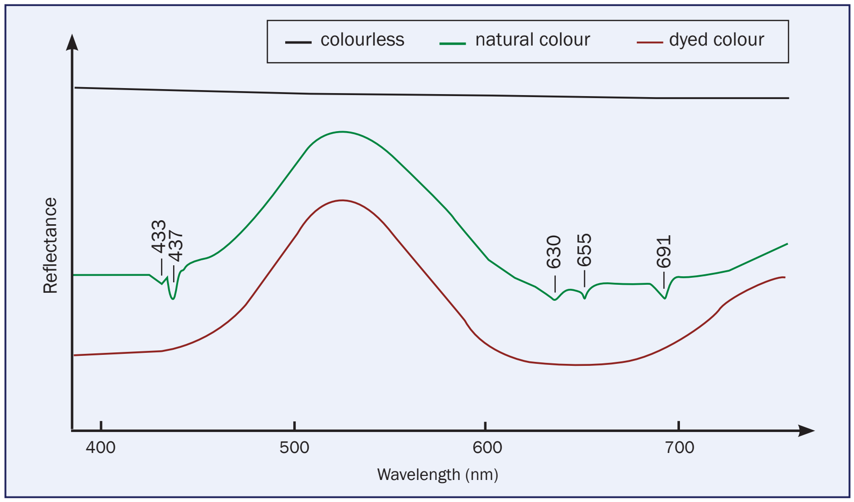

Figure 3: Reflection spectra of a typical natural green jadeite (green line), a dyed green jadeite (red line) and a colourless jadeite (black line).

sample integrating spheres, the sample integrating sphere is then fitted on the top, the measurement button on the screen of the computer is clicked, and a reflection spectrum will be collected and displayed on the screen. The whole measurement process takes about one minute. For many (opaque) jadeites where only reflection is measured, the sample integrating sphere is not necessary, and any size of specimen can be measured as long as it can be put on the spectrometer.

Many hundreds of natural, impregnated, dyed-only, and impregnated and dyed jadeites have been examined. Most samples have been green, but a few were lavender. A natural colourless jadeite slice was measured as a reference spectrum. Several jadeite slabs of B+C type with different colours (obtained from a jadeite factory in Guangdong province, China) were examined in detail using non-destructive imaging and spectroscopic techniques at the National Gemstone Testing Center, China (see *Figure 2* for typical samples).

Results

Figure 3 shows typical reflection spectra in the visible wavelength range of naturally-coloured green jadeite and dyed green jadeite. That of the natural jadeite shows the characteristic absorption lines at 433 nm, 437 nm, 630 nm, 655 nm and 691 nm. The strengths of these five lines

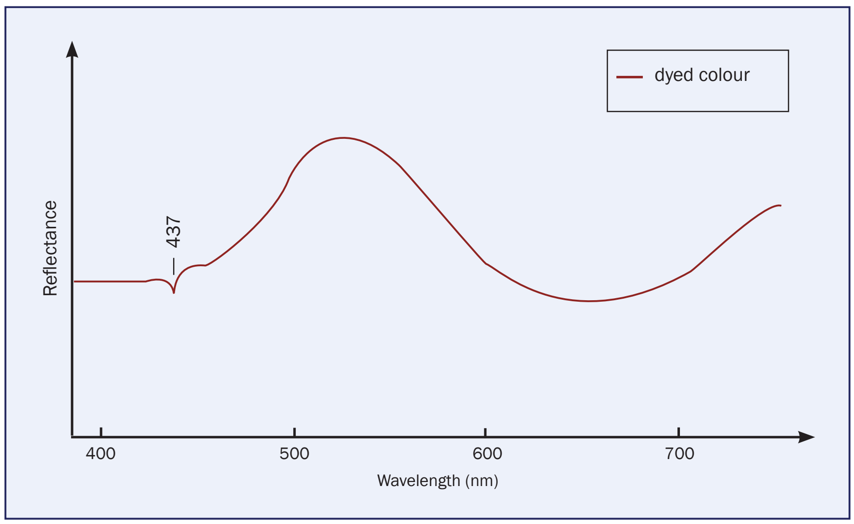

Figure 5: The reflection spectrum of a B+C type green jadeite with a weak 437 nm absorption line.

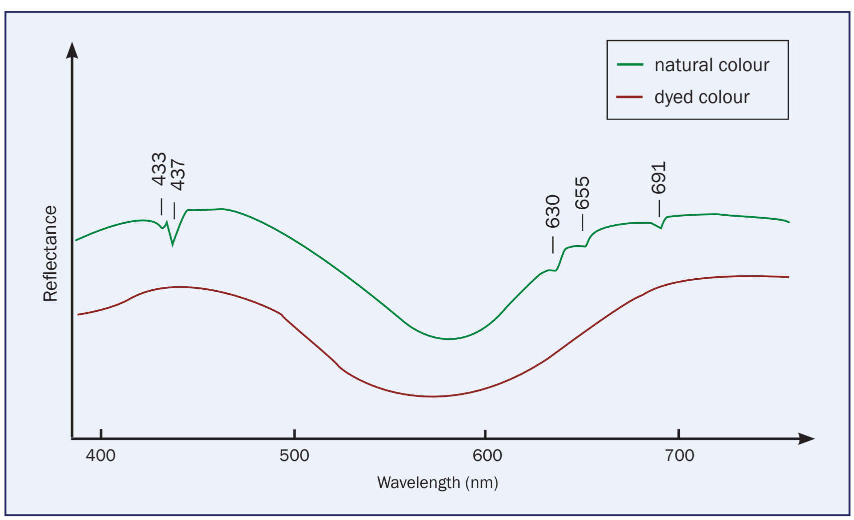

Figure 6: Reflection spectra of natural lavender jadeite and dyed lavender jadeite.

change significantly depending on the nature and saturation of the colour, but normally the 437 nm line is the strongest. The reflection spectra of many natural jadeites show only the absorption line at 437 nm, with the other four lines being very weak or invisible.

Although the reflection spectrum of dyed green jadeite does not have the five sharp absorption lines (see *Figure 3*), its basic shape is similar to that of the naturally coloured green jadeite, thus appearing similar in colour. Indeed, the two greens cannot be distinguished using only the naked eye.

Figure 4 shows a B+C type of green jadeite Buddha pendant, and its reflection spectrum is the same as the red line spectrum shown in *Figure 3*. This is typical of most B+C type green jadeites.

Although only a few of 'B+C' jadeites with an enhanced green colour due to dye treatment show a weak 437 nm absorption line *(Figure 5)*, almost all show a relatively strong and broad band at longer wavelengths near 680 nm. In other words, a weak 437 nm absorption line together with a broad absorption band and a long wavelength range is a diagnostic feature of a B+C type jadeite. The long wavelength transmittance band visible in *Figure 5* are probably the reason that such dyed jadeite appears red under the Chelsea Colour filter.

The spectrum of natural colourless jadeite is flat in the visible range and lacks any sharp absorption lines (*Figure 3*), so when such material is dyed, it too lacks sharp absorption lines and appears similar to the red spectrum in *Figure 3*.

The five characteristic absorption lines in the reflection spectra of naturally coloured green jadeites are also present in naturally coloured lavender jadeites (see *Figure 6*). The red line in *Figure 6* shows the typical spectrum with similar broad absorption bands but without the five sharp spectral lines.

Discussion and conclusions

Jadeites are translucent to opaque, and not sufficiently transparent for transmittance spectra to be routinely obtained by the kind of UV-Visible spectrophotometer used in most gemmological laboratories. To study the spectral properties and to measure the colours of jadeites, we have to measure the reflection spectra.

Naturally coloured green jadeites from Burma typically show five absorption lines at 433 nm, 437 nm, 630 nm, 655 nm and 691 nm in their reflection spectra as shown in *Figure 3*.

In contrast, the reflection spectra of most dyed green jadeites do not show these five absorption lines and this absence is an indication that the measured jadeite has been dyed, particularly for those jadeites with vivid green colours. The reflection spectra of both dyed only (C type) and impregnated and dyed (B+C type) jadeites can be identified by this method. Since the 437 nm absorption line is the strongest of the five lines, it may be detected in some of the jadeites dyed vivid green, which suggests that the starting material was a low grade pale green jadeite. The reflection spectra of such dyed green jadeites also show a relatively strong broad absorption band above about 680 nm, which is related to the dye. The existence of both the weak 437 nm absorption line and this broad band at the longer wavelength in vivid green jadeites indicate that they are low saturation jadeites that have been dyed. In fact, any vivid green jadeite with only a weak 437 nm absorption line suggests that it has been dyed, since natural vivid green jadeites should show all five absorption lines.

Identification of some dyed-only green jadeites without clearly visual microscopic features can be a challenge using only traditional microscopic observation and FTIR techniques, but measurement of their reflection spectra by the TrueColor spectrometer with dual integrating spheres can provide a rapid and effective technique for their identification and distinction from natural jadeite.

The reflection spectra of naturally coloured lavender jadeites also show the five narrow absorption lines characteristic of green jadeite, whereas dyed lavender jadeites only show broad absorption bands in their reflection spectra.

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References

Fritsch, E., Wu, S.T., Moses, T., McClure, S.F., and Moon, M., 1992. Identification of bleached and polymer-impregnated jadeite. *Gems & Gemology,* **28**, 176-87

GIA., 1990. *Gem Reference Guide.* Gemological Institute of America, Santa Monica, California, USA

Lu, T., and Shigley, J.E., 2000. Non-destructive testing for identifying natural, synthetic, treated, and imitation gem materials. *Materials Evaluation*, **43**, 1204–8

Nassau K., 2001. *The Physics and Chemistry of Color,* 2nd edn. John Wiley & Sons, New York

Webster, R., 1994. *Gems, Their Sources, Descriptions and Identification*, 5th edn. Revised by P.G. Read. Butterworth–Heinemann Ltd., Oxford

Zhang, B. (Ed.), 2006. *Systematic Gemmology*. Geological Publishing House, Beijing, p.550

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