GEMSTONE IDENTIFICATION USING FLUORESCENCE TECHNIQUE

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Abstract

Fluorescence is the emission of light by a substance that absorbs light or other electromagnetic radiation. To date, fluorescence is useful in separating genuine and artificial gemstones. In this study, multiple excitation sources, namely blue, green, red lasers, and white lamp were used to illuminate several samples to produce fluorescence. The samples used were genuine ruby crystal, fake ruby crystal and two dye solutions. The fluorescence signal was then detected using a spectrometer. From spectroscopic analysis, each sample gave a different spectrum and the corresponding wavelength was identified through its peak. The analysis showed that the spectrum peak of genuine ruby crystal was at 694.32 nm, whereas the spectrum peak of fake ruby was at 807.72 nm. This study successfully demonstrated the use of the fluorescence technique to distinguish genuine ruby crystal from its artificial. A similar technique can also be used to identify other gemstones.

Keyword: Excitation, Fluorescence, Gemstone, Ruby Crystal

Introduction

Luminescence can be divided into two categories which are fluorescence and phosphorescence, depending upon the nature of the excited state. In excited singlet states, the electron in the excited orbital is paired to the second electron in the ground state orbital. Consequently, return to the ground state is spin allowed and occurs rapidly by the emission of a photon. The emission rates of fluorescence are typically 108 s-1, such that a typical fluorescence lifetime is approximately 10 ns (10×10-9s). Short timescale of fluorescence, measurement of the time-resolved emission requires sophisticated optics and electronics. Fluorescence is widely used because of the increased information available from the data, as compared with stationary or steady-state measurements (Lakowicz, 2013).

The florescent phenomena have been established in the early 19th century in the research of chlorophyll by Sir David Brewster in 1833 (White and Argauer, 1970). Then, the use of fluorescence technique has been on the increase in the study of water pollution and dissolved organic matter. Orlov et al. (1995) reported that fluorescent diagnosis of organic pollution in the water environment is an effective method especially for the identification of hydrocarbons content in the open sea. The use of the fluorescent technique as a diagnostic tool for water and wastewater control was investigated and discussed by Babichenko et al. (1995). The method involved simple apparatus and quick pretreatment of the water sample. The fluorescence technique can be an alternative, which allows on-line processing and control at a reduced operating cost (Marhaba et al., 2000).

The fluorescence technique mainly involves the measurement of the fluorescence spectrum of certain materials either in the form of liquid, solid, or gas. Sodium vapor was first observed by Wiedemann and Schmidt and later studied with the most interesting results by R.W. Wood. In gases, the factors determining luminescence are probably easier and more amenable to experimental control than in the other state of matter. However, the fluorescence technique is more suitable to be applied for the material in the form of liquid and transparent solid. In this form, the sample does not need any special chamber during the fluorescence measurement (Morse, 1906).

In the basic system of fluorescence spectroscopy, a laser with a wavelength varying between 180 nm to 800 nm passes through a solution in a cuvette. Then, the signal from the solution is collected by a spectrometer. The mechanism of this process is when an atom or molecule of certain material first absorbs energy from the laser called excitation. Shortly after the excitation, the material emits a photon of a longer wavelength known as fluorescence. This technique is normally used for analytes that can be dissolved in solvents such as water, ethanol, and hexane. However, it is also can be used for transparent solid materials, for example, glass and gemstone. In this study, we applied this technique to observe the fluorescence spectra of different materials that can be used as fingerprints of specific materials. These spectra were further used to determine the identification of genuine gemstone used in this study.

Materials and Methods

The experimental setup consisted of three main parts including sources, samples, and detection units (**Figure 1**). Three different laser pointers and a white lamp were used as the sources. The laser pointer is a small hand-held device with a power source (usually battery) and laser diode emitting with a narrow coherent low-powered laser beam of visible light, intended to be used to highlight the sample of interest by illuminating it with a small bright spot of colored light. In this study, blue, green and red lasers were employed. A wide range of laser wavelengths is crucial as different materials require specific wavelengths to effectively absorb the photon during excitation process. A small box was used for the sample compartment. The box was opaque-based material to inhibit any reflection of the excitation sources from being exposed to the surroundings as well as to prevent the outside light entered the compartment. A spectrometer was used to view and analyze a range (or a spectrum) of a given characteristic for a substance. The samples used in this study were genuine ruby crystal, fake ruby crystal and two types of dyes (methyl orange solution and yellowish dye). Ruby crystal is a pink-colored gemstone and is extremely hard. It is known as corundum, which contains small percentage of chromium in sapphire (Al_2O_3) host. This gemstone is used widely as jewelry. Therefore, a detection using a fluorescence technique is necessary to ensure the genuineness of the stone.

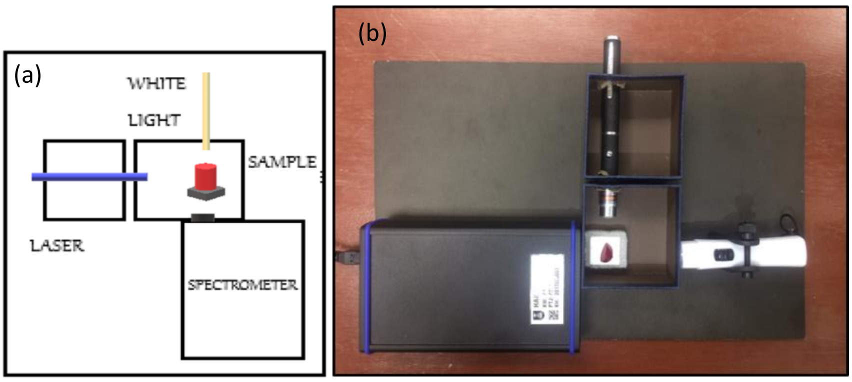


Figure 1 Schematic (a) and actual (b) diagram of the setup

Result and Discussion

From the spectrometer measurement, the peaks of the blue, green and red lasers were at 406.13 nm, 533.06 nm, and 656.28 nm, respectively. Meanwhile, the white lamp exhibited a broad spectrum with the main peak at 452.87 nm. The spectra of excitation sources are shown in **Figure 2**.

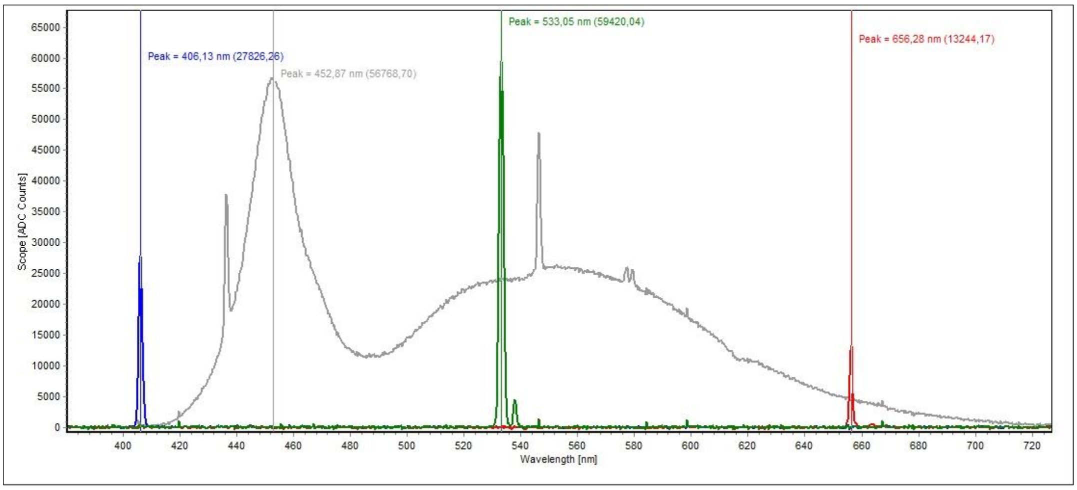
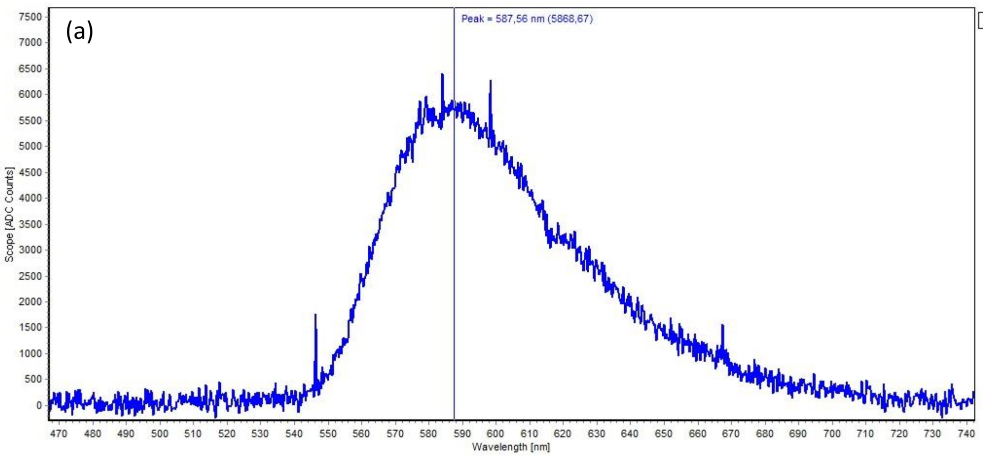


Figure 2 Spectra of different types of lasers (blue, green, red) and white lamp used in this study

The fluorescence of methyl orange solution and yellowish dye was easily detected due to their bright and broad spectra. Among the sources, the white lamp gave a better fluorescence compared to blue, green and red lasers. From the spectrometer analysis, methyl orange solution showed a broad spectrum with the peak was at 587.56 nm, Similarly, yellowish dye also showed a broad spectrum where its peak was at 532.39 nm. The spectra of both dyes are shown in **Figure 3**.



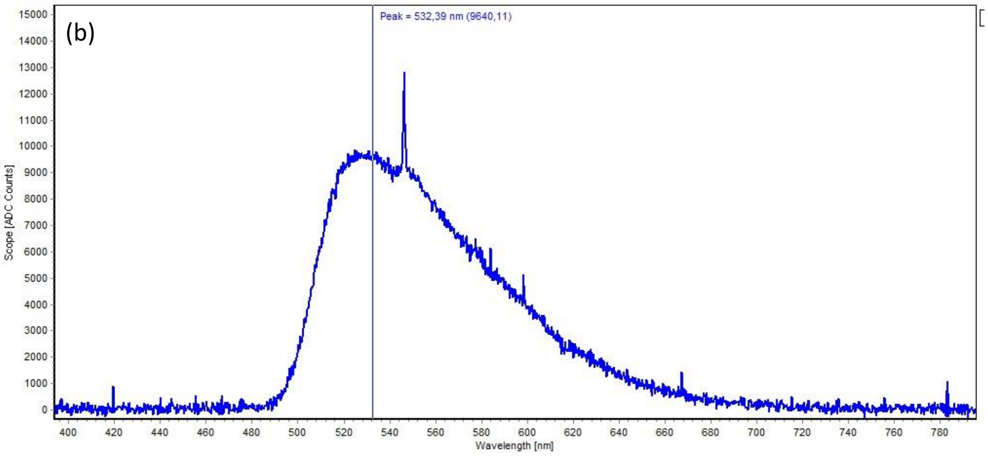
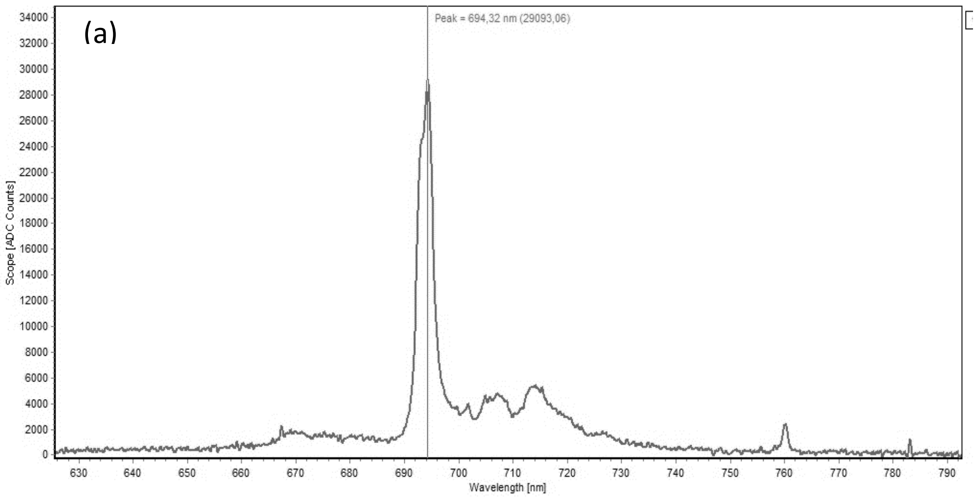


Figure 3 Spectra of methyl orange solution (a) and yellowish dye (b) after excited with white lamp

The identification of the gemstone was demonstrated by using a ruby crystal as a sample. Based on literature, the ruby crystal possesses an intense emission peak at 694 nm (Ueda and Tanabe, 2010). This peak is originated from the transition of Cr^{3+} ions from excited electronic states ^2E to ground state $^4A_2$ (Machenko and Kiselev, 2017). **Figure 4** indicates the difference of peak spectra between the genuine and the fake ruby crystal following excitation by lasers at 532 nm. The peak spectrum of the genuine ruby was at 694.32 nm, meanwhile the peak of the fake ruby was at 807.72 nm. The identification of the genuine ruby was confirmed based on these spectral differences. This technique potentially can be used to identify original gemstones. For instance, it can be used to identify real diamonds from zirconia. The identification is vital given the fact that zirconia is very much identical to diamonds, but its price is much cheaper than diamonds. By using the fluorescence technique, these gemstones can be convincingly differentiated, and the genuineness of the diamonds can be determined. From literature, diamonds have a broad fluorescence spectrum with a central peak of approximately 700 nm (Schreyvogel et al., 2015).



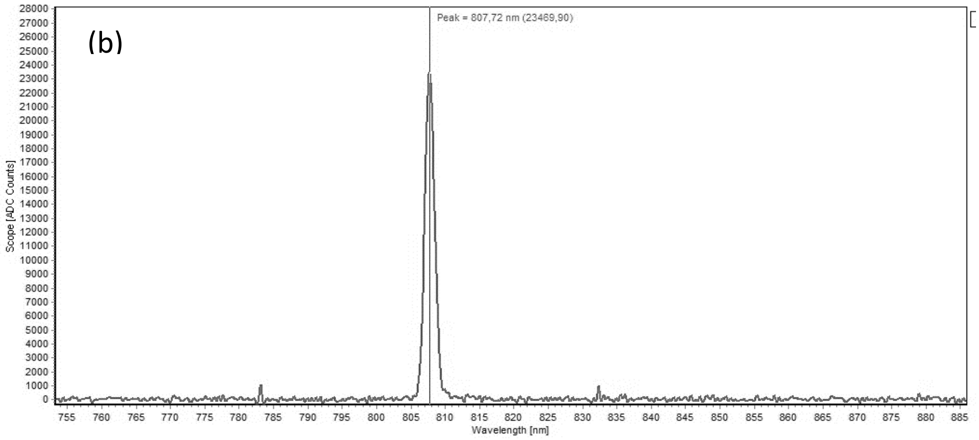


Figure 4 Spectra of ruby crystal (a) and fake ruby crystal (b) after been excited with 532 lasers

Conclusion

Different spectra were obtained from different samples using four different excitation sources. The spectra of the genuine ruby crystal, fake crystal and dye solutions were detected by blue, green, red lasers, and white lamp. Based on the results, we can conclude that genuine gemstone can be identified using the fluorescence technique. This technique can be considered as simple, quick and non-destructive. We hereby proposed the use of this technique for identification other types of gemstone such as diamonds, sapphires, and emerald.

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Conflict of interests

Authors hereby declares that there is no conflict of interests with any organization or financial body for supporting this research.

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