Analysis of luminescence on Aceh natural gemstone

Suhrawardi Ilyas*, Kurnia Lahna, Mutia Larasary Ariyani

Department of Physics, Faculty of Science, Syiah Kuala University, Darussalam, Banda Aceh

*Email: suhra2020@gmail.com

Abstract. Luminescence is an optical characteristic of materials under optical illumination. We have studied the luminescence of gemstone samples of nephrite which are common in Aceh. The samples were illuminated using two laser beam, green laser at 543 nm and red laser at 633nm. The transmitted and scattered light from samples were then resolved using a prism and characterized using spectrometer. The analysis shows a various luminescence and optical absorption across samples, which is due to some minutes of impurity in Aceh’s natural nephrite.

1. Introduction
Nephrite is a variety of the calcium, magnesium, and iron-rich amphibole minerals. The common name for nephrite is jade. The chemical formula for nephrite is Ca_2(Mg,Fe)_5Si_8O_22(OH)_2. Most nephrite comes in translucent green or grey, while occasionally yellow, brown, and white nephrites may be found. Nephrite is used as ornamental stone as carvings, beads, or cut gemstones. It has been used in many cultures since Early Neolithic times in form of tools or amulets. Archeological excavations in Balkans, Poland, Sardinia and Switzerland have resulted a lot of artifacts made of nephrite [1]. The crystalline nephrite has monoclinic crystal system and possesses splintery to granular fracture [2].

In recent years the natural gemstone business in Aceh has reached its booming time. Suddenly people found their interest in procuring or acquiring the best looking gemstones for rings and bracelets. One of Aceh natural gemstone that attracts a lot of attention is nephrite, which mostly originated in Aceh Barat and Nagan Raya districts. Initially raw nephrites were smuggled out from Aceh, until the people realized their value. However, little attention has been put on scientific studies of this nephrite to reveal their specific properties. Therefore we put some effort in investigating its optical properties under illumination.

The optical properties of gemstone minerals have been investigated thoroughly in many part of the world. In more recent times there has been a lot of scientific interest in colors and color modifications in gemstone minerals. Science of gemstones deals with their identification by nondestructive means and understanding of origin of color and excellent optical properties [3]. Optical methods have long been used to obtain properties like refractive index which still remains an important parameter as a preliminary test to identify the gemstone/mineral. The spectroscopic studies of gem grade minerals are essentially directed towards some of these features in identifying and understanding the spectral
properties of chromophores, either chemical impurities and/or radiation induced point defects, in solids. A variety of spectroscopic methods are used to address the problems of the gemstone identification and identification of origin of colors and color modification treatments. Luminescence studies may reveal the electronic absorption on optical range, i.e, ultra violet, visible and near infrared region [4]. Some gemstone revealed strong absorption spectrum at certain wavelength. This absorption may indicate impurities in material or certain optical characteristic of crystalline structure.

There are almost 4000 known minerals, of which only about 50 are commonly used as gemstones. Those that form crystals of sufficient size and quality to be cut and fashioned as gems are referred to as ‘gem quality’ or ‘cuttable’ pieces; other minerals or rocks with particularly attractive features (color, texture, or pattern) may be called ‘decorative’ pieces. Crystals are usually faceted (cut and polished) to give a gemstone with a number of flat faces, while decorative stones are mainly tumbled or polished to produce pieces for personal adornment [5,6].

In this study we investigated the luminescence from Aceh natural nephrite illumination by two laser beam simultaneously. We used green laser beam at 543 nm and red laser beam at 633 nm. This is a preliminary study of optical properties of Aceh natural gemstones.

2. Experimental Methods
We acquired natural nephrite gemstone materials from some amateur gemstone polishers in Banda Aceh of Indonesia. Some materials had been cut and polished in common form (as for ring and bracelet) and some in raw form that had been cleaved along their natural surface. They were mined from natural rock formation in Aceh Barat and Nagan Raya districts.

The size of samples that had been cut and polished is about 1 to 1.5 cm in length and 1 cm in width. The shape of raw materials were irregular, with surfaces that showed its natural fracture patterns. Samples were placed on sample holder and were illuminated with 543 nm green and 633 red HeNe laser sources. Then the scattered light from samples was collected through an aperture and sent to an optical prism spectrometer. The spectrometer resolved the light from the samples and separated each spectrum spatially. We also rotated samples in such a way that any difference in light scattering due to minute impurities or crystalline defects may be observed.

3. Result and analysis
When samples were placed under laser illumination, the scattered light came in two forms, the reflected beam and transmitted beam. Both the reflected and transmitted beams tend to be diffusely scattered by the samples, due to the optical diaphaneity of samples. Most samples came as translucent materials, not transparent, although they show some degree of crystalline structure. Figure 1 showed the reflected beam from both the surface and the internal granulation of the jadeite sample, under red laser illumination. The reflection from surface is specular, which is seen as bright spot inside a wide reflected bean on a sheet of paper. The translucency of sample gave semi-diffuse reflection which is seen as broad, granulated reflected beam on the paper. This is due to the degree of granularity of sample. Figure 2 showed the internal scattering of amber when most laser beam penetrated the sample. The internal scattering occurred within the sample, that makes the inside of sample was illuminated almost fully by laser light scattering. Amber is amorphous; therefore it is more transparent to light penetration. Laser light could then be transmitted out by sample, which is not the case at sample on Figure 1 where more light is diffused.

Meanwhile, the interesting reflection was observed in Figure 3, when the crystalline microstructure produced specular backscattering from the sample. When light penetrated into the sample, the microstructure of crystal produced several reflections from certain crystal orientations, therefore many specular orientations at different direction were produced.
Figure 1. Jadeite under red 633 nm laser illumination, gave semi-diffuse reflected beam from the surface and the grain within the depth of 2 mm inside the gemstone. The reflected beam was shown on a sheet of paper on the top picture. Reflection from the surface is almost specular due to the polished surface, seen as bright spot in the middle of reflected beam, while the semi-diffuse reflection is originated from the internal structure of samples.

Figure 2. Translucent properties of amber produced strong internal scattering within the sample. This means more volume of bulk material can be exposed to laser light.
Luminescence spectroscopy is very important in gemstone analysis that it could be used to measure the energy levels of luminescence centers. Luminescence centers may explain the energy band structure of crystalline materials as well as impurities that may occur in the materials. Under 633 red HeNe laser illuminations, we did not observe any luminescence from the sample. This is due to low photon energy of red spectrum, which caused no excitation of electron onto conduction band. The spectrometer only showed red line associated with original 633 nm spectrum from the laser that is scattered or transmitted through the sample.

However under illumination by 543 nm green laser, we observed several luminescence lines originated within the samples. Figure 4 shows the luminescence spectrum from the gemstone sample under simultaneous green 543 nm and red 633 nm illumination. We observed a blue luminescence spectrum emitted by the sample at 422 nm as shown in Figure 5. This spectrum showed an excited energy level of natural nephrite crystal.

When the optical arrangement is optimized under green 543 nm illumination only, several weak luminescence spectra appeared, as shown in Figure 6. We observed three more spectra, at 485, 462, and 443 nm, respectively. These luminescence spectra may appear due to impurities inside materials, because they are almost uniformly distributed. These luminescence spectra may open new opportunities in using Aceh natural nephrite other that as rings or necklaces. Several observations are needed in order to understand the source of impurities in the material.
**Figure 4.** The original laser line as resolved by the prism spectrometer

**Figure 5.** The spectra resulted under red 633 nm and green 543 nm light. The blue line at 422 nm appeared on the left
Figure 6. The spectra resulted under green 543 nm light. The blue line at 422 nm appeared on the left, as well as three light blue lines at 485 nm, 462 nm, and 443 nm.

4. Conclusion
We have observed the luminescence spectra on Aceh natural nephrite sample from Aceh Barat and Nagan Raya districts, Aceh Province. Under green 543 nm illumination, we observed several luminescence spectra at 485 nm, 462 nm, 442 nm, and 422 nm. The strong luminescence line of blue 422 nm is originated from energy band structure of the crystalline material, and the rest are weak lines from impurity centers. More observations are needed to reveal the energy band structure of this natural nephrite and the possible impurities which may locally varies according to the environment when the gemstone was formed in the past.

References
[1] Burns, R.G. 1993 Minerological Applications of Crystal Field Theory, Second Edition, Cambridge University Press
[2] Gemological Institute of America 1988 Gem Reference Guide
[3] Germer, T.A., Zwinkels, J.C., Tsai, B.K. 2014 Spectrophotometry: Accurate Measurement of Optical Properties of Materials, Elsevier
[4] Henderson, B., Frank-Imbusch, G. 2006 Optical Spectroscopy of Inorganic Solids, Clarendon Press
[5] Kostov, R.I 2003 Nephrite yielding prehistoric cultures and nephrite occurrences in Europe, Hemus
[6] Sastry, M.D., Mane, S., Gaonkar, M., Bhide, M.K., Desai, S.N., and Ramachandran, K.T., International Journal of Luminescence and Applications 3 293