

CHAPTER 1

INTRODUCTION

1.1 Introduction

Ruby is one of the gemstones in the corundum group deemed as highly precious. The market demands for rubies, particularly in the jewelry industry, are high and unceasing. The term “corundum” comes from the Sanskrit word *kurunvida*, which translated as “hardstones.” Compared to iron, silver, and gold, ruby is one of the most beautiful naturally produced red stones that has high economic value. The values of iron, silver, and gold are determined by weight and purity. Rubies, on the contrary, require more complex grading techniques, just as the grading techniques established by the diamond trade using the 4Cs (color, clarity, cut, and carat).

Rubies can only be formed in areas where the geographical structures comprise their constituent elements, such as in Myanmar, Thailand, Africa, and Madagascar (Giuliani et al., 2020). Due to its hard-to-get characteristic, several synthetic rubies have been synthesized in laboratories to cater to its increasing demand (Sahoo et al., 2016). Hence, it becomes challenging to determine and distinguish whether the rubies are formed naturally or artificially.

The cost of a ruby is generally based on its color because it is easier to differentiate this particular feature with the naked eye (Intarasiri et al., 2016). Currently, the grading valuation of rubies is solely based on the experts' experiences due to the lack of a globally standardized grading valuation (Giuliani et al., 2020). Out of the four grading valuation criteria of rubies, three criteria—namely color, clarity, and cut—are quite difficult to grade. These criteria need further evaluation and in-depth analyses. In terms of color, rubies appear from pink to blood red, depending on their proportion of Cr^{+} .

Besides, cut plays a crucial part in finding the value of rubies. Different types of cut afford different appearances to rubies, which becomes a key factor in determining the attractiveness of rubies (Moses et al., 2004). Among the abovementioned three criteria, this research focuses on the clarity of rubies because the optical properties of rubies closely related to their clarity.

Generally, the clarity of rubies is related to inclusions and blemishes. Inclusions are the natural elements that exist within rubies and produce geological features such as fissures, fractures, and cavities (Sahoo et al., 2016), whereas blemishes occur on the outer surface of rubies, such as scratches (Matlins, 2010). Transparency is also a vital aspect that may affect the clarity of a ruby stone, regardless of whether the ruby can transmit light, and is determined by the presence of opacity in the rubies (Moses et al., 2004). The inclusions and opacity of rubies can be detected using a charge-coupled device (CCD) linear sensor equipped with a laser-diode.

This research aims to develop an inspection system using a CCD linear sensor for determining the clarity of ruby stones. A detailed study on the clarity criteria of ruby

stones is performed, along with the analysis of the characteristics of the CCD linear sensor. Simulations are conducted using the LabVIEW software to investigate the light intensity emitted by ruby stones. Furthermore, a CCD linear sensor system is developed to inspect the clarity of ruby stones. Finally, statistical engineering analysis is used to validate the data obtained from the CCD linear sensor system. From the statistical analysis, it shows that this CCD linear sensor system can distinguish between natural and synthetic rubies with the accuracy of 96.90%. Detailed experiment setup and discussion is thoroughly explained in Chapter 3 and 4.

1.2 Problem Statement

The combination of clarity, cut, carat, and color is used to determine a ruby's quality and value. Except for carat, the other criteria of a ruby still need professional and experienced gemologists (Joseph et al., 2000) to decide the value and quality of the ruby. This is because these three criteria are difficult to differentiate by naked eye (Tariwong et al., 2020). Moreover, the clarity of ruby plays an important role in determining the appearance of the ruby (Sinkevicius et al., 2017). The light reflection and light absorption that occurs in the ruby will affect the clarity of the ruby as the light will pass through the blemishes and inclusions in the ruby. The higher amount of inclusions in the ruby will makes the ruby looks duller and less attractive (Matlins, 2010).

In addition, Gemology Tools Professional software is used to evaluate gemstones. It comprises almost 542 databases of gemstones, consisting of a series of different estimations of the weight of gemstones, colorful stones, and cabochons,

spectral images of gemstones, carat weight charts, and precise gravity calculators (*Gemology Tools Professional*, 2016). This is another approach to classify gemstone criteria using previous databases as guides for evaluating gemstone. Such methods of visual evaluation are based on years of knowledge from gemologists and gemstone traders (*Gemology Tools*, n.d.).

Thus, these methods result in an unstandardized evaluation due to human error (Brazeal, 2019). Notably, light absorption, light reflection and light intensity can be used to analyze the clarity of rubies. A CCD linear sensor can be used to detect and analyzed the light intensity quantitatively. Therefore, this research aims to analyze the characteristic of light distribution in ruby stones using a CCD linear sensor.

1.3 Aim of the Research

This research proposes a clarity inspection system for rubies using a CCD linear sensor. The analysis of the light intensity received by the CCD linear sensor will determine the transparency of the ruby. Hence, the clarity of the ruby can be analyzed.

1.4 Objectives of the Research

The objectives of the research are as follows:

1. To design and develop a CCD linear sensor system for inspecting the clarity of rubies.

2. To conduct several experiments for validating the capability of the CCD linear sensor to be used as a clarity inspection system of rubies.
3. To perform statistical analysis and reverse mathematical modelling in order to validate the effectiveness of the CCD linear sensor.

1.5 Scopes of Research

This research analyzes the characteristic of light distribution in rubies for grading valuation. The experiment is set up in an optimal condition for the CCD linear sensor to work efficiently. The temperature is set at 25°C -33°C, light intensity in the black opaque box is maintained at 0.5 lux, and input voltage source of 5V for the CCD linear sensor are the main conditions needed to be maintained so that the CCD linear sensor does not become saturated and produce undesirable results. Simulations have been developed based on Beer-Lambert law to investigate the light intensity received by the CCD linear sensor from rubies with different clarities.

The light propagation conditions involved in this research—light reflection and absorption—are analyzed mathematically using the LabVIEW software. Then, the light intensity data received by the sensor, which is represented by the CCD output voltage, is statistically analyzed using the Minitab software. These data determine the clarity of the ruby stone.

For this research, the CCD linear sensor system was designed and developed based on the study conducted. The CCD linear sensor system was operated in a black opaque box. The light intensity of the laser was fix to a distance of 16 mm between the

CCD linear sensor and the laser. The CCD linear sensor was equipped with lens and a filter to acquire the optimum result with minimum noise.

Several experiments were conducted under different conditions, including laser ON and OFF conditions, with and without the ruby. The experimental data were obtained using Agilent U1620A oscilloscope. These data is in the form of CCD voltage output values, where it represents the light intensity reflected by the ruby. Finally, the refractive index of the ruby is acquired using the reverse mathematical expression.

