

**A CONCEPTUAL MODELING OF OPTICAL PROPERTIES
OF RUBY STONE USING CHARGE-COUPLED DEVICE
(CCD) TOMOGRAPHY APPROACH**

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UNIVERSITI SAINS ISLAM MALAYSIA

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RUBY STONE USING CHARGE-COUPLED DEVICE (CCD)
TOMOGRAPHY APPROACH**

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Thesis submitted in the fulfilment for the degree of
MASTER OF SCIENCE IN ENGINEERING

UNIVERSITI SAINS ISLAM MALAYSIA

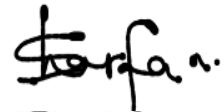
March 2023

AUTHOR DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged.

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ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious and the Most Merciful.

First and foremost, Alhamdulillah all the praises and thankful for Allah Almighty for giving me the strength, insight and slightly part of His knowledge for me to complete this research study. Without His mercy and blessing, I will not be able to finish this study.

Here, I would like to convey my deepest thanks to my main supervisor, Ir. Ts. Dr Juliza Jamaludin for the continuous support of this study and related research, for her patience, motivation, and immense knowledge. Her guidance helped me in all the time for research and writing of this thesis. I could not have imagined having a better advisor and mentor for my research study. May Allah bless you and your family always Dr Thanks too to my other supervisors for their continuous support, Dr Irneza Ismail, and Dr Yasmin Wahab.

I would like to acknowledge Ministry of Higher Education of Malaysia under FRGS grant (FRGS/1/2020/WAB07/USIM/02/1), led by Ir. Ts. Dr Juliza Jamaludin and Universiti Sains Islam Malaysia (USIM) for the funding and support. I also wish to express my gratitude to all lecturers and staffs of Faculty of Engineering and Built Environment (FKAB) for the physical and technical contribution for helping me throughout the whole study. Without their support and help, I cannot complete this research.

My most sincere appreciation goes to my parents and my husband, Raisin bin Saidin, Nor'aini binti Bahari and Abd Hafeez bin Abd Gaffar for their endless sacrifice, encouragement, and prayers throughout the study. They have been entrusted me to do this master journey and always make dua's for my best. Towards my siblings, Aman, Kamelia, Khaled, Izyan, and Ameer, they are good companions that I could ever asked for.

Besides, I would like to appreciate support and great love of my friends in ISMA whole heartedly. They kept me going on and this research cannot be accomplished without their presence and input. Finally, yet importantly, sincere thanks to my best friend, Fatimah Mohd Rahalim and Mahfuzah Samirah Ideris, for their companion, sacrifice, and advice, together with me through the thick and thin in this whole journey.

ABSTRAK

Malaysia merupakan antara negara yang mengimport batu delima dari Myanmar untuk pelbagai kegunaan dalam industri pembuatan, industri batu berharga, pergigian dan aplikasi perubatan. Peralatan sebelumnya yang digunakan untuk menentukan penggredan batu delima adalah berdasarkan penilaian oleh mata manusia dan memerlukan banyak pengalaman. Kajian ini telah membentangkan model konsep penggredan kuantitatif penilaian batu delima menggunakan teknik Tomografi 'Charge-Coupled Device' (CCD). Ketelusan dan kejelasan batu delima adalah beberapa sifat penting yang dinilai dalam kajian. Objektif pertama kajian ini adalah untuk mengkaji sifat optik batu delima menggunakan tomografi CCD. Objektif kedua adalah untuk menyiasat dan mengenal pasti keamatan cahaya pelbagai gred batu delima menggunakan Tomografi 'Charge-Coupled Device' dan perisian pengaturcaraan 'Laboratory Virtual Instrument Engineering' (LabVIEW) seperti yang diklasifikasikan secara komersial oleh pangkalan data Institut Gemmologi Amerika (GIA). Objektif ketiga adalah untuk mengesahkan penggredan kuantitatif batu delima dengan membandingkan imej keluaran simulasi dengan imej keluaran eksperimen. Di sini, penyelidikan akan membentangkan model konsep piawai untuk penilaian penggredan kuantitatif batu delima menggunakan teknik Tomografi CCD. Algoritma Linear Back Projection (LBP) digunakan untuk membina semula imej 3D bagi batu delima berdasarkan nilai Indeks Biasan (IB) 1.762 dan 1.770. Algoritma tersebut telah diprogramkan menggunakan alat perisian pengaturcaraan LabVIEW. Pembinaan semula imej ini membantu dalam menganalisis ketelusan batu delima dengan menggunakan 2-sampel ujian-t, yang diperlukan untuk menilai dan menggred kualiti batu. Selain itu, dua jenis sistem pembinaan semula imej Tomografi CCD, dengan dan tanpa penggunaan laser sebagai sumber cahaya, telah dianalisis untuk menyiasat pemodelan konsep terbaik yang digunakan untuk menilai penggredan kuantitatif batu delima. Kajian mencadangkan bahawa sistem pembinaan semula imej dengan laser sebagai sumber cahaya atau pemancar adalah cekap dalam membezakan antara 2 nilai IB yang berbeza bagi batu delima. Dapatan akhir mencadangkan bahawa untuk nilai ralat relatif antara nilai teori dan eksperimen sistem ini ialah 10.15% yang telah berjaya membuktikan keupayaan sistem tomografi CCD dalam menilai ciri-ciri optik batu delima berdasarkan kejelasannya.

ABSTRACT

Malaysia is one of the countries that imports rubies from Myanmar for various uses in the manufacturing industries, precious stone industries, dentistry, and medical applications. Previous tools for determining the gradation of ruby stones are based on the assessment by human eyes and require a lot of experience. In this study, the research presented a conceptual model of optical properties of ruby stones using the CCD Tomography technique. The transparency and clarity of the ruby stones are some of the important attributes that are evaluated in the study. The first objective of this present study was to examine the optical properties of ruby stones using charge-coupled device (CCD) tomography. The second objective was to investigate and identify the light intensities of various grades of ruby stones using CCD tomography and Laboratory Virtual Instrument Engineering Workbench (LabVIEW) programming software as classified commercially by the Gemmological Institute of America (GIA) database. The third objective was to validate the optical properties of the ruby stones by comparing the simulation output images to that of the experimental output images. Here, the research presented a standardized conceptual model for the optical properties of the ruby stones using the CCD Tomography technique. A Linear Back Projection (LBP) algorithm was used for reconstructing the 3D images of the ruby stones based on the Refractive Index (RI) values of 1.762 and 1.770. The algorithm was programmed using the LabVIEW programming software tools. These image reconstructions assisted in analysing the transparency of the ruby stones after the 2-sample t-test, which were necessary for evaluating and grading the stone quality. Apart from that, two types of CCD tomography image reconstruction systems, with and without the use of a laser as the light source, were analysed to investigate the best conceptual modeling with which to evaluate the optical properties of ruby stones. The study suggested that the image reconstruction system with laser as the light source or transmitter was efficient in differentiating between the 2 different RI values of the ruby stones. The result also concluded that the relative error value between the theoretical and experimental value of this system is 10.15% which has successfully proved the capability of CCD tomography system in evaluating the optical properties of ruby stone based on its clarity.

الملخص

ماليزيا هي إحدى الدول التي تستورد الياقوت من ميانمار لاستخدامات مختلفة في الصناعات التحويلية وصناعات الأحجار الكريمة وطب الأسنان والتطبيقات الطبية. الأدوات السابقة لتحديد تدرج أحجار الياقوت تستند إلى التقييم بالعين البشرية وتتطلب الكثير من الخبرة. قدم البحث في هذه الدراسة نموذجاً مفاهيمياً للتدرج الكمي لتقدير أحجار الياقوت باستخدام تقنية التصوير المقطعي CCD. تعد شفافية ووضوح أحجار الياقوت من السمات المهمة التي تم تقييمها في الدراسة. كان الهدف الأول من هذه الدراسة هو فحص الخصائص البصرية لأحجار الياقوت باستخدام التصوير المقطعي بجهاز اقتران الشحنات (CCD). كان الهدف الثاني هو التحقق من شدة الضوء لدرجات مختلفة من أحجار الياقوت وتحديد ما باستخدام برنامج برمجية CCD للتصوير المقطعي والمختبر الظاهري للأدوات الهندسية (LabVIEW) وفقاً لتصنيفه تجارياً بواسطة قاعدة بيانات معهد الأحجار الكريمة الأمريكية (GIA). الهدف الثالث هو التحقق من صحة التصنيف الكمي لأحجار الياقوت من خلال مقارنة صور مخرجات المحاكاة بصور المخرجات التجريبية. هنا، قدم البحث نموذجاً مفاهيمياً موحداً لتقدير التقدير الكمي لأحجار الياقوت باستخدام تقنية التصوير المقطعي CCD. تُستخدم خوارزمية الإسقاط الخلفي الخطي (LBP) لإعادة بناء الصور ثلاثية الأبعاد لأحجار الياقوت بناءً على قيم معامل الانكسار (RI) البالغة 1.762 و 1.770. تمت برمجية الخوارزمية باستخدام أدوات برمجية LabVIEW. تساعد عمليات المكون من عينتين، والتي تعد ضرورية لتقييم جودة الحجر t إعادة بناء الصور هذه في تحليل شفافية أحجار الياقوت بعد اختبار، وتصنيفه. بصرف النظر عن ذلك، تم تحليل نوعين من أنظمة إعادة بناء الصورة المقطعية باستخدام الليزر كمصدر للضوء وبدونه وذلك للتحقيق في أفضل النمذجة المفاهيمية التي يمكن من خلالها تقييم التصنيف الكمي لأحجار الياقوت. تشير الدراسة إلى أن نظام إعادة بناء الصورة بالليزر كمصدر للضوء أو جهاز إرسال فعال في التمييز بين قيمتي RI المختلفتين لأحجار الياقوت. تشير النتيجة النهائية إلى أن قيمة الخطأ النسبي بين القيمة النظرية والتجريبية لهذا النظام هي 10.15٪ والتي أثبتت بنجاح قدرة نظام التصوير المقطعي CCD في تقييم التصنيف الكمي لأحجار الياقوت بناءً على وضوحها.

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LIST OF ABBREVIATIONS

CCD	Charge Coupled Device
LBP	Linear Back Projection
LED	Light Emitting Diode
GIA	Gemological Institute of America
ERT	Electrical Resistance Tomography
ECT	Electrical Capacitance Tomography
EIT	Electrical Impedance Tomography
CT	Computed Tomography
SPSS	Statistical Package for the Social Sciences
RI	Refractive Index

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