UNIVERSITI PUTRA MALAYSIA

EFFECT OF FILM THICKNESS ON NARROWBAND THERMOCHROMIC LIQUID CRYSTAL CALIBRATION

NADIA BINTI ABDULLAH

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EFFECT OF FILM THICKNESS ON NARROWBAND THERMOCHROMIC LIQUID CRYSTAL CALIBRATION

By

NADIA BINTI ABDULLAH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirement of the Degree of Master of Science

January 2009

DEDICATION

To my family, with love:

It takes many inches to become a mile…be patient and persevere, and the mile will come in time…

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Master of Science

EFFECT OF FILM THICKNESS ON NARROWBAND THERMOCHROMIC LIQUID CRYSTAL CALIBRATION

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January 2009

Chairman : Abd. Rahim Abu Talib, PhD

Faculty : Engineering

Thermochromic liquid crystals (TLCs or TLC) are complex organic substances which selectively reflect visible light as function of temperature. Narrowband TLCs are attractive for temperature measurements due to their higher precision in temperature measurements associated with their narrow bandwidths, and calibrations of narrowband TLCs are less affected by variations in illumination-viewing angles and background illumination. In order to properly utilize narrowband TLCs and intensity-matching methods for quantitative temperature measurements, it is important to investigate film thickness effects on intensity-based calibrations of narrowband TLCs, which have been previously ignored in previous research. Film thicknesses of 10, 20, 30, 40 and 50 μm were investigated on green intensity-based calibrations of R35C1W narrowband TLC during heating and cooling. The results showed an increase in magnitude of peak green intensity with increasing film thickness, with a percentage increase of approximately 18% when film thickness increased from 10 μm to 50 μm. The results also showed an inconsistent shift in peak green temperature, with a maximum temperature shift of 0.40ºC, suggesting that film thickness effects may be insignificant for narrowband TLCs compared with wideband TLCs.

A theoretical method for estimating the volume of coating formulation required to achieve a desired film thickness was presented in this research, based on the film coverage and dry solids content of the TLCs. Results were presented for seven samples of sprayable narrowband TLCs with desired film thicknesses of 10, 20, 30, 40 and 50 μm based on a square shaped model surface area. The percentage uncertainties in volume of coating formulation was obtained to be significant, within 57 – 67%, however, the results were attributed mainly to the lack in accuracy of the electronic balance, which was ± 1 g. Simulation results showed that if the accuracy was increased to ± 0.001 g, the percentage uncertainties decreased to less than 5% for all samples. The method is easily implemented, and is likely to be beneficial to users intending to employ sprayable TLCs for temperature measurements.

In this research, a graphical user interface (GUI) was developed to process images and data in transient calibration of TLCs. The GUI functions to generate full intensity-based calibration curves based on single colour intensity in the Red-Green-Blue (RGB) colour space. The GUI greatly simplifies, streamlines and automates image and data processing, which at present, is carried out by low-level programming and keyboard-entered commands. The GUI is likely to be a useful tool for users intending to utilize TLCs for temperature measurements.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan Ijazah Sarjana Sains

KESAN KETEBALAN LAPISAN TERHADAP PENENTUKURAN CECAIR HABLUR TERMOKROMIK JALUR SEMPIT

Oleh

NADIA BINTI ABDULLAH

Januari 2009

Pengerusi : Abd. Rahim Abu Talib, PhD

Fakulti : Kejuruteraan

Cecair hablur termokromik (TLC) adalah sebatian organik kompleks yang memantulkan cahaya nampak secara memilih dengan perubahan suhu. Penggunaan TLC jalur sempit adalah menarik kerana kepersisan pengukuran suhu yang tinggi, dan penentukuran TLC jalur sempit kurang terjejas dengan perubahan sudut pencahayaan-pemandang dan pencahayaan latar. Dalam mengaplikasikan TLC jalur sempit dan kaedah padanan keamatan cahaya untuk pengukuran suhu, kajian ketebalan lapisan terhadap penentukuran TLC jalur sempit adalah penting kerana aspek ini tidak diberi perhatian khusus pada penyelidikan sebelumnya. Kesan ketebalan lapisan 10, 20, 30, 40 dan 50 μm terhadap penentukuran berasaskan keamatan cahaya hijau telah dikaji untuk TLC jalur sempit R35C1W semasa pemanasan dan penyejukan. Hasil kajian menunjukkan bahawa magnitud puncak keamatan cahaya hijau bertambah apabila ketebalam lapisan bertambah, dengan peratusan sebanyak 18% apabila ketebalan lapisan bertambah dari 10 μm hingga 50 μm. Hasil kajian juga menunjukkan peralihan suhu puncak keamatan cahaya hijau yang tidak konsisten apabila ketebalan lapisan bertambah, dengan nilai maksimum sebanyak 0.40ºC. Hasil kajian mencadangkan bahawa kesan ketebalan lapisan mungkin tidak ketara untuk TLC jalur sempit berbanding dengan TLC jalur lebar.

Suatu kaedah teoretikal telah dikemukakan dalam penyelidikan ini, bertujuan menganggarkan isipadu perumusan TLC yang diperlukan untuk mencapai ketebalan lapisan yang diingini berdasarkan luas liputan dan kandungan pepejal kering TLC. Hasil kajian telah dikemukakan untuk tujuh sampel TLC jalur sempit jenis semburan dengan ketebalan lapisan 10, 20, 30, 40 dan 50 μm berdasarkan luas permukaan model berbentuk segiempat sama. Hasil kajian menunjukkan bahawa peratusan ketakpastian isipadu perumusan TLC adalah tinggi, dalam lingkungan 57 – 67%. Peratusan ketakpastian yang tinggi mungkin disebabkan oleh kejituan neraca elektronik yang rendah, iaitu sebanyak ± 1 g. Hasil simulasi menunjukkan bahawa apabila kejituan neraca elektronik adalah ± 0.001 g, peratusan ketakpastian kesemua sampel adalah kurang daripada 5%. Kaedah anggaran ketebalan lapisan yang telah dikemukakan adalah mudah dan mungkin memanfaatkan para pengguna TLC.

Sebuah antara muka pengguna grafik (GUI) telah dicipta dalam penyelidikan ini, bertujuan memproses imej dan data daripada penentukuran TLC. GUI tersebut berfungsi untuk menghasilkan keluk penentukuran TLC berasaskan keamatan cahaya dalam model warna Merah-Hijau-Biru (RGB). GUI yang dihasilkan bertujuan memudahkan, menyelaras dan mengautomatik pemprosesan imej dan data, dan mungkin menjadi alat pemprosesan imej yang berguna kepada pengguna yang ingin mengaplikasikan TLC untuk pengukuran suhu.

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“We can only do to the best of our capability; perfection is only for Allah the Almighty.”

APPROVAL SHEET NO. 1

I certify that a Thesis Examination Committee has met on 8 January 2009 to conduct the final examination of Nadia binti Abdullah on her thesis entitled “Effect of Film Thickness on Narrowband Thermochromic Liquid Crystal Calibration” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

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Date: 19 March 2009

APPROVAL SHEET NO. 2

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date: 9 April 2009

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any degree at Universiti Putra Malaysia or other institutions.

NADIA ABDULLAH

Date: 4 May 2009

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