

**SUDAN UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF GRADUATE STUDIES**

**FABRICATION OF CuO DISKS TO ATTENUATE
AND FILTER SOME VISIBLE AND I.R.
WAVELENGTHS**

**A THESIS SUBMITTED FOR PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF M.Sc. IN PHYSICS**

By:

MOHAMMED SULEIMAN HUSSEIN SULEIMAN

Supervised by:

**Prof. Dr. NAFIE ABD AL-LATIEF AL-MUSLET
Institute of Laser**

DECEMBER 2006

Dedication`

This work is dedicated to the marvelous success of my sister, Um-Alharith, at her B.Sc. final exams.

ACKNOWLEDGEMENTS

"Who does not thank people will never thank Allah"

First of all, I thank my god for the uncountable granted blessings and for the help in completion of this work.

I am indeed indebted to the expert guidance I received from my supervisor, Prof. Nafie, who very patiently gave me all the stimuli required to complete this work, and whose constant encouragement have made me go a head with this work, in spite of many set backs.

I am at loss when I think of expressing my sincere gratitude to those, who helped me in this work, with their assistance in various forms at various times. While the list is very large, to accommodate in this limited space, I will be failing if I do not mention the members of the department of chemistry (at Sudan University of Science and Technology), my colleagues at the Institute of Laser, specially my classmate Suleiman Al-Tyib and Mr. Abbass, my classmates at the M.Sc. programme, specially Mr. Mustafa Ahmed, the staff of the Institute of Environment Researches,

and Mr. Asaad (at the department of chemistry, University of Khartoum).

It would never have been possible for me to complete this work without the support of my mother (to whom I owe everything), my two sisters, my wife and my brother, whom without their prayers, constant encouragement, continuous services and patience; this work would never have seen the light . .

Finally, I would like to express my sincere appreciation to my two little daughters, whom their lovely smiles left a lasting fervent impressions on me.



الهدف من هذه الدراسة هو تصميم و تصنيع مُوهِنَات و مُرَشِّحات بصرية لبعض الأطوال الموجية في المنطقتين المرئية و تحت الحمراء من الطيف الكهرومغناطيسي. تم اختيار المواد الداخلة في تصنيع هذه المكونات بالمقام الأول اعتماداً على الفحوصات الطيفية الأولية و التي تم إجراؤها بواسطة المقياس الطيفية التالية : (UV-VIS. NIR spectrophotometer) ، (spectrophotometer) و (FT-IR spectrometer). تم ضغط خليط من مسحوق أكسيد النحاس و مسحوق بروميد البوتاسيوم بواسطة ماكينة ضغط و ذلك بإتباع طريقة التشكيل بالقولبة. تم إنتاج طقمين من الأقراص : طقم به أقراص ذات سماكات متساوية لكنها تختلف في تراكيز أكسيد النحاس فيها، و طقم به تركيز ثابت من أكسيد النحاس إلا أن الأقراص فيه لها سماكات مختلفة. الأقراص المنتجة كانت متماسكة بدرجة جيدة و يمكن التعامل معها بسهولة. تم اختبار خصائص توهين لاهله قراص لايزر ذات الأطوال الموجية : (675، 820، و 1064 نانوميتر) و ذلك باستخدام كاشف ضوئي و فولتميتر رقمي حساس، حيث تم قياس شدات الأشعة الساقطة و النافذة، و من ثم دونت النتائج و مثلت بيانياً، و تم منها

حساب امتصاصيات هذه الأقراص كدوال في الأطوال الموجية المستهدفة. أثبتت النتائج درجة عالية من الاعتمادية على هذه الأقراص بغرض استخدامها كموهنات للأشعة تحت الحمراء ذات الأطوال الموجية المذكورة. كما أثبت أن أقراص الطقم الثاني – ذات التركيز الثابت – لها خصائص وكفاءة توهين أفضل، وذلك لثبات انعكاسيتها. جميع هذه القياسات تمت عند السقوط العمودي للأشعة.

عن طريق الفحوصات الطيفية (التي أجريت في المدى 200-25000 نانوميتر) أمكن الحصول، من هذه الأقراص، على مرشح تمرير نطاق في المنطقة تحت الحمراء المتوسطة (2.5 – 25 ميكروميتر) عند طول موجي أعظمي ($\lambda_m \sim 15.2 \mu m$) و بعرض نطاق $\Delta\lambda_{0.5}$ ($\sim 1.9 \mu m$). كما أثبت أنه يمكن استخدام هذه الأقراص كمرشحات ذات كثافة ضوئية متعادلة ND في المدى (2.5 – 10.0 ميكروميتر). بناءً على النتائج المتحصلة، تم اقتراح بعض الأعمال المستقبلية.

ABSTRACT

The main objective of this work is to design and fabricate suitable optical attenuators and filters for some wavelengths in the visible and the infrared regions of the electromagnetic spectrum.

Selection of the attenuators materials was based mainly on the pre-spectroscopic investigations of these materials. These had been carried out using: UV-VIS. spectrophotometer, NIR spectrophotometer, and FT-IR spectrometer.

Using a classical pressing machine, copper oxide disks had been synthesized after mixing with potassium bromide. Two sets of disks were produced : a set with different concentrations of the CuO and constant physical thickness, and a set with different physical thicknesses and fixed concentration of CuO. The produced disks were rigid enough to be dealt with.

Using a photodetector, accompanied with digital multimeter, intensity attenuation measurements of these two sets for the wavelengths : 675, 820, and 1064 nm, were carried out. Graphs were plotted from the results and the absorptivities were calculated in each case showing a good liability of using these disks as good optical attenuators for the three tested laser beams at normal angle of incidence. It was noticed that the performance of the second set, with constant concentration of CuO, was better than the performance of the first set. This is because of the constant reflectance of the second set.

The spectral performance, extending from 200 to 25000 nm, of these disks were investigated. An optical pass-band filter in the middle IR region (2.5 – 25 μm) at wavelength ($\lambda_m \sim 15.2 \mu\text{m}$) with bandwidth of ($\Delta\lambda_{0.5} \sim 1.9 \mu\text{m}$), and an absorption neutral density filter in the range: (2.5 ~ 10.0 μm) was obtained from the same materials and the same fabricated disks.

Based on the obtained results, some future works were suggested.

CONTENTS

Chapter One: Basic Concepts	
1.1	Introduction 1
1.2	Electromagnetic Spectrum and Spectroscopy 1
1.2.1	Electromagnetic Spectrum 1
1.2.2	Spectroscopy 3
1.3	Expressions of Optical Intensity 3
1.3.1	Radiometric System 3
1.3.2	Photometric System 4
1.4	Interaction of EM Radiation with Matter 5
1.4.1	Microwave Interactions 5
1.4.2	Infrared Interactions 5
1.4.3	Visible Light Interactions 5
1.4.4	Ultraviolet Interactions 6
1.4.5	X-Ray Interactions 6
1.5	Basic Optical Relationships 6
1.5.1	The Conservation Law 6
1.5.2	The Laws of Reflection and Refraction 7

1.5.3	The Absorption Law	8
1.6	Properties of Optical Materials	11
1.6.1	Refractive Index	11
1.6.2	Other Properties	12
1.7	Lasers and Laser-Materials Interactions	13
1.7.1	Characteristics of Laser Light	13
1.7.2	Laser Types and Parameters	14
1.7.3	Laser-Materials Interactions & Laser Damage	15
1.8	Optical Components and Devices	16
1.8.1	Optical Sources	17
1.8.2	Optical Detectors	17
1.8.3	Optical Filters	18
1.8.4	Optical Attenuators	20
1.9	Spectroscopic Measurements	22
1.9.1	Introduction to Molecular Spectroscopy	22
1.9.2	Spectroscopic Methods	22
1.9.3	Absorption spectroscopy	23
1.9.4	UV & Vis. Molecular Absorption Spectrophotometry	23
1.9.5	Infrared Spectrometry	24
Chapter Two: Equipments, Materials & Methodology		
2.1	Introduction	25
2.2	The Equipments & Tools	25
2.2.1	The Pressing Machine and its Die	25
2.2.2	The UV-VIS. Spectrophotometer	25
2.2.3	The NIR Spectrophotometer	26
2.2.4	The Fourier Transform Infrared Spectrometer	26
2.2.5	The Laser Sources	27
2.2.6	The Electro-Optical Detector	30
2.2.7	The Digital Multimeter	30
2.2.8	The Software (Origin Program)	30
2.3	The Materials	30
2.3.1	The Copper(II) Oxide	31
2.3.2	The Potassium Bromide	32
2.4	The Setup & Methodology	33
2.4.1	Disks Fabrication and Pressing	33
2.4.2	Spectrophotometric Investigations	35
2.4.3	Attenuation Measurements for Diode Laser 675 nm	35

2.4.4	Attenuation Measurements for Diode Laser 820 nm	36
2.4.5	Attenuation Measurements for Nd:YAG Laser 1064 nm	36
2.4.6	Spectrometric Investigations & Filtering Characteristics	37
Chapter Three: Results, Discussion & Conclusions		
3.1	Introduction	38
3.2	Results and Discussion	38
3.2.1	Disks Characteristics	38
3.2.2	Spectrophotometric Investigations	41
3.2.3	Attenuation Measurements for Diode Laser 675 nm	46
3.2.4	Attenuation Measurements for Diode Laser 820 nm	50
3.2.5	Attenuation Measurements for Nd:YAG Laser 1064 nm	53
3.2.6	Calculations of the Absorptivities	57
3.2.7	The Apparent Deviation from Beer's Law	58
3.2.8	Spectrometric Investigations and Filtering Characteristics	60
3.3	Conclusions	70
3.4	Future Work	71
References		72