

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

Sudan University of Science and Technology

College of Graduate Studies

CO₂ Laser Micromachining of Acrylic Sheets to Increase Their Thermal Insulation

التشغيل الميكروني بليزر ثاني أكسيد الكربون لصفائح من
الأكريلك بغرض زيادة عزلها الحراري

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Declaration

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إقرار

..... أنا الموقع أدناه أقر بأنني المؤلف الوحيد لرسالة الدكتوراه المعنونة *الميكانيكا الليزرية CO₂ لقطع صفائح الأكريليك لزيادة عزلتها الحرارية*.....
..... *بالتيسر لطاى أكسييد الكربون لصناعة مع الأثرى بالليزر*.....
..... *ليقرض تريلادة بحولها الحراسى*.....
وهى منتج فكري أصيل . وباختياري أعطى حقوق طبع ونشر هذا العمل لكلية الدراسات العليا جامعه السودان للعلوم والتكنولوجيا ، عليه بحق للجامعة نشر هذا العمل للأغراض العلمية .

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بِسْمِ اللّٰهِ الرَّحْمٰنِ الرَّحِیْمِ

﴿ سُرِّیْهِمْ آیَاتِنَا فِی الْآفَاقِ وَفِی أَنْفُسِهِمْ حَتَّىٰ یَتَبَيَّنَ
لَهُمْ أَنَّهُ الْحَقُّ أَوْ لَمْ یَكْفِ بِرَبِّكَ أَنَّهُ عَلَىٰ كُلِّ شَیْءٍ

شَهِیْدٌ ﴿ فَصَلَتْ ٥٣

Dedication

To the sole of my father, sister, and uncle Omer Osman;

To my mother;

*To my wife, Hussam, Noor, Kamal, Ala 'a and
Dhia 'a;*

To my sister, brother and their families;

To all those who love science and technology;

I would like to dedicate this work

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May ALLAH bless all of them

Abstract

In this work, electro-pneumatically operated x-y table was fully designed, installed, tested and operated in order to micro-machine coloured acrylic sheets to increase thermal insulation.

The x-y table had been designed and installed to give a longitudinal distance of 100mm, with variable speed from 500 mm/s down to nearly 21% of it. The lateral electrically operated part of the table was designed to give a step of 1mm down to 47 μ m distance along the overall lateral distance of 50mm. The table was used to move Polymethylmetacrylate, PMMA, sheets of 100 x 100 x 2mm under irradiation of CO₂ laser to engrave micro-channels resemble blackbody cavities. Five colours of PMMA were chosen for this purpose, namely red, green, blue, black and white sheets, RGBKW. Laser power 30, 25, 20 and 15 Watts, beside 1, 2, 3 and 4 laser passes were also chosen to give a combinations of 35 samples different in parameters.

When thermal infrared radiation enter these micro-channels they will undergo multiple reflections and re-emission losing some of their energy and resulted in reduction of the transmitted thermal radiation crossing the channels.

Experimental results showed temperature reduction between micro-machined and standard samples of PMMA, when using different colours, laser powers and laser passes, which fulfilled the state of increased thermal insulation of acrylic sheets when laser micro-machined, and consequently fulfill the purpose of this research.

المستخلص

في هذا البحث، تم التصميم الكامل والترصيف والأختبار والتشغيل للطاولة الكهرو-هوائية وذلك لعمل التشغيل الميكروني لألواح من الأكريليك بألوان مختلفة بغرض زيادة عزلها الحراري.

تم تصميم وترصيف الطاولة ذات الحركة في المحورين السيني والصادي لتعطي مسافة حركة طولية مقدارها ١٠٠ ملليمتر وسرعات متغيرة تبدأ من ٥٠٠ ملليمتر في الثانية نزولاً لـ ٢١% من هذه القيمة. تم تصميم جزء الحركة المستعرضة المشغل كهربائياً ليعطي مسافة عرضية مقدارها ١ ملليمتر لكل خطوة إلى ٤٧ ميكرومتر لمسافة كلية مقدارها ٥٠ ملليمتر.

استعملت الطاولة لتحريك ألواح من البولي مثيل ميثاكريلات ذات الأبعاد ١٠٠×١٠٠×٢ ملليمتر ليتم تشعيها بواسطة ليزر ثاني أكسيد الكربون لحفر قنوات ميكروية تمثل تجويفات جسم اسود.

تم اختيار خمسة ألوان مختلفة لعملية التشعيع هي الأحمر، الأخضر، الأزرق، الأسود والأبيض كما تم اختيار قدرات ليزر مقدارها ٣٠، ٢٥، ٢٠ و١٥ واط بجانب عدد اشواط ليزرية مقدارها ١، ٢، ٣ و٤ اشواط لتكوين توافقيات من ٣٥ عينة مختلفة الخواص.

عند دخول الأشعة تحت الحمراء الحرارية هذه القنوات الميكروية ستخضع لانعكاسات متتالية وإعادة انبعاث لطاقتها ماينتج عنه انخفاض في الأشعة الحرارية النافذة من هذه القنوات.

أظهرت النتائج انخفاض في درجة الحرارة بين الألواح ذات القنوات الميكروية وتلك المرجعية بدون قنوات وذلك عند استعمال ألوان مختلفة للألواح، قدرات مختلفة لليزر و عدد اشواط ليزرية مختلفة ، وهذا ما يحقق حالة زيادة العزل الحراري لشرائح الأكريليك بواسطة المكننة الميكروية بالليزر وبالتالي يحقق الهدف من هذا البحث.

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List of Abbreviations

PMMA	Poly-methyl-methacrylate
CO ₂ Laser	Carbon dioxide laser
DVD	Digital versatile disc
LMP	Laser material processing
Nd:YAG Laser	Neodmium-Yettrium-Auminium-Garnet laser
D	Depth of heat penetration
α	Diffusivity of materials
dT	Pulse duration
I	Laser intensity
I _o	Laser intensity at the top surface
a	Absorption coefficient
A _s	Surface absorptivity
UV	Ultraviolet
IR	Infrared
CW	Continuous Wave
TEM	Transverse electromagnetic mode
SP	Spatial distribution of laser intensity
λ	Wavelength
D _{min}	Focal spot size
D	Unfocused beam diameter

PDAs	Personal digital assistan
MAV	Micro-aerial vehicles
3D	3-dimentional
SEM	Scanning electron microscope
LIGA	From German, Lithographie, Galvanoformung, Abformung meaning lithography,electroplating And molding
Θ	Half the divergence angle
W	Beam waist size
M^2	Beam quality number
f	Focal distance
δ	Minimum spot size diameter
τ	Thermal relaxation time
k	Thermal diffusivity
MALDI	Matrix-assisted laser deposition/ionization
LIBS	Laser induced breakdown spectroscopy
PLD	Pulsed laser deposition
LIMPS	Laser-induced periodic microstructures
eV	Electron volt
PC	Polycarbonate
PS	Polystyrene
PEEK	Poly-ether-ether-ketone

R	Fraction of light reflected
S	Fraction of light scattered
T	Fraction of light transmitted
SRI	Solar reflectance index
CRRC	Cool roofing rating council
A	Absorptivity
ϵ	Emissivity

