UTILIZATION OF CW ND- YAG LASER (1064NM) FOR TRIMMING FIXED CARBON RESISTORS.

by

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Abstract:

In this work a Continuous Wave (CW) Nd – YAG laser with 1064 nm wavelength was used to accomplish one of the modern applications for laser in electronic industry, which is the trimming of carbon resistors. Trimming of fixed carbon resistors is done, usually, by ablation material from the conducting path which leads to the required value of the resistor.

In this work, different powers of the Nd:YAG laser ranged from 20,25, and 30 Watt and exposure times of 1,2,,3,5, and 10 seconds repeated for several times, gave different resistance values .

The results illustrated that low power and long exposure time (20 Watt and 10 seconds) changed the resistor value gradually to very high values so it can be controlled to reach the value that is suitable for specific application.

Key words: Laser, Trimming, Resistors.

Introduction:

Laser processing is widely used for fabrication of electronic components. Applications include trimming of resistors, drilling, scribing, and marking. Lasers may also be used to fabricate microcircuits via the controlled deposition of semiconductors, metals, and insulators [1].

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The use of the CO_2 and Nd: YAG lasers in electronic processing applications are well established; these lasers have been used for many years for applications such as trimming and drilling. The green and ultraviolet lasers may be focused to smaller spot than the infrared devices, and they may be chosen when small focal diameter is desired. The use of ultraviolet lasers is relatively new, especially the excimer and frequency -tripled and – quadratic Nd:YAG lasers. Infrared lasers have become mature and reliable, and they now present viable options for electronic processing. They offer the attractive feature of very high absorption in many materials of interest [2].

Lasers have reached production status for variety of applications in the electronics industry. One of the most significant is trimming of resistors. This can significantly increase the yield in the processing of resistive elements.

Resistors for use in electronic circuits may be printed on a substrate from a liquid ink and subsequently fired and dried. Such resistive elements are called thick film resistors. In some cases, resistors are formed by vacuum deposition of metals. These resistive elements are called thin film resistors [3].

In either case, it is difficult to control the value of the resistance to within the tolerances required by the circuit. Thus, resistors are fabricated with intentionally low values of resistance and then trimmed by removing material from the conducting path[3]. The value of the resistance may be monitored during the trimming process, and the trimming is terminated when the desired resistance is reached. Alternatively, the performance of the circuit may be measured during trimming; in this case, trimming is terminated when the circuit is operating properly [4].

Trimming by laser ablation most often uses a Q-switched Nd:YAG laser, emitting a train of pulses with peak power in the kilowatt range, pulse durations around 250 ns, and pulse repletion rates in the kilohertz

regime. Typical parameters for the trimming of thin and thick film resistors with Nd:YAG lasers are presented in Table 1 [2].

Table (1) Thin and Thick Film Resistor Trimming Parameters

Typical Values for Nd:YAG Laser Trimming of Thin Film Resistors	
Peak power	1200W
Pulse repetition rate	10KHz
Pulse duration	250 ns
Cut width	0.001 in.
Over lap	65 percent
Typical Values for Nd:YAG Laser Trimming of Thick Film Resistors	
Peak power	4000W
Repetition rate	3KHz
Pulse repetition rate	250 ns
Cut width	0.002 in.
Overlap	95 percent

The Nd: YAG laser offer the advantage of smaller cut widths than the carbon dioxide laser, which has also been used. The infrared Nd: YAG laser is perhaps the most common choice, but if the fine trimming cuts are desired, the frequency-doubled Nd: YAG laser is employed. Trimming with excimer lasers has also been demonstrated, but this has not yet become common [5].

Laser trimming of resistors is especially notable because it is a process that has become routine in the electronics industry, and it has essentially replaced the older method, which was abrasive trimming. Laser trimming offers the advantage of better cleanliness and better control over the final resistance. The laser trimming operation results in a higher yield; that is, a larger fraction of the resistors within the prescribed tolerance [6].

The experimental part:

In any electronic circuit one can find one or more of the resistors, diodes, transistors, and operational amplifiers. Some fixed carbon resistors were irradiated in this work by CW Nd: YAG laser with

different parameters. The equipments and tools used in the experimental part of this study, in addition to the procedure, will be described here.

Experimental equipments:

The devices and tools used in this work are described as follows:

CW Nd: YAG Laser (Dornier Medials Fiberton 5100):

The Nd:YAG laser wavelength is located in the near-infrared region of the electromagnetic spectrum with usual wavelength of 1064 nm. The Nd: YAG laser consist of a solid crystal of yttrium-aluminum-garnet. It is doped (laced) with rare earth element called neodymium that actually produces the laser light energy when exposed to bright flash lamps [7].

The CW Nd: YAG laser used in this work was supplied from Dornier Med Tech, Medials laser Gmbh, - Germany.

The CW Nd: YAG laser light can be delivered to the target through the laser fiber which includes a focal lens to focus the laser beam into small spot size [8]. Since the laser is invisible, a milliwatt helium – neon laser is attached with the Nd: YAG and used as an aiming beam. Plate (1) shows the Nd: YAG laser used in this work.

Plate (1) CW Nd: YAG Laser (Dornier Medials Fiberton 5100)

Digital Real – time Oscilloscope, Tektronix TDS 220, U.S.A.

This device was used in this work to check the value of the resistor during irradiation by CW Nd: YAG laser. The specifications of this device are as follows:

(1) 60 MHz and 100 MHz BW
(2) 1 GS/s Sample Rate on Each Channel
(3) 2.5k Record Length on Each Channel
(4) 2 mV/div to 5 V/div
(5) 8-bit Vertical Resolution
(6) Video Triggering
(7) Automatic Measurements - Period, Frequency, Cycle RMS, Mean, & Peak to Peak
(8) Bright, Backlit Liquid Crystal Display [9].

Digital Multimeter:

Digital multimeter was used to identify the resistor value before trimming and also was used after laser trimming to record the new value of resistor.

Fixed carbon resistors:

Figure (1) shows schematic diagram of the fixed carbon resistor used in this work.

Table (2) shows the specifications of the used resistors.

Figure (1) Fixed carbon resistor

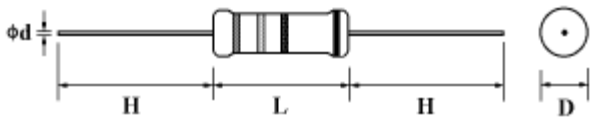


Table (2) fixed carbon resistor specifications

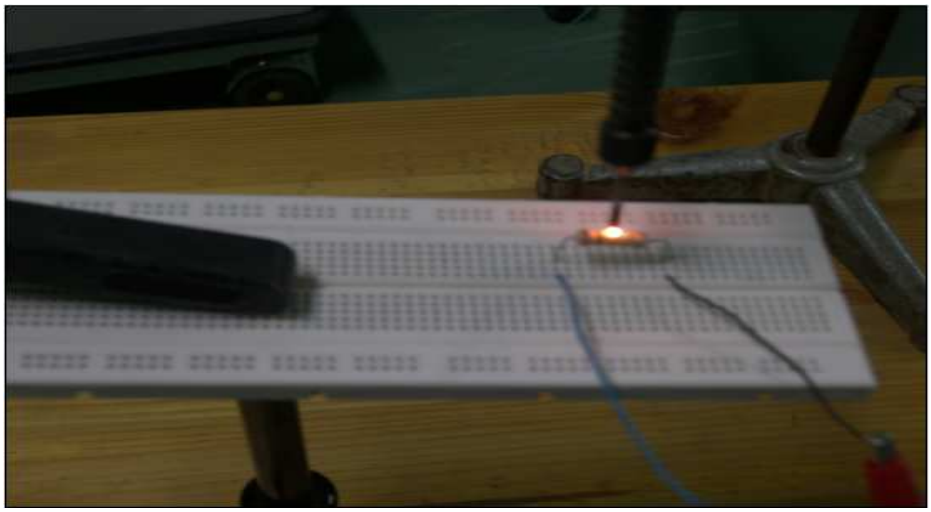
Power Rating at 70^0C	Dimension (mm)				Max working voltage	Max. overlod voltage	Dielectric with standing voltage	Resistor range
	D max	L max	$H \pm 3$	$d^{+0.02}_{-0.05}$				
1/8(0.125W)	1.85	3.5	28	0.5	200V	400V	400V	1Ω-1M Ω

Experimental setup and Procedure:

First of all, the resistor was connected to the digital multimeter in order to measure the resistance before irradiation and during irradiation by the CW Nd: YAG laser the resistor value was doubly checked using the oscilloscope and the multimeter, simultaneously, as shown in plate (2). The laser beam was focused to a small spot size (2.27 mm ^{2}) in order to obtain high power density. The resistor was scanned by this focusing beam with fixed laser power and varied exposure times and vice versa.

The range of the laser power was between 20W and 30W while the exposure time was between one second and 10 second, and each exposure time was repeated 15 times with a period of 1 minute between each exposure time and the other. The resistance value was measured after each exposure and this value was plotted as a function of number of irradiation times.

Plate (2): Fixed carbon resistor during radiation



Results and discussion:

The results of irradiation of fixed carbon resistor are shown in Figures (1) to (8) where the irradiation of each sample was repeated 15 times

with 1 minute between each irradiation and the other, except in Figures (2) and (5), it was repeated 4 times,. In Figure (2), after irradiation by 25W for 5 second several times, the resistance value decreased from 98.4 KΩ to 80.7 KΩ, and then increased gradually up to 104.7 KΩ after repeating the irradiation for 15 times. The decreasing of this resistance in the first irradiation was due to the removal of the coating material and the increasing after that was due to the laser power that penetrates the coating and removing internal conducting material.

Figure (4) and Figure (5) show the results of irradiation of the same resistor by the same laser power but with different exposure time also for several times. The figures show the same behavior, but there is a small difference that is due to the difference of exposure time, 5seconds and 10 seconds.

Figure (2): The effect of CW Nd:YAG laser with 25 watt for 5 second on carbon resistor

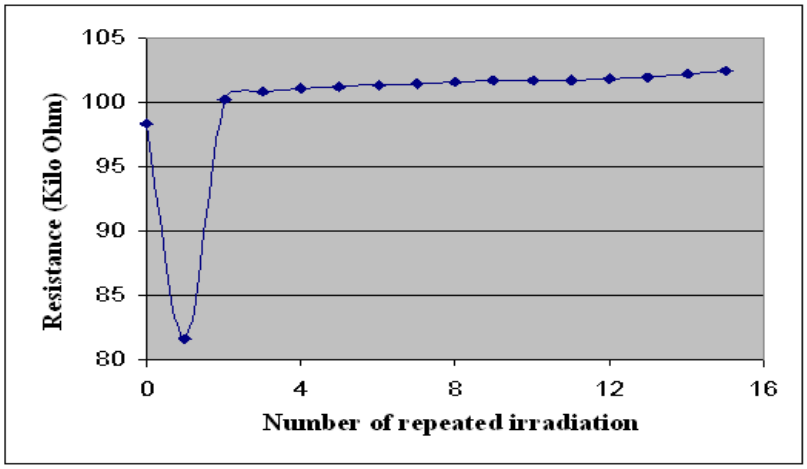


Figure (3): The effect of CW Nd:YAG laser with 25 watt for 10 second on carbon resistor.

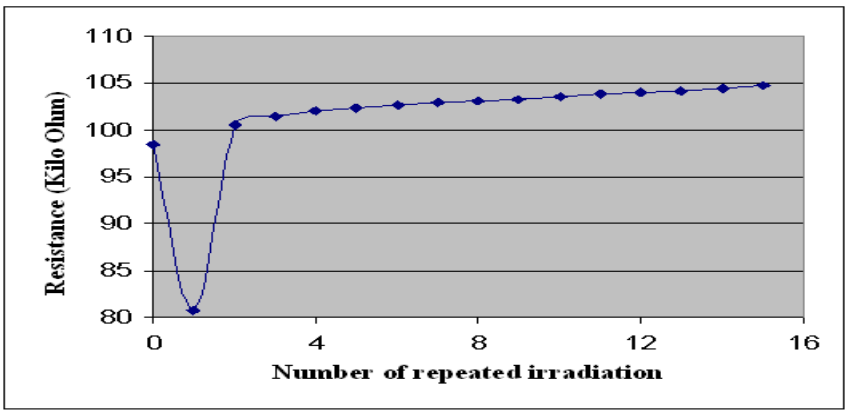
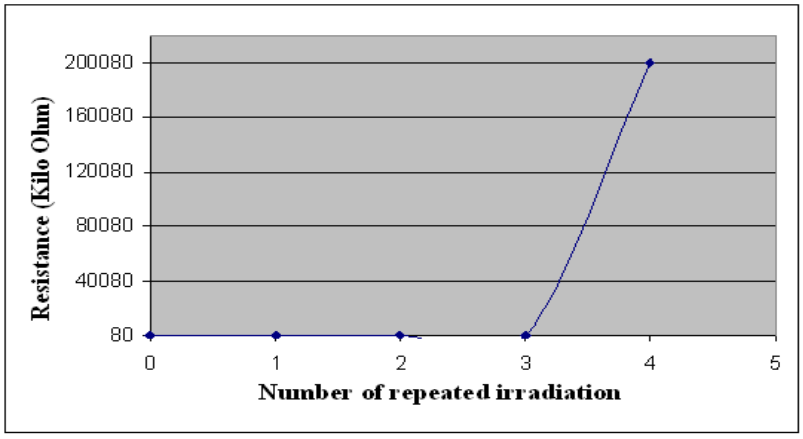


Figure (4) shows that the resistance value decreased to 80.9 KΩ and increased rapidly to 100.6 KΩ and the final value was obtained to be above 200 MΩ after repeating the irradiation for 4 times. Increasing the resistance from range of kilo ohm to the range of mega ohm was due to the high used laser power (30 Watt) and exposure time of 5 second.

Figure (4): The effect of CW Nd:YAG laser with 30 watt for 5 second on carbon resistor.



In Figure (5), the applied power was 30 Watt for one second. The Figure shows that the resistance did not increased rapidly and that was due to the short exposure time. This result proves the importance of selection the suitable exposure time.
Figures (5) and (6) are approximately the same, but the exposure time in Figure (6) is 2 second and in Figure (5) is 1 second, this difference in exposure time makes small change in the final result.

Figure (5) :The effect of CW Nd:YAG laser with 30 watt for 1 second on carbon resistor.

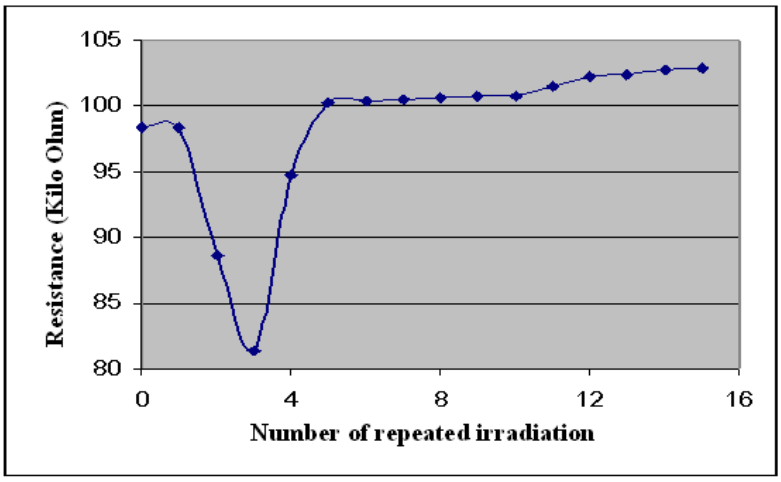
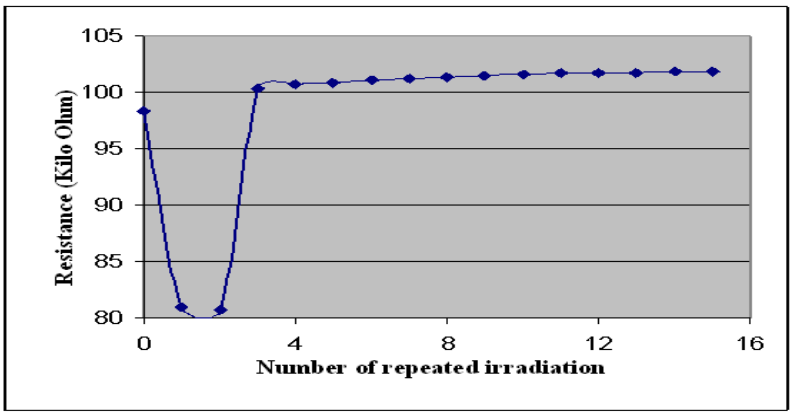


Figure (6): The effect of CW Nd:YAG laser with 30 watt for 2 second on carbon resistor



In figure (7), increasing the exposure time to 3 seconds raises the resistance above 200 mega ohm. Figure (8), shows that the resistance value increased gradually without decreasing and increasing again as seen in all figures above, and this was due to the long exposure time (8 seconds).

Figure (7): The effect of CW Nd: YAG laser with 30 watt for 3 second on carbon resistor

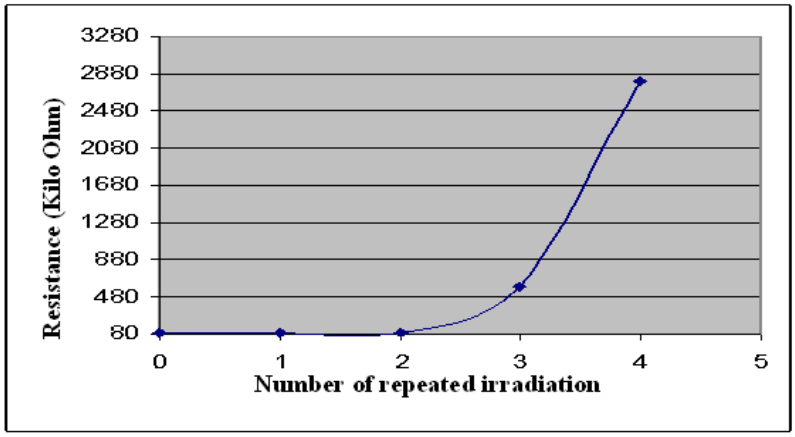
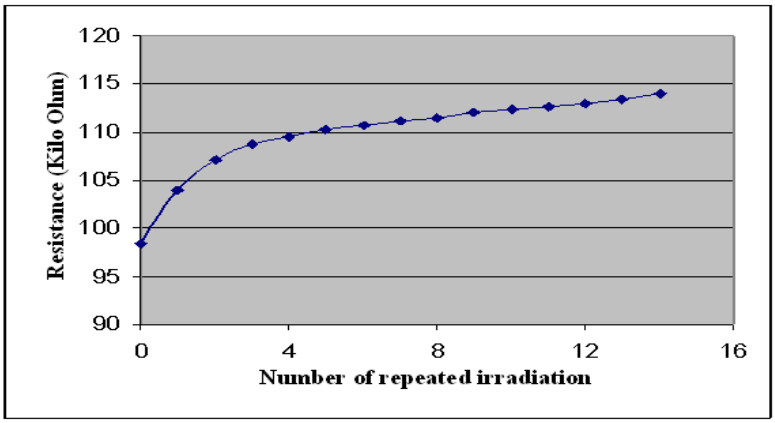


Figure (8): The effect of CW Nd:YAG laser with 20 watt for 10 second on carbon resistor



Discussion:

The obtained results from laser trimming of fixed carbon resistors using CW Nd:YAG laser, showed clearly that it is easy to trimmed fixed carbon resistors by focusing the laser beam on the resistor surface which is coated by insulating material. The minimum power of the laser that trimmed the resistor was 20W with laser beam spot size of (2.27 mm^2) and the minimum exposure time was only one second. Power of 25W and exposure time of 5 seconds removed small amount of the insulating material in the outer surface of resistor and also it removed a part of the conducting material inside the resistor. Fixing of power at 25W and increasing the exposure time to 10 seconds, showed that the amount of insulating material removed was the same as in the case of exposure time of 5 seconds, but amount of conducting material that was removed by using exposure time of 10seconds gave enough time to the laser power to penetrate deeply to remove conducting material greater than that in the case of exposure to 5seconds.

Increasing laser power to 30W and fixing the exposure time at 5seconds changed the resistance value from range of kilo ohm to the range of

mega ohms; this was due to relatively long exposure time (5seconds) and high power that penetrated deeply inside resistor surface and removed a big amount of conducting material inside the resistor.

Decreasing the exposure time to 3 seconds and applying relatively high power of 30W showed that the conducting material that was removed was less than in case of using 30W laser power and exposure time of 5seconds.

Continuous decreasing of exposure time to 2sec and 1sec, respectively, gave a small change in resistance values and this was due to short exposure time. These results are in very good agreement with previous work [10].

Finally, we can see that the exposure time is the important factor besides using suitable power for trimming the fixed carbon resistors to obtain the targeted value of carbon resistor.

Conclusions:

From the obtained results, one concludes that:

1- A fixed carbon resistor can be trimmed easily by a CW Nd: YAG laser, this laser gives good results.

2- Desired or targeted value of certain resistor can be achieved by applying a suitable laser power and a suitable exposure time.

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دراسة استخدام ليزر النيوديميوم – ياق ذي التشغيل المستمر في تشذيب المقاومات الكربونية الثابتة

نافع المسلط ، سعد الدين الصديق محمد ابراهيم ، وفاء صالح عبد الرحمن

مستخلص:

في هذا البحث تم استخدام ليزر النيوديميوم – ياق ذي التشغيل المستمر (طوله الموجي 1064 نانومتر) لاجراء احد التطبيقات الحديثة في مجال الصناعات الالكترونية وهو تشذيب المقاومات الكربونية الثابتة الذي يجرى عادة باستخدام طريقة الازالة لمادة المقاومات وبالتالي التحكم الى حد ما في قيمة المقاومة بحيث توائم القيمة المطلوبة للاستخدام.

تمت عملية تشذيب المقاومات الكربونية الثابتة باستخدام ليزر النيوديميوم– ياق المستمر بقدرات مختلفة هي : 20 ,25 و 30 واط وبعدة ازمان تعريض (أو تشعيع) هي : 1 ,2 ,3 ,5 و10ثواني حيث أعطت هذه المتغيرات قيم مختلفة للمقاومة. أوضحت النتائج ان استخدام قدرة قليلة من الليزر (20 واط) وبزمن تعريض يساوي 10 ثواني يغير قيمة المقاومة تدريجياً ويصل الى قيم عالية جدا بحيث يمكن التحكم بقيمة المقاومة وصولاً الى القيمة المناسبة للتطبيق المستهدف.

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