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# The Effect of Water Film on Built Oxide Layer in Copper Plate Using Laser Shock Wave

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**Abstract**

After Nd-Yag laser treatment with and without water thin film, copper plate material was used under 2880 hours of humidity environment to build a green oxide layer. Oxide layer and water thin film were studied; corrosion rate and oxide percent were measured with and without water film under same environment for one laser pulse, 2 pulses, 3 pulses and 4 pulses. The results show improvement and stability in corrosion rate for water thin film of one pulse during the test period. This paper gives comparative results referring to water laser technology on corrosion rate of green oxide layer for copper plate with and without water thin film during specific period of time.

## تأثير طبقة الماء على تكون طبقة ألاوكسيد في صفائح النحاس باستخدام موجة الصدمة بالليزر

**الخلاصة**

بعد المعاملة بـNd-Yag الليزر مع طبقة الماء الرقيقة وبدونها,تم تعريض صفائح النحاس لمدة 2880 ساعة من اجواء الرطوبة لبناء طبقة أكسيد الخضراء.تمت دراسة طبقة الاوكسيد وطبقة الماء الرقيقة ؛تم قياس معدل التآكل ونسبة أكسيد لنفس الضروف بوجود طبقة الماء وبدونها ومن واحد الى اربع نبضات باستخدام الليزر ومقارنة النتائج .أظهرت النتائج تحسنا واستقرار في معدل التآكل في وجود طبقة الماء الرقيقة ولنبضة واحده خلال فترة الاختبار. هذا البحث يعطي نتائج مقارنه في اشارة الى تكنولوجيا الليزر والماء على معدل نمو طبقة أكسيد الاخضر لصفائح نحاسية مع وبدون طبقة الماء الرقيقة خلال فترة محددة من الزمن.

## Introduction

Copper is a metal that has a wide range of applications due to its good properties. It is used in electronics for production of wires, sheets, tubes, and also to form alloys. Copper is resistant toward the influence of atmosphere and many chemicals, however, it is known that in aggressive media it is susceptible to corrosion. The use of copper corrosion inhibitors in such conditions is necessary since no protective passive layer can be expected. The possibility of the copper corrosion prevention has attracted from many researchers so until now numerous possible inhibitors have been investigated amongst them there are inorganic inhibitors [1].At ordinary temperatures, most engineering metals are protected by very thin oxide films of the order 3 to 10 nm thick. These films form very rapidly on contact with atmospheric oxygen subsequent growth in uncontaminated air with low humidity

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is usually imperceptible, for this reason that aluminum, chromium, zinc, nickel, and some other common metals remain bright in unpolluted indoor atmospheres [2]. A general corrosion attack on copper is most often associated with soft and acidic waters. It usually proceeds at a slow rate and is characterized by a build-up of cupric acids. The most important factors influencing the general corrosion rate of copper are the pH of the water, softness, temperature, oxygen content of the water and stress (Stress Corrosion). Water that is soft--less than 60 mg/l of hardness--with a pH of less than 6.5 will be aggressive to copper. If the water is heated, the aggressive nature will be greater due to the destruction of the metal-oxide layer on the copper [3] [4].

Moist, oxygen and temperature have most important effect on the material corrosion; moist air is usually insufficient for corrosion to occur. Materials on the surface of metals such as corrosion products and salt deposits can be hydroscopic and can absorb sufficient amounts of water from moist air to allow corrosion to proceed [5].

The laser beam can be used to generate surface acoustic waves in the substrate, where the mechanical forces associated with the wave were sufficient to allow for surface damage to the substrate if the laser beam was not controlled [6].

Laser shock wave is a process that imparts compressive stresses on the surface of a material. It is used primarily for increasing fatigue life and component for stress corrosion cracking [7].tensile stress is known to be necessary component for stress corrosion cracking (SCC)[8], whereas compression stress can mitigate SCC initiation or decelerate propagation [9].

**Experimental Part**

Thermo-hygrometer model 303 was used to measure the natural environment of humidity during corrosion time table (1).2880 hours was the humidity exposure time for all specimens.

Q switched (1.6J), $3x10^{-9}$ pulse duration Nd-Yag laser system with thin water film was used to generate shock wave. A lens has focal length 10cm was used to irradiate the copper plate B152 (1.5cm x1.5cm x 0.5mm) with (1.5mm) laser spot diameter. The laser beam was focused on wet copper surface below the transparent solution (distilled water). The liquid height ~ 1mm figure (2).The plasma formation was (~ 2µm) equation (1) [10].

$L_p\ (\Delta\tau_p) = 2\times10^4(P\Delta\tau_p/z$…………… (1)

P in k bars, z is the shock impedance in $g/cm^2$ s, $L_p$ thickness of the interface in µm, and $\tau_p$ pulse duration in ns

The interface pressure of plasma formation was ($213x10^8$ Pa) equation (2)

$$P_0 = 0.10 \times \sqrt{\left[\frac{f_E}{3}\right] Z I_0} \quad \text{………} (2)$$

$I_0$ in $W/cm^2$

$f$E is constant fraction of internal energy ≈ 0.1 − 0.2

Percent of oxide was measured using grid square technique (GST) figure (3).

Area = [(full cells+1/2(partial cells)] X (cell area value)……………………..… (3)

With the technique described above it will be possible to make estimates of area.

Percent of copper oxide to the total surface was measured starting from 570 hours ending by 2880 hours figures (4 to 7).

The corrosion rate is the corrosion effect on a metal per unit time [11]; the corrosion effect may vary with time and may not be the same at all points of the corroding surface. Therefore, reports of corrosion rates should be accompanied by information on the type, time dependency, and location of the corrosion effect will calculated from the equation (4) [12] at each time intervals ( 570 ,1140,1710,2280 ,2880) hours.

$mpy=22.273W_L /(D*A*t)$ ……….. (4)

mpy=corrosion rate (mils per year penetration) g.$W_L$=weight loss in g, D, density g/cm3, A=area in $cm^2$, t=time

The corrosion rate of oxide layer was measured after laser treatment with water film and without water film figures (8 to 11).

The laser-shock wave supported by water film method based on the photomechanical effect of a laser pulse has been used to produces a cylindrical convergent surface acoustic wave under ( $4.7*10^8$ $W/cm^2$ ) laser intensity, Generating shock waves on the surface will leads to acoustic wave at the surface and inside the surface, wide-band microphone with frequency of 20Hz-20 kHz placing 5cm near to the laser spot diameter, the acoustic wave emission under water thin film was 15720 hertz figure (1) which can enhance to change the surface properties figures (13,14).

**Results and Discussion**

We have compared the experimental data of the oxide formation percent with and without water film in laser shock wave processing.

This comparing shows improvement in most specimens of water film during the test period, this improving in corrosion rate can be seen very clearly in figures (8, 9, 10, and 11), figure (9) shows the best improvement under one pulse treatment because of efficient amount and distribution of compressive stress due to laser shot, figures (9, 10 and 11) the oxide rate is become not stable and goose height this due to compressive stress generating beyond the specific limits on the surface, The improvement can be clarify to formation of compressive stresses on the surface this will effect directly of the on the formation of localized corrosion. The localized corrosion leads to oxygen concentration penetrate on the surface and this will be starting point of corrosion figure (11). The stability in corrosion rate can be seen for one pulse, 2 pulses with and without water film in range of first three points of time this happened when exposed to the atmosphere over long periods of time, copper will form coloration on the surface known as patina. When first formed, the patina exhibits a dark color that gradually turns green. The length of time required to form the patina depends upon the atmosphere.

Figures (4, 5, 6 and 7) shows Percent of oxide formation after laser treatment, in figure (6) the percent of oxide at first 570 hours was zero percent but its goes up again in figure (7), this fluctuating is due to compressive stress formation, when it’s certain limit its will work on accelerate the penetration of localized corrosion, below this limit compressive stresses will decelerate the localize corrosion hence oxide formation it can be seen in all periods of test.

In figures (13, 14) shows the acoustic waves emitted from an oxidized copper substrate under the laser irradiation on the same spot. When the first laser pulse is irradiated on the surface, a very strong acoustic wave is observed. This strong acoustic wave implies that the shock wave was generated on the surface and the laser pulse interacted strongly with the oxides surface due to the short laser pulse length. The emission of the acoustic waves is strong; especially in the initial period and decays rapidly due to change in material properties which will affect further interactions.

It is clear that strong absorption and interaction between the laser and the surface to the generation of plasma and the changing the stresses on the surface when water film is found because this will leads to confine the generating waves and reflected directly to the surface this will create strong hammer on the work surface, these waves will transform the tensile stresses in to compressive stresses.

**Conclusions.**

- The corrosion rate and percent of oxide formation during specific time can be controlled by surface treatment.
- The oxide formation cannot be reach to zero because of the environment effect.
- The shock wave process with water film more efficiently to decelerate the corrosion.
- This type of process can be use efficiently to small devices.

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**Table (1) Shows the Humidity Percent for January, February, March and April.**

| Humidity (%) | | | Humidity (%) | | | Humidity (%) | | | Humidity (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| high | avg | low | high | avg | low | high | avg | low | high | avg | low |
| 93 | 74 | 45 | 77 | 58 | 46 | 94 | 75 | 49 | 58 | 34 | 21 |
| 87 | 65 | 46 | 93 | 68 | 46 | 100 | 80 | 49 | 45 | 30 | 15 |
| 88 | 67 | 35 | 72 | 51 | 22 | 93 | 59 | 40 | 59 | 34 | 15 |
| 94 | 77 | 52 | 71 | 49 | 27 | 82 | 54 | 28 | 52 | 27 | 9 |
| 100 | 75 | 33 | 87 | 51 | 24 | 93 | 64 | 43 | 57 | 31 | 13 |
| 87 | 62 | 34 | 93 | 80 | 40 | 67 | 44 | 23 | 43 | 21 | 12 |
| 76 | 49 | 28 | 81 | 61 | 36 | 59 | 39 | 20 | 64 | 38 | 21 |
| 76 | 57 | 37 | 81 | 56 | 31 | 72 | 47 | 28 | 68 | 43 | 26 |
| 87 | 58 | 31 | 66 | 47 | 33 | 59 | 38 | 18 | 52 | 28 | 15 |
| 66 | 42 | 22 | 66 | 46 | 28 | 41 | 28 | 15 | 48 | 29 | 16 |
| 81 | 48 | 27 | 66 | 46 | 26 | 60 | 37 | 20 | 45 | 25 | 17 |
| 66 | 44 | 23 | 76 | 47 | 23 | 49 | 34 | 19 | 57 | 34 | 20 |
| 59 | 49 | 40 | 47 | 39 | 27 | 56 | 33 | 13 | 78 | 43 | 28 |
| 77 | 57 | 40 | 59 | 39 | 21 | 55 | 33 | 20 | 48 | 29 | 16 |
| 82 | 71 | 55 | 67 | 41 | 19 | 43 | 27 | 13 | 42 | 22 | 12 |
| 100 | 78 | 46 | 55 | 40 | 24 | 41 | 31 | 23 | 34 | 21 | 10 |
| 77 | 58 | 32 | 52 | 45 | 32 | 48 | 33 | 21 | 82 | 49 | 21 |
| 72 | 51 | 27 | 59 | 49 | 34 | 48 | 33 | 19 | 94 | 55 | 22 |
| 77 | 56 | 35 | 82 | 56 | 32 | 66 | 39 | 17 | 60 | 36 | 16 |
| 77 | 58 | 27 | 88 | 69 | 43 | 46 | 27 | 13 | 56 | 26 | 12 |
| 88 | 69 | 49 | 87 | 53 | 24 | 47 | 28 | 13 | 36 | 29 | 21 |
| 87 | 69 | 46 | 55 | 34 | 23 | 50 | 32 | 14 | 73 | 45 | 30 |
| 87 | 54 | 28 | 51 | 37 | 24 | 48 | 32 | 18 | 88 | 61 | 23 |
| 67 | 51 | 33 | 54 | 40 | 26 | 48 | 36 | 31 | 63 | 32 | 14 |
| 88 | 62 | 35 | 54 | 37 | 23 | 58 | 33 | 15 | 59 | 27 | 10 |
| 81 | 48 | 21 | 88 | 68 | 36 | 94 | 49 | 26 | 49 | 24 | 13 |
| 69 | 48 | 32 | 88 | 71 | 43 | 94 | 87 | 77 | 83 | 32 | 13 |
| 69 | 44 | 25 | 88 | 65 | 40 | 94 | 78 | 56 | 61 | 43 | 20 |
| 54 | 39 | 30 | | | | 94 | 58 | 28 | 88 | 46 | 21 |
| 61 | 46 | 28 | | | | 68 | 44 | 23 | 56 | 30 | 15 |
| 67 | 53 | 43 | | | | 58 | 37 | 21 | | | |

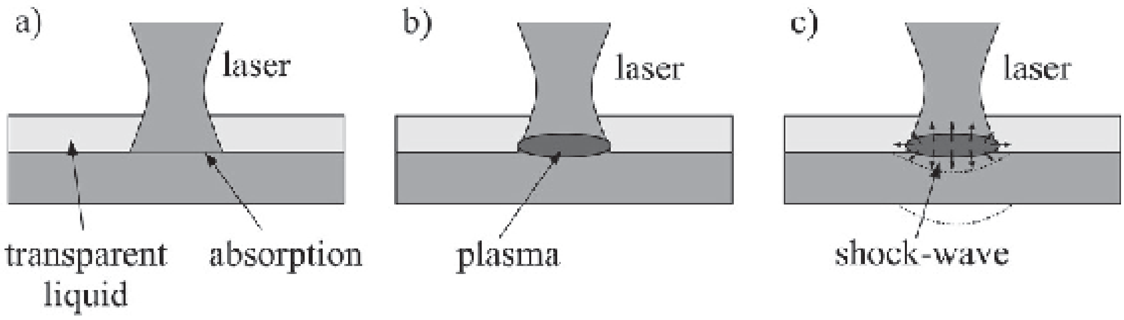



**Figure (1) Shock Wave Process**

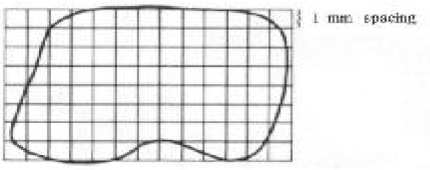



**Figure (2) Shock Wave Process**

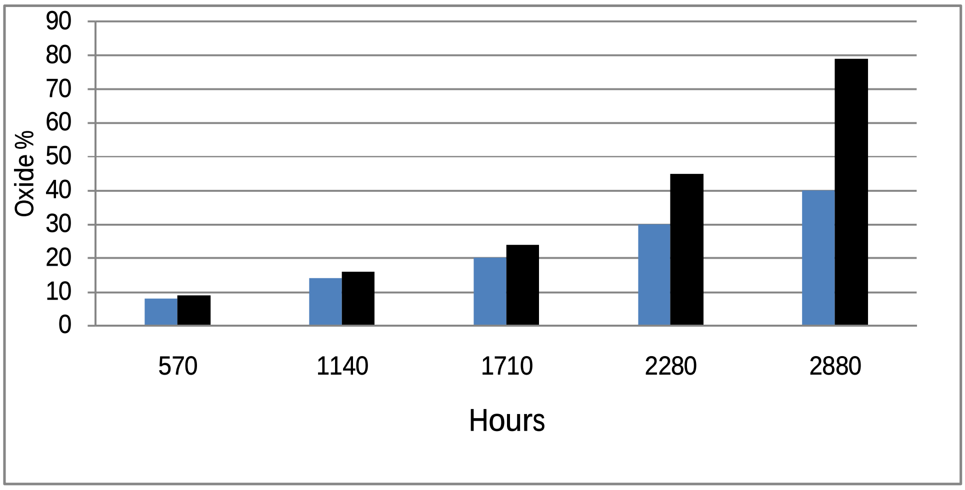



**Figure (3)Percent of Oxide formation to the total surface with hour for 1 pulse**

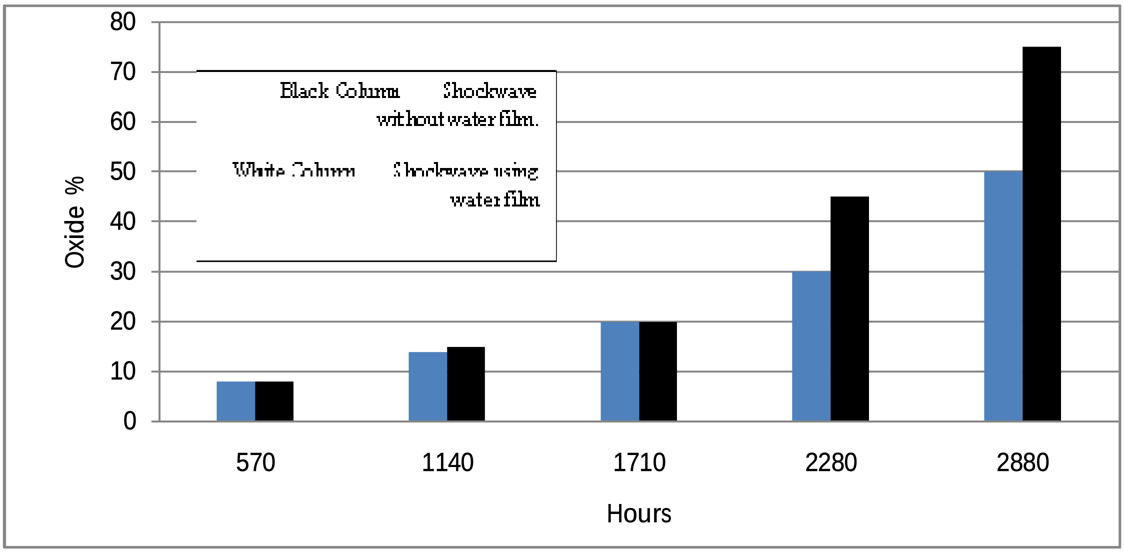



**Figure (4) Percent of Oxide Formation to the total surface with Hour for 1 pulse**

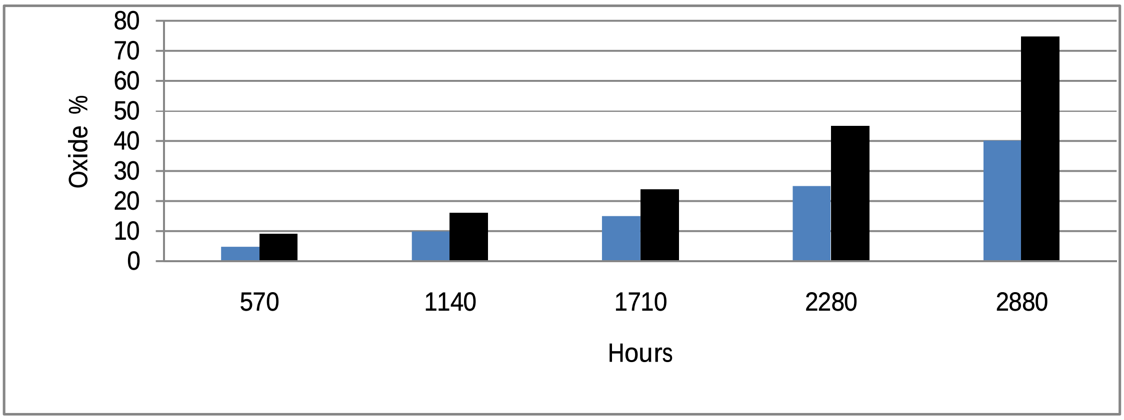



**Figure (5) Percent of Oxide Formation to the total surface with Hours.2 pulses**

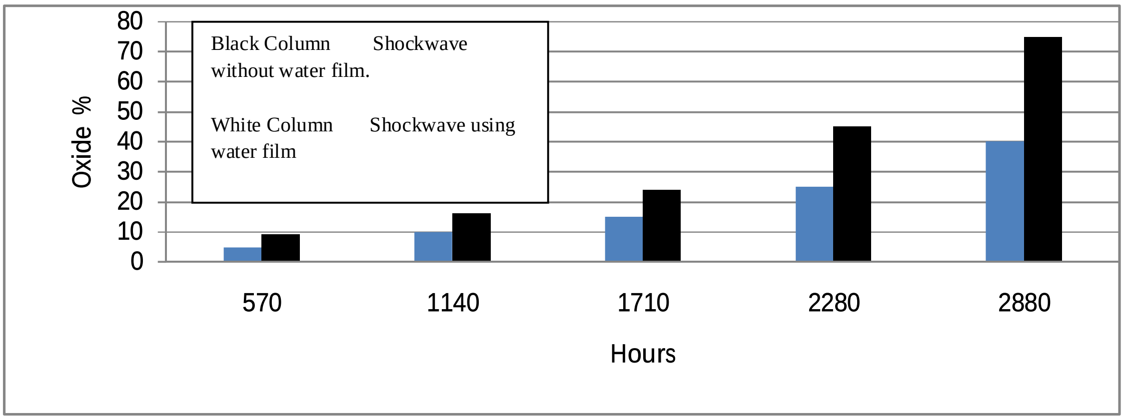



**Figure (6) Percent of Oxide Formation to total surface with hours for 4 pulses**

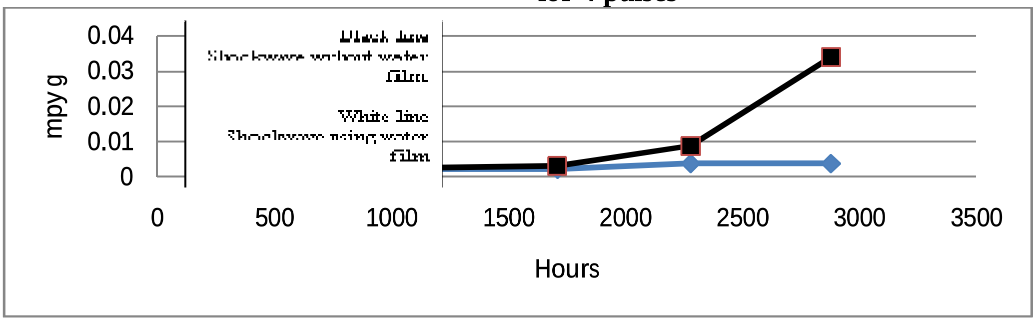



**Figure (7) Percent of Oxide Formation to the total surface with Hours for 4 pulses**

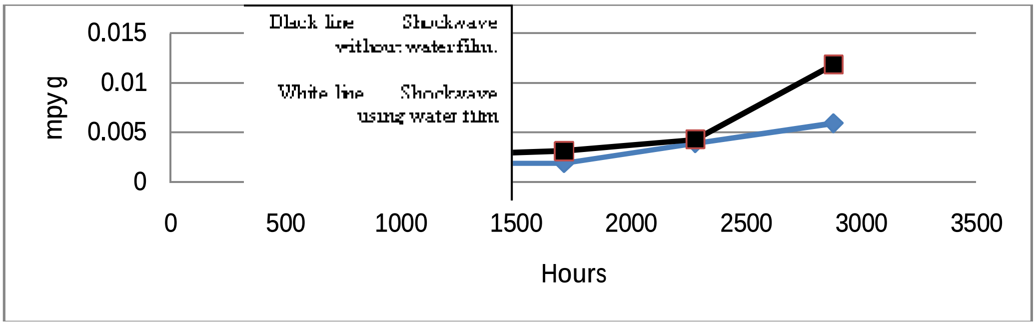



**Figure (8) one pulse**

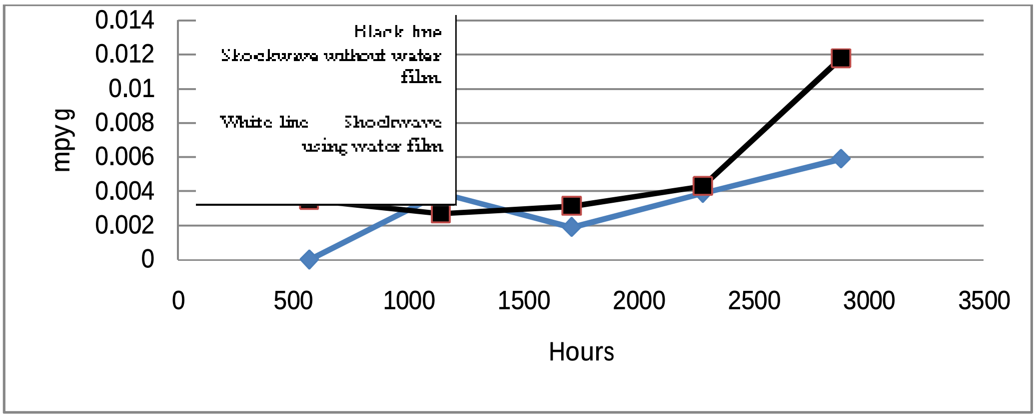



Figure (9) two pulses

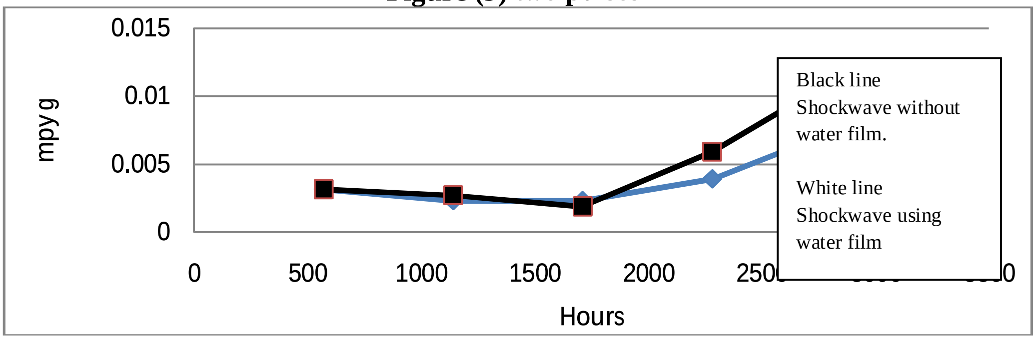



Figure (10) three pulses

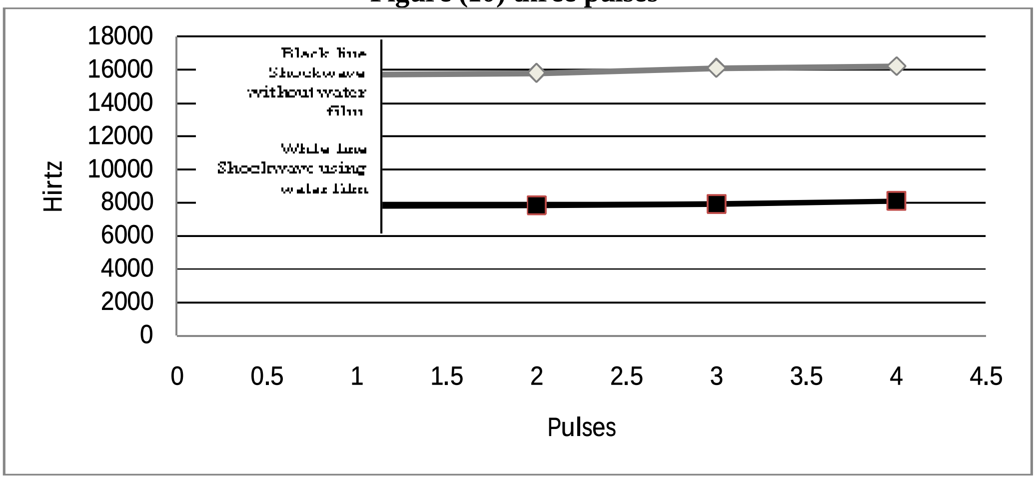
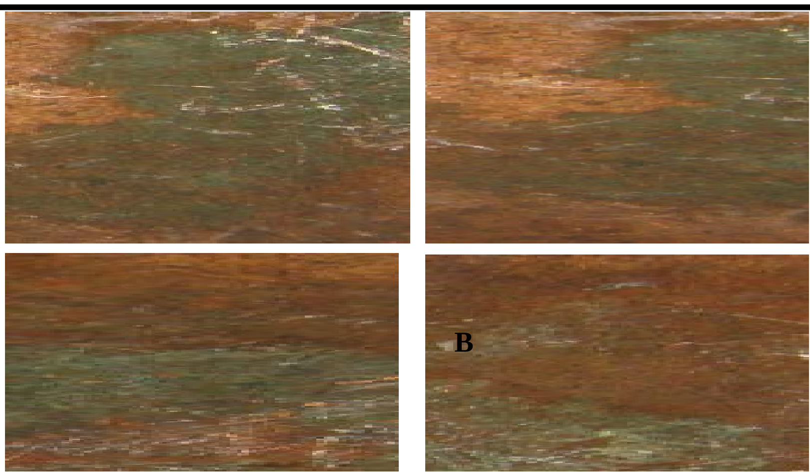



Figure (11) four pulses

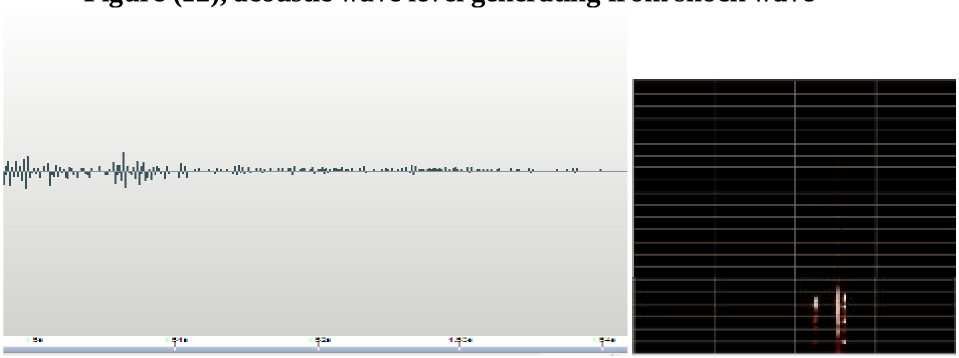


A B

A B

**Figure (12), acoustic wave level generating from shock wave**

Acoustic Wave pressure



B

A time (sec)

**ure (13) A the acoustic wave pressure generated from lasershock wave without water film one pulse, B is hertz level (8000) hertz,**

Acoustic Wave pressure

**Figure (14) A the acoustic wave pressure generating from laser shock wave with water film one pulse, B is hertz level (15720) hertz.**

A time (sec)