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Optimized Distance for Non-damaging In Laser Cleaning preparation

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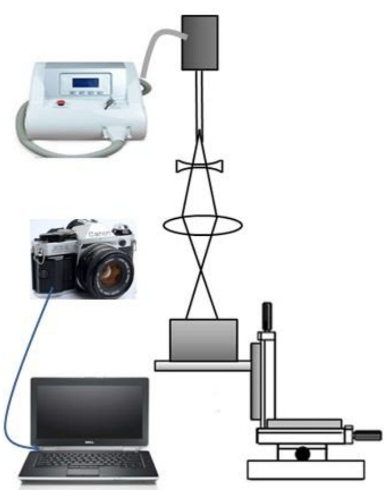
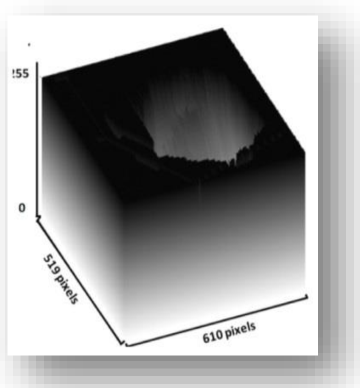
Graphical abstract





Abstract

Laser Technology has wide application in industry as well as in scientific research. Semiconductor industry also interested to use laser for cleaning contaminant. However, until today, no laser has been deployed to take over the traditional method due to lack of intension on it. As a first step to embark into industrial solution, initiative has been carried out to do fundamental experiment. Optimization has been established to find out the best position for cleaning without associated with damage. A Q-switched Nd:YAG laser was focused to create breakdown in the air. This is an indicator for plasma formation and shock wave generation as the main mechanisms of damage. Pure aluminium was used as a substrate and mounted on précised a 3D linear translational stage. The defocused distance was varied in the range of 0-25 mm. The damage image was recorded and analysed via the aid of ImageJ software. Small and deep dense deformation was observed as the target located at the focal point. As the defocused distance move further away, the damage tend to be eliminated and its depth approaching the same level as original.

Keywords: Damage, Nd:YAG laser, breakdown, optimization, distance, depth

Abstrak

Teknologi laser mempunyai pemakaian yabg meluas dalam industry serta dalam penyelidikan Sains. Industry semicondtor juga berminat untuk menggunakan laser bagi membersihkan kotoran. Walaubagaimanapun, sehingga hari kini, beleum ada laser yang digunakan untuk mengantikan kaedah tradisional kernana kurangnya perhatian terhadapnya. Sebagai langkah pertama untuk terlibat dalam menyelesaikan masalah industry, inisiatif telah diambil untuk menguji secara fundamental. Optomasi telah dilaksanakan untuk mencari kedudukan terbaik bagi pembersihan tanpa disertai kerosakan. Satu laser Nd:YAG Q-suis telah difokuskan untuk mengwujudkan runtuhan dalam udara. Ia sebagai pertunjuk pembentukan plasma dan penjanaan gelobang kejutan sebagai mekanisma utama kerosakan. Aluminum tulin digunakan sebagai substrat yang dipegang pada aras persis translasi linear 3D. Jarak bukan focus dipelbagaikandalam julat 0-25 mm. Image kerosakan dirakamkan dan analysis melalui bantuan perisian ImageJ. Lekukan yang kecil dan dalam diperhatikan apabila saran diletakan pada titik focus. Apabila jarak bukan focus di gerakan lebih jauh, kerosakan cenderung ke arah pelupusan dan kedalaman mendekati sama rasa dengan permukaan.

Kata kunci: Kerosakan, laser Nd:YAG, runtuhan, optomas, jarak, kedalaman

1.0 INTRODUCTION

The semiconductor industry has been searching a green technology to remove contaminant induced during etching or thin film deposition processes. Currently chemical method [1-6] stills a common practice for industrial cleaning. Although the method is effective but it costly and involved chemical waste which is polluted to environmental.

There are various types of cleaning including dry [7] and wet cleaning [8-11] to remove particulate contaminants. Very high purity chemicals are required for preparation of semiconductor materials and manufacture of printed circuit boards because low presence of metallic impurities is needed to avoid defects on silicon surface [6]. Up to now, most dry process has not yet been able to remove inorganic particles effectively without inducing damage. Meanwhile wet cleaning although relatively more effective, consume large amounts of water which not economical and it is particularly compatible only with vacuum process [12].

Laser cleaning has been considered by many scientists and engineers as possible technique for the removal of particulate contaminants [13-16]. However, direct dry laser irradiation of wafers has not been shown to remove inorganic particles and could easily cause surface damage. Wet or (explosive evaporation) laser cleaning has been shown to be effective in the removal of organic particles, however, it has been shown to damage patterned wafers. Thus, proper scientific research indeed is important to optimize the parameter of laser, materials and technique suitable for cleaning without or the absence of damage to the substrate.

Laser is a powerful tool, very short pulse duration, rapid operationand can control to scan on the material target. Focusing laser pulse can produce micro-plasma bursts, shockwaves and thermal pressure [17-20] resulting in sublimation and ejection of the target material. However there is still lack of process optimization of the laser beam. As a result laser treated surface always associated with harmful to the base materials. Laser beam power density is desired to be adjusted to achieve cleaning results.

In this article, optimization of defocused distance is carried out to determine the right position of undamaged area. A Q-switched Nd:YAG laser is employed as a source of dry cleaning. Pure aluminum was prepared as substrate. The procedure and experimental results are demonstrated and discussed in detail.

2.0 EXPERIMENTAL

In this experiment a Q-switched Nd:YAG laser (manufactured from China) have been used. The laser operated at fundamental wavelength of 1064 nm. Pulse duration of the laser is 10 ns. Energy output of the laser is kept constant at 40 mJ/pulse. The laser was expanded by a concave lenses with -30 mm focal length. It is then collimated with 250 mm before converge back using convex lenses 70 mm focal length. The accomplishment of such alignment is to ensure the formation of a point source of optical breakdown (Figure 1). Aluminum bulk (purity of 99.9%) was employed as a substrate. The detail property of the substrate is listed in Table 1. The substrate was polished to shine for metallurgical study. 3D linear translation stage was utilized to precisely change the defocused distance. Initially the substrate was positioned right on the focal distance which referred as a zero distance. At least 3 samples were utilized in order to get the average damaged area for each tested cleaning distance. The same procedure was followed for the next tested distance. The cleaning distance was studied in the range from 0 -25 mm. Each of the exposed substrate was recorded using digital camera. The image was then analysed with the aid of imageJ software.

Table 1 Substrate Property

Parameter	Quantity
Metal type	Pure Aluminum (purity 99.9%)
Melting point	660 °C
density	2.708 g/cm^3
Elasticity	69 GPa
Hardness	30 HV
Dimension	1 x 1 x 1 cm^3

3.0 RESULTS AND DISCUSSION

Typical result obtained after laser interaction on aluminum plate at different defocused distance is shown in Figure 2. Initially when the pure aluminum substrate was focused right of the top surface of the aluminum substrate, a deep hole is created. Laser induced breakdown is associated with plasma formation and shock wave generation. The temperature of the plasma is known more than 11000 K which is far higher than melting point of the aluminum (933 K). Thus when the plasma is in direct contact on top of the aluminum surface, vaporized and particle removal occur immediately. However due to the transient life time of the pulse within 10 ns, conduction is not allow, consequently, small and deep hole are created as illustrated in Figure 2. However as the defocused distance is incremented, the dense was observed to be enlarged and the depth getting shallow. A series of typical results are depicted in Figure 3. The pictures are arranged in increasing order of the distance. Each frame was analysed with the aid of ImageJ. Using verities option including, inverted the picture, editing the contrast in order to measure precisely the damaged area.

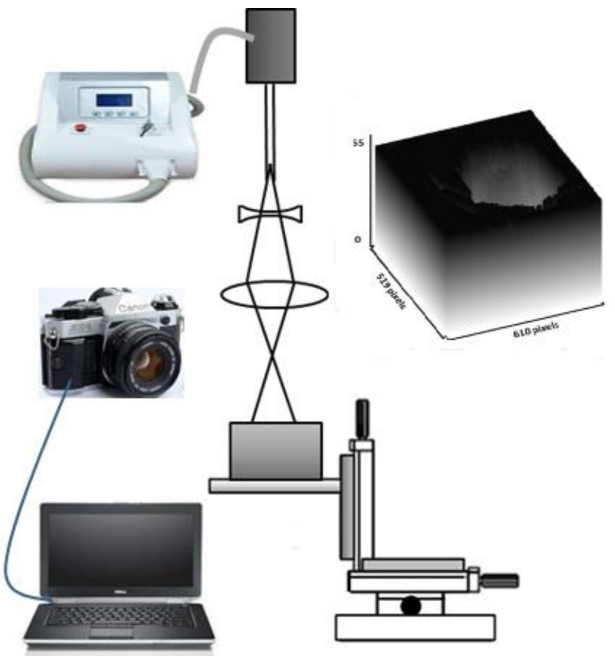


Figure 1 experimental set-up

The average measurement of the damaged area is summarized in Figure 3. The damaged area is found to be nonlinearly increases with respect to the distance. This is appropriated with the Rayleigh range of the beam profile, where the laser beam pressure is still strong enough to cause damage. The beam area is increased which cause in lowering the power density delivered on the target. The bigger the beam size the lower the power density, thus less impact or momentum delivered on the aluminum. Furthermore the bigger damage size also lowered the depth of dense. This is manifested by examining the depth profile as shown in Figure 4. Clearly the depth profile have shown that the deepest depth is obtained at the focal point and soon approaching at 21 mm distance the dense almost the same level of the top surface of the substrate. Based on the profile the depth of dense due to the beam pressure is presented against distance as shown in Figure 5. Interestingly the formation of dense depth is linearly decreasing with the distance. Hence the depth is found inversely proportionally with defocused distance. This can be a calibration curve to determine the distance for cleaning process without harmful to the substrate material.

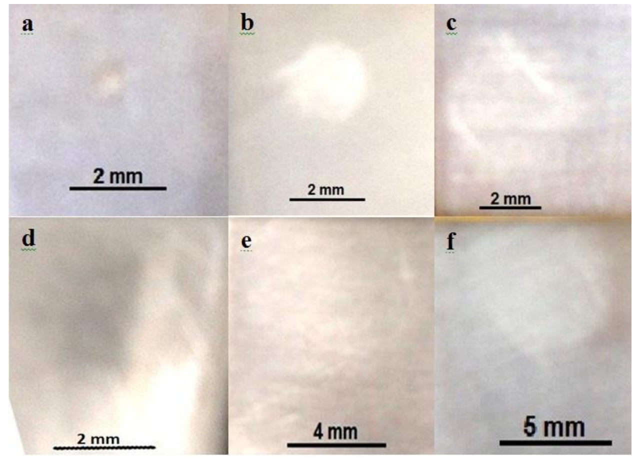


Figure 2 The damaged area generated at difference distances, a. 0 mm, b. 9 mm, c. 15 mm, d. 19 mm, e. 19 mm, f, 21 mm

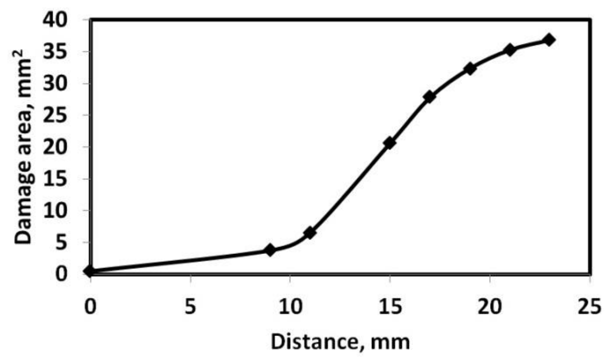


Figure 3 Damaged area of dense formation with respect to defocused distance

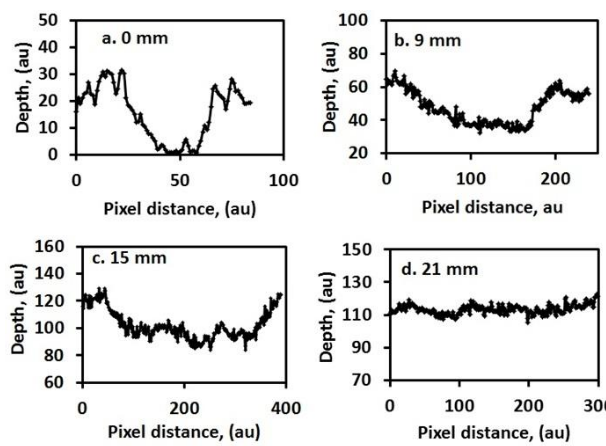


Figure 4 Surface profile at different distance from focal point, a. 0 mm, b. 9 mm, c. 15 mm, d. 21 mm

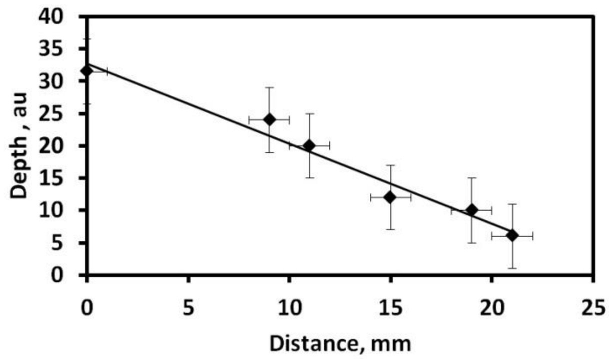


Figure 5 Depth of the dense against the defocused distance

4.0 CONCLUSION

Laser is a grateful tool for laser cleaning. In order to ensure the cleaning is not associated with damage the optimization is important. This work has demonstrated that less effect of damage is realized when the distance is placed within Rayleigh region. Less than optimized distance always accompanied with damage, but if greater than 25 mm subjected to not enough power density to cause particle removal. Thus for laser cleaning purposes, it is advisable that to determine the optimized distance prior contamination removal in order to avoid damage to the substrate material.

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References

[1] Ohmi, T. 1996. Total Room Temperature Wet Cleaning of Silicon Surfaces. *Semiconductor International*. 19(8): 323-338.
[2] Hattori, T. Osaka T., Okamoto, A. Saga, K. and Kuniyasu, H. 1998. Contamination Removal by Single-Wafer Cleaning with Repetitive Use of Ozonated Wafer and Dilute HF. *J. Electrochem. Soc.* 145(9): 3278-3284.
[3] Uemura, K. Mori, Y., Haibara, T. 2001. Cleaning Technology Silicon Wafer. *Nipon Steel Technical Report*. 83: 61-68.
[4] Abejon, R., Garea, A. Irabien, A. 2010. Ultrapurification Of Hydrogen Peroxide Solution From Ionic Metals Impurities To Semiconductor Grade By Reverse Osmosis. *Separation and Purification Technology*. 76: 44-51.
[5] Abejon, R., Garea, A., Irabien, A. 2012. Analysis, Modelling And Simulation Of Hydrogen Peroxideultrapurification by Multistage Reverse Osmosis. *Chemical Engineering Research And Design*. 90(3): 442-452.
[6] Robert, H. Pagliaro, Jr., Mesa, A. Z. 2014. Silicon Surface Preparation. United States Patent. No.: US 8,765,606 B2.
[7] Braha, D. and Shmilovici, A. 2001. Data Mining for Improving a Cleaning Process in the Semiconductor Industry. *IEEE Transactions On Semiconductor Manufacturing*. 15(1): 91-101.
[8] Nelson, S. L., 1997. The Effect of Oxygen Passivation of Silicon by Wet Cleaning Processes on Contamination and Defects. Proceedings of the Electrochemical Society. *Pennington, NJ: Electrochemical Society*. 35: 38-45.
[9] Bergman, E., and Lagrange, S. 2001. HF-Ozone Cleaning Chemistry. *Solid State Technology.* 46(7): 115-124.
[10] Heyns, M., Meuris, M. and Paul Mertens, P. 1999. Particle Removal Efficiency and Silicon Roughness in HF-DIW/O3/Megasonics Cleaning. *Solid State Phenomena*. 65-66: 27-30.
[11] Zhang, J., Birnbaum, A. J., Yao, Y. L., Xu, F., Lombardi, J. R. 2008. Mechanism and Prediction of Laser Wet Cleaning of Marble Encrustation. *Journal of Manufacturing Science and Engineering*. 130: 031012.
[12] DeJule, R. 1998. CMP Challenges below a Quarter Micron. *Semiconductor International*. 56-64.
[13] Yue, L., Z. Wang, Z., Guo Wand Lin Li L. 2012. Axial Laser Beam Cleaning Of Tiny Particles On Narrow Slot Sidewalls. *J. Phys. D: Appl. Phys.* 45: 365106.
[14] Vereecke, G., Rohr, E., Heyns, M. 1999. Laser-Assisted Removal of Particles on Silicon Wafers. *J. Appl. Phys.* 85: 3837.
[15] Busnaina, A. A., Park, J. G., Lee, J. M., You, S. Y. 2003. Laser Shock Cleaning of Inorganic Micro and Nanoscale Particles. *The 14th Semiconductor Manufacturing Conference (ASMC)* March 31 – April 1, Munich, Germany: 41-45.
[16] Curran, C., Watkins, K. G., Lee, J. M. 2002. Ultravolet Laser Removal Of Small Metallic Particles Fromsilicon Wafers. *Optics and Lasers in Engineering*. 38: 405-415.
[17] N. Bidin, R. Qindeel, M. Y. Daud, and K. A. Bhatti. 2007. Plasma Splashing from Al. and Cu Materials Induced by an Nd: YAG Pulsed Laser. *Laser Physics.* 17(10): 1222-1228.
[18] Rabia Qindeel, Noriah Bidin, and Yaacob Mat Daud. 2007. IR Laser Plasma Interaction with Glass. *American Journal of Applied Sciences.* 4(12): 1009-1015.
[19] Alwafi, Y. Bidin N., Riban G. D., Harun. S. W. 2012. Alloying Aluminum with Fe Using Laser Induced Plasma Technique. *Laser Physics*. 22(8): 1364-1367.
[20] Bidin, N., Abdullah, M., Shaharin, M. S., Al-Wafi, Y., Riban, D. G, and Yasin, M. 2013. Optimization of Super Lateral Energy In Laser Surface Alloying Aluminium. *Laser Phys. Lett.* 10: 106001.