Optimisation of fabrication of micro-holes in PCB using ND:YAG laser drilling

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Abstract

Laser micro-drilling is a versatile process for fabrication of micro-holes in different components irrespective of its hardness and whether it is electrically conducting or not. Micro-holes are the inherent features in different micro-products used in MEMS, aerospace application, bio-medical, nuclear engineering and automotive applications. In the present investigation, the optimization of the fabrication of micro-holes with the help of solid state ND:YAG laser in PCB has been carried out using Grey-Taguchi method.

Key Words:- *Laser micro drilling, Micro holes, Taguchi Method*

1. Introduction

Laser drilling is having advantages over conventional micro-drilling and other non-conventional processes. A large number of investigators have carried out research for fabrication of micro-holes in different materials. The general perceptions of a hole related to laser drilling has been given in order to differentiate between bore,large hole, small hole and micro-hole. It is observed that the deep holes can not be drilled with single laser pulse, but must be pulsed repeatatively in the place. It is reported that it is more efficient to drill deep holes with multiple laser pulses of low energy than with a single high energy pulse. There are a number of advantages of drilling a hole using a laser. There is no tool wear. Holes of smaller dimension with large aspect ratio can be drilled. The process is very rapid with less set-up time irrespective of any high strength material. The automation of the process can be made easily with low operating cost. However, the high equipment cost is the limitation of the process. A taper is formed naturally in the process which is to be minimized with optimization of the process parameters. It is also difficult to drill blind hole with accurate depth. A number of investigators have developed a number of models to study the different aspects of laser drilling process. Jones et al.[3] developed basic thermal balance model. C. Bor-Issac and U. Korn[4]investigated the moving heat source dynamics in laser drilling process. Minardi et al.[5] investigated the hole profile characteristics with consideration of mass removal. A. Minardi and P. J. Bishop[6] analysed temperature distribution within a metal by a laser of spatially varying intensity. U. C. Parek and F. P> Gogliano[7] investigated the thermal stress propagation with temperature profile. Material removal process is estimated approximately using simple energy balance equation [8]. Von Alliman [9] developed a theoretical model to determine the drilling velocity and drilling efficiency as a function of the absorbed intensity. Wagner[10] developed a quantitative model to predict the depth and the shape of the hole drilled. Forget et al.[11]developed the thermal model coupled with an energy-matter balance equation to predict the depth per pulse in the laser drilling. The relationship of the taper and the thickness of the work-piece is analysed by B. F. Scott[12]. It is observed that the taper angle decreases with increase in thickness of the work-piece. Yilbos[13] studied the barreling of the hole. He concluded that the barreling effect can be reduced by reducing the pressure of assist gas. A cause- and –effect diagram showing the various parameters affecting the quality of drilled has been demonstrated [14]. Broadly the quality of hole is influenced by the material, laser pulse, and environment assist gas and focusing lens. The pulse shape plays a significant role for the material removalin laser drilling. Ross[15] investigated that the drilling of small hole in 0.1mm thick tool was not possible with a normal 200µs Nd:YAG laser pulse upto 400mJ. In the present investigation, the fabrication of micro-holes in PCB has been carried out using ND:YAG laser. The circularity error, taper angle of the micro-hole, heat affected zone (HAZ) are measured using scanning electron microscope. The optimization of the process parameters has been carried out using Grey Taguchi Method.

2. Experimental Investigation

The micro-holes are laser-drilled in PCB using ND-YAG laser. The experiment has been conducted using L_9 orthogonal array. The power, pulse on time, focus diameter and frequency are taken as the process parameters. Grey-Taguchi method has been used to optimize the multi-objective criteria. The optimum process parameters are determined in order to minimize the circularity error, taper angle angle no of shots, heat affected zone and maximize MRR

3. Results and discussion

The micro-holes are drilled in PCBusing a ND:YAG laser using L_9 orthogonal array. Powe, T_{on}, focus dia and frequency are considered as the variable process parameters. All the process parameters are varied at three levels. The range of the process parameters are chosen from the capacity of the machine.

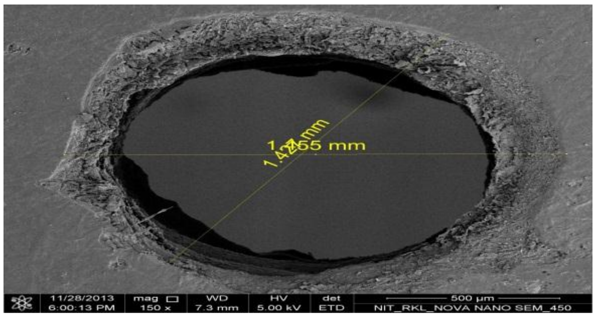

Fig. 1. Micro hole 1

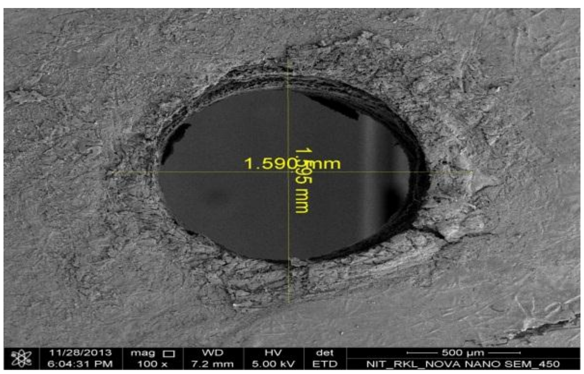

Fig. 2. Micro hole 2

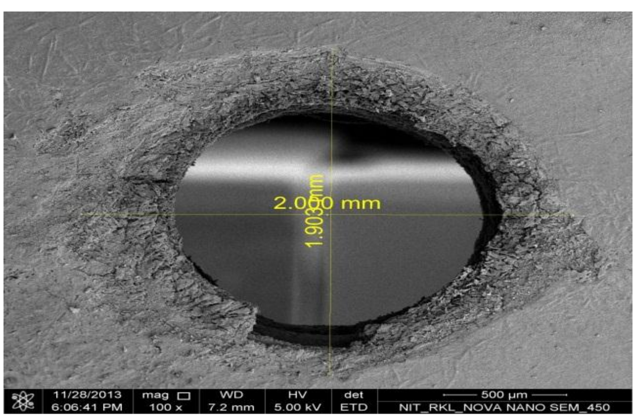

Fig.3. Micro hole 3

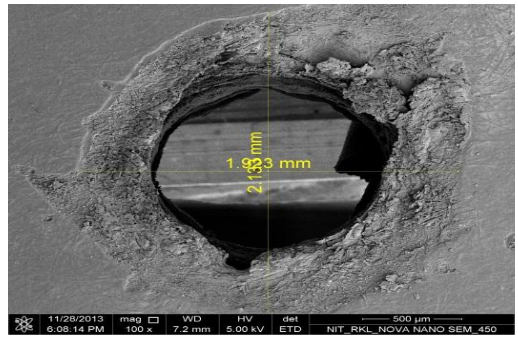

Fig. 4. Micro hole 4

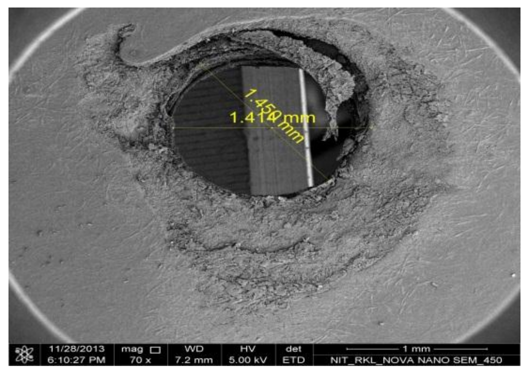

Fig. 5. Micro hole 5

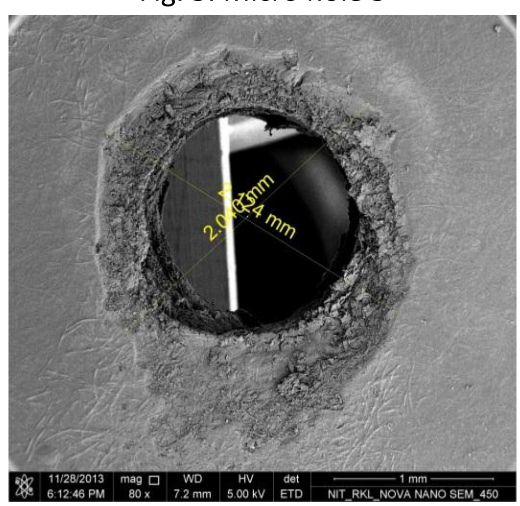

Fig. 6. Micro hole 6

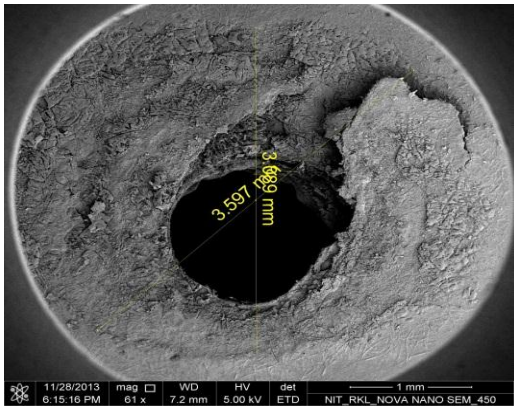

Fig. 7. Micro hole 7

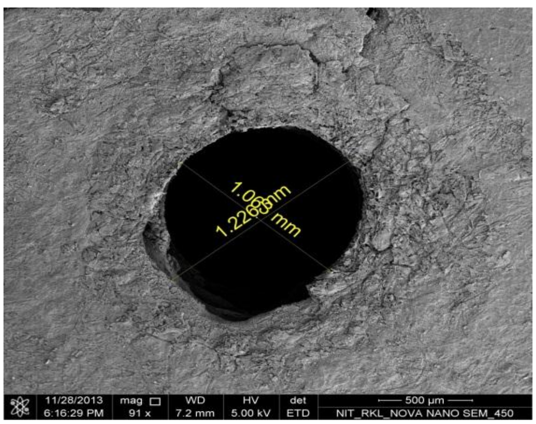

Fig. 8. Micro hole 8

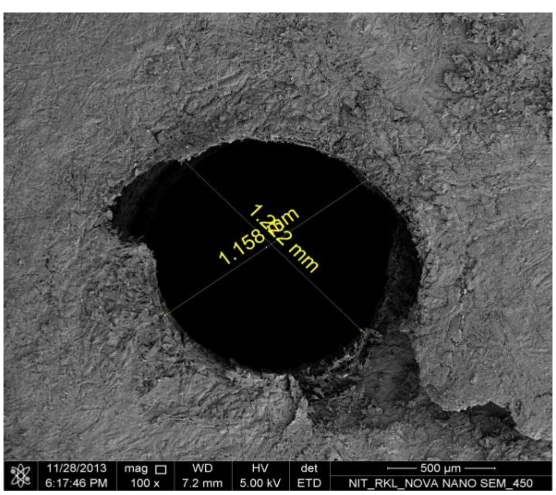

Fig. 9. Micro hole 9

Table No 1. Cutting Factors and Experimental Results

Expt No	Pow-er (kw)	T_{on} (µs)	Focus Dia (mm)	Frequency (Hz)	Circularity Error	HAZ
1	2.5	2	0.8	2	0.045	0.325
2	2.5	4	0.9	5	0.004	0.037
3	2.5	6	1	7	0.567	0.088
4	4.5	2	0.9	7	0.08	0.122
5	4.5	4	1	2	0.983	0.036
6	4.5	6	0.8	5	0.746	0.031
7	6.5	2	1	5	2.04	0.025
8	6.5	4	0.8	7	0.087	0.163
9	6.5	6	0.9	2	0.091	0.064

Table No 2. Data Preprocessing of each performance characteristic

Experiment No	Circularity Error	HAZ
Ideal Sequence	1	1
1	0.980	0.000
2	1.000	0.960
3	0.723	0.790
4	0.963	0.677
5	0.519	0.963
6	0.636	0.980
7	0.000	1.000
8	0.959	0.540
9	0.957	0.870

The micro-holes (Fig.1-Fig.9) are laser drilled as per the parameters in Table1. The circularity error and heat affected zone(HAZ) are measured using scanning electron microscope. The minimization of circularity error and heat affected zone has been carried out using Grey Taguchi method using multi-objective criteria (Table2 & Table3). The main effect plot is shown in Fig.10. The equation for combined response is found out from regression analysis as shown in equation1. The optimization of taper angle and

MRR will be carried out later along with circularity error and HAZ.

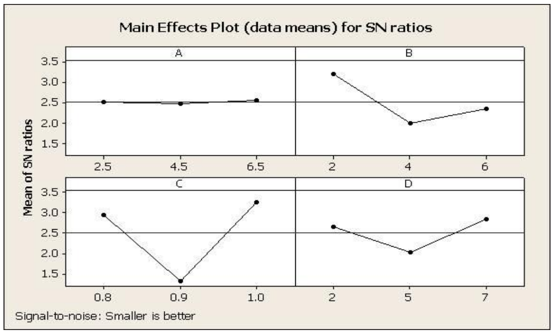

Fig. 10 Main Effects plot

Table No 3. Grey relational grade and its order

Experim ent -No	Grey relational grade	S/N Ratio	Order No
1	0.647	3.78191	9
2	0.963	0.32747	1
3	0.674	3.4268	7
4	0.769	2.28147	4
5	0.721	2.84129	6
6	0.770	2.27019	3
7	0.667	3.51748	8
8	0.723	2.81723	5
9	0.857	1.34038	2

F= 2.51158+0.00048*(power at level 1)-0.04726*(power at level 2) +0.68204*(T_{on} at level 1) -0.51625*(T_{on} at level 2) +0.44486*(Focus Dia at level 1) -1.19514*(Focus Dia at level 2) +0.14295*(Frequency at level 1) -0.47320*(Frequency at level 2) (1)

4. Conclusion-

Multi-objective optimization of laser drilling has been carried out for minimization of circularity error and HAZ in micro-hole using Grey-Taguchi Method.

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