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Scribing of Ceramic Circuit Board with Q-Switched Nd:YAG Laser

Yoshiyuki UNO*, Shin-ichiro KUBOTA**, Seiichi YOKOMIZO**,
Kojiro OGATA*** and Nobuhiko TADA***

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SYNOPSIS

Scribing of copper coated alumina ceramic board with Q-switched YAG laser used for the maskless direct patterning of circuit board[1] is experimentally investigated, which leads to efficient production of trial circuit board. Better dividing of alumina circuit board 655μm in thickness can be attained by the scribing of about 100μm depth. Higher repetition frequency of laser irradiation leads to smaller notch angle and lower breaking load.

1. INTRODUCTION

High efficiency dividing of brittle materials such as ceramics, glass and so on can be attained by scribing the surface of materials firstly and then dividing it by bending stress. Recently, laser has been used as the means of scribing. Alumina ceramic used as the base material of circuit board is usually scribed by CO_2 laser. It is possible for CO_2 laser to machine efficiently the alumina ceramic, since the wavelength is 10.6μm and it fits the absorptive band of alumina ceramic. However, the width of groove generated by CO_2 laser has a tendency to be wide[2]. In this paper, scribing of ceramic curcuit board with Q-switched YAG laser is experimentally investigated. The absorption ratio of YAG laser for alumina ceramic is lower than that of CO_2 laser, since the wavelength of YAG laser is 1.06μm. However it leads to smaller focus spot and more precise machining. The purpose of this study is to scribe the ceramic circuit board with

* Department of Mechanical Engineering
** Industrial Technology Center of Okayama Prefecture
*** Hitachi Construction Machinery Co.,Ltd

the same YAG laser system used for maskless direct patterning[1] without detaching and attaching of workpiece.

2. EXPERIMENTAL PROCEDURE

2. 1 Experimental Apparatus

Fig.1 shows the schematic diagram of experimental apparatus used in this study. The rated average output of this YAG laser is 15W maximum and the peak output is 30kW maximum with acoustic optic Q-switch device. Minimum pulse duration is more than 100ns. The focal length of the condensing lens is 100mm. The laser was irradiated onto the ceramic board mounted on the x-y table moving at the setting speed. The workpiece is copper coated alumina ceramic board 655μm in thickness. Copper film of 20μm in thickness is coated on the base material.

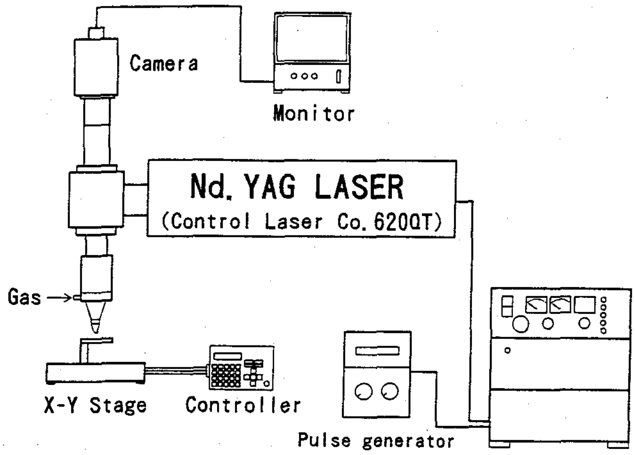

Fig.1 Schematic diagram of experimental apparatus

2. 2 Bending Test

The size of testpiece is 38mm x 4mm and the laser was irradiated from the side of copper coated surface. After measuring the shape of notch formed by laser, four-point bending test was carried out. Fig.2 shows the schematic diagram of the method of bending test. Four-point bending test is superior in loading uniformly and can prevent the loading point from separating the notch point. The test was carried out based upon Testing Method for Flexural Strength of High Performance Ceramics established in Japanese Industrial Standerds R1601.

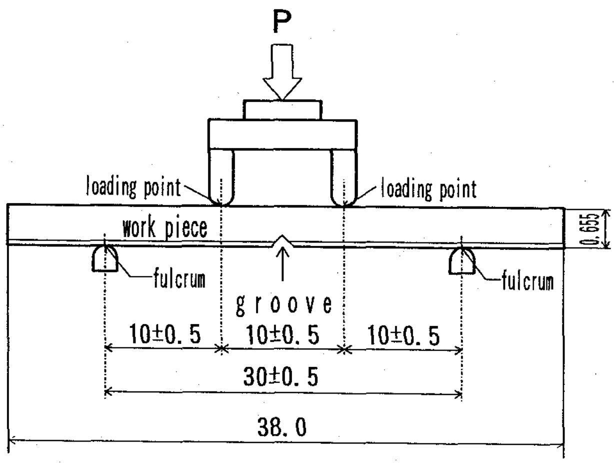

Fig.2 Loading method in four-point bending test

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

3. 1 Characteristics of Laser Scribing of Alumina Ceramic Board

Fig.3 shows the relationship between the depth of notch and the number of laser scanning. In the case of laser scribing with low power Q-switched YAG laser, it is impossible to cut off the workpiece by one passing. It is necessary to irradiate the laser beam repeatedly along the setting path. As shown in the figure, the depth of notch increases rapidly with the earlier number of scanning, however the machining rate decreases with an increase of the number of scanning. It is considered that the decrease in machining rate is due to the decrease of energy density resulted from the out of focus. For higher efficiency dividing, it is desirable to generate the proper notch on the ceramic board by making use of the earlier stage of machining and load the bending moment.

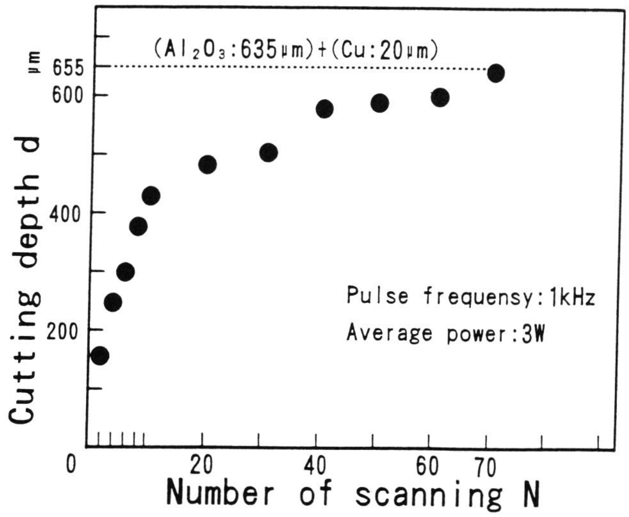

Fig.3 Relationship between the notch depth and the number of scanning

Figs.4 (a) - (c) show micrographs of the cross section of the workpiece which was machined under several conditions and fractured by the bending test. The arrows in the figures show the notch point. As shown in the figure, differences in the dividing manner are caused by the shape and the depth of notch.

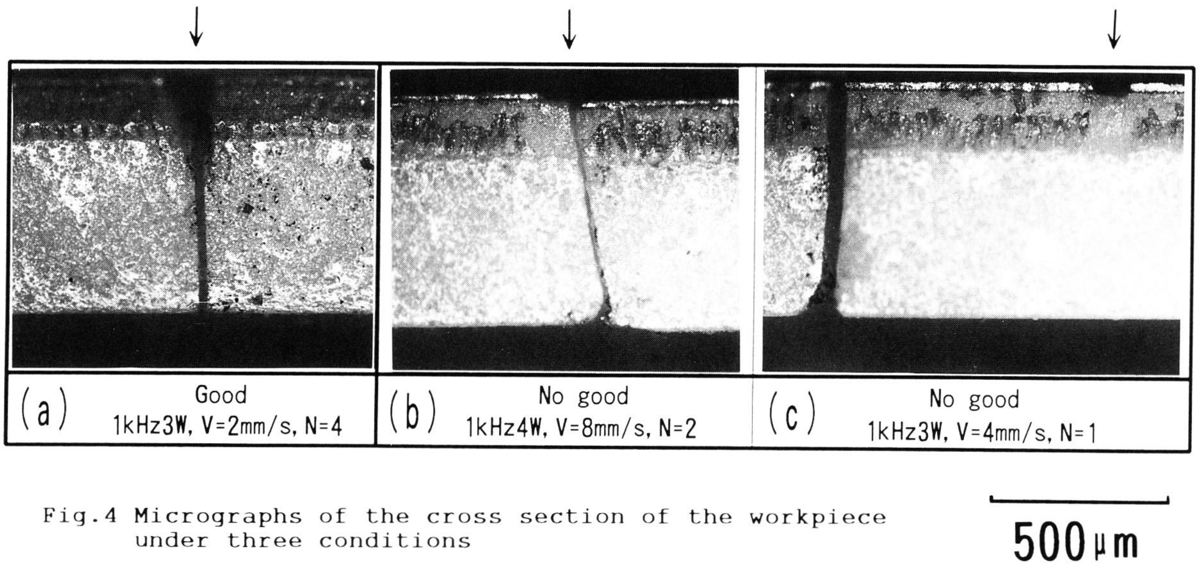

Fig.4 Micrographs of the cross section of the workpiece under three conditions

In the case of (a), crack line is perpendicular to the notched surface. This testpiece is judged as good. In the case of (b) and (c), the crack line is inclined to the notch surface or far from the notch point. These testpieces are judged as no good.

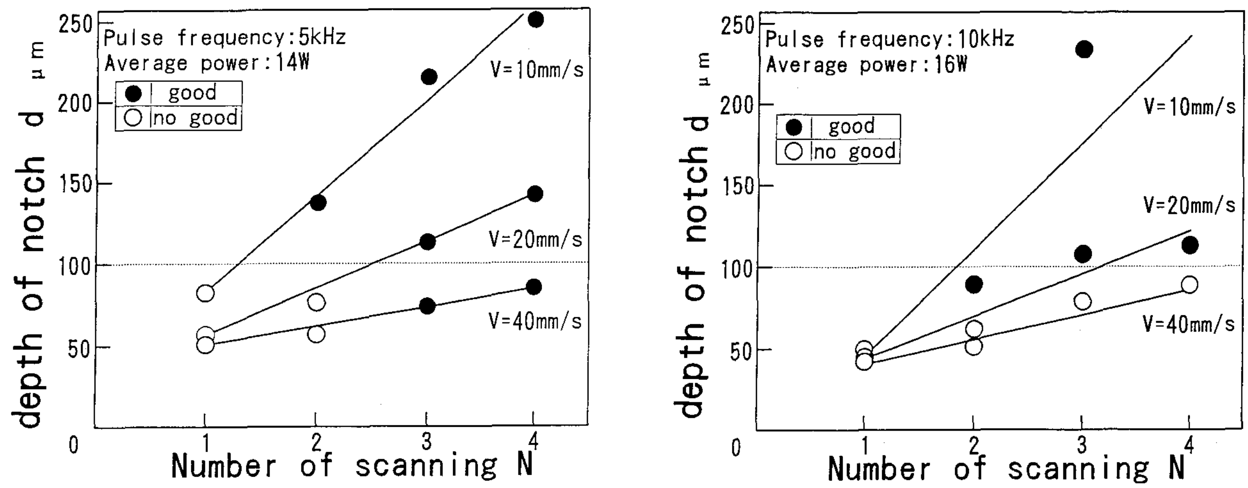

Fig.5 Characterisics of scribing with Q-switched YAG laser

Fig.5 shows the relationships between the depth of notch and the number of scanning when the machining conditions such as repetition frequency, avarage power and feed rate are varied. In these figures, solid circles show the case of good dividing result. It is clear that the larger the input heat quantity per unit length, the deeper the depth of notch. Judging from these figures, the testpiece whose notch depth is more than 100μm results in good dividing.

Fig.6 shows the relationship between the depth of notch and the breaking load under the machining condition f=1kHz constant. As shown in the figure, the deeper the depth of notch, the smaller the breaking load. This is due to the stress increase with a decrease of sectional area. The similar relationships are seen for some diffrent frequencies.

Fig.7 shows the relationships between the depth of notch and the breaking load for several repetition frequencies. As can be seen from the figure, the breaking load is different for different repetition frequency even if the depth of notch is the same. For example, in the case of the depth of notch is 100μm, the breaking load for f=1kHz is about 10N, while that for f=10kHz is about 5N. This is because the shape of notch varies with the repetition frequency.

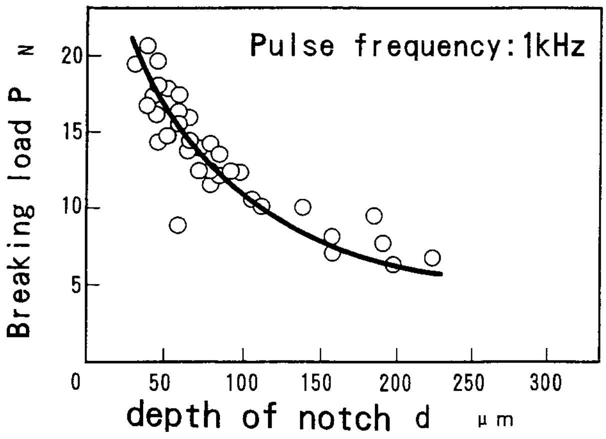

Fig.6 Relationship between the notch depth and the breaking load (f=1kHz)

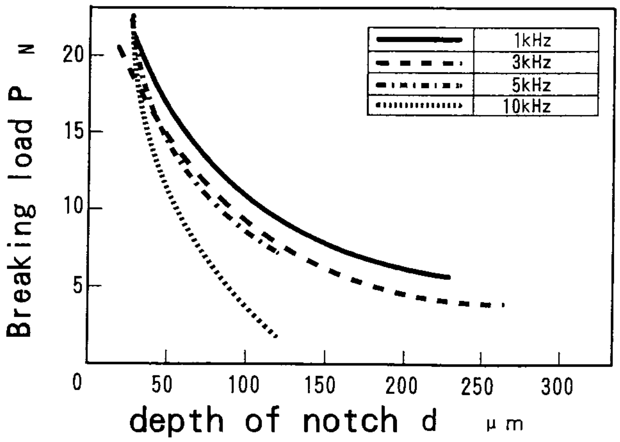

Fig.7 Relationships between the notch depth and the breaking load for several repetition frequencies

3. 2 Considerations of the Notch Shape and Stress Concentration

Stress concentration has a close relation to the notch shape genarated by laser scribing. Factors which have influence on the stress concentration are the radius of curvature ρ at the tip of notch, the notch angle 2θ and the depth of notch d. If the plate in thickness B has a notch on one side, the stress concentration is calculated by means of angle coefficient $f(\theta)$ which expresses the effect of notch angle on stress concentration[3]. The stress concentration factor α_θ is expressed as the following equations. (Stress concentration factor α_0 is a basic value when $\theta=0$.)

$$\alpha_\theta = 1 + f(\theta)(\alpha_0 - 1)$$

where

$$f(\theta) = \{1 - \mathrm{EXP}(-0.90A(\pi - 2\theta))\} / \{1 - \mathrm{EXP}(-0.90\pi A)\}$$

$$A = \sqrt{(B / d)}$$

As shown in the above equations, α_θ is affected by the value d/B. For example, at the limit when d approaches 0, the stress concentrarion factor α_θ becomes α_0 because the angle coefficient $f(\theta)$ becomes 1. On the other hand, at the limit when d approaches B, $f(\theta)$ decreases exponentially with 2θ. In other words, when ρ and d are constant, the stress concentration factor α_θ decreases with the opening notch angle 2θ. But the decreasing tendency of stress concentration factor depends on the depth of notch d.

Fig.8 shows the micrographs of the cross section of notch which is machined under two different repetition frequencies. As shown in the figure, the higher the repetition frequency, the smaller the notch angle 2θ . It is considered that the decrease of notch angle is due to the decrease of peak power of Q-switched YAG laser with an increase of repretition frequency. This phenomenon leads to the decrease of breaking load of testpiece as mentioned in 4. 1.

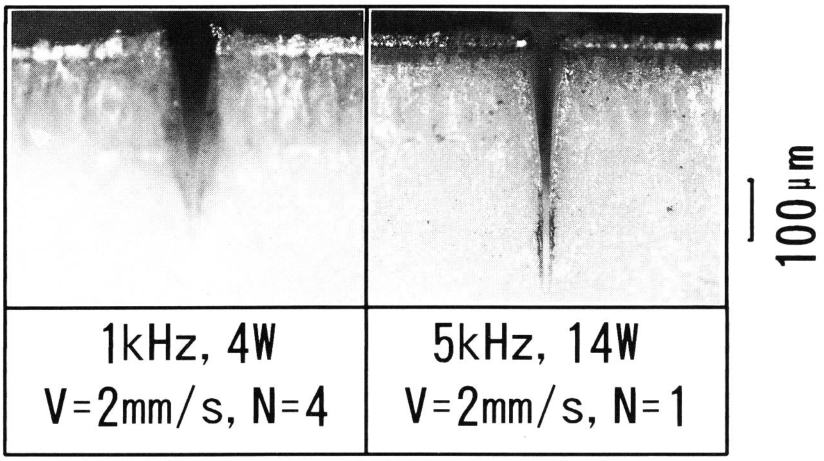

Fig.8 Micrographs of the cross section of notch

4. CONCLUSIONS

This paper deals with the application of Q-switched YAG laser for the scribing of alumina ceramic circuit board. Main conclusions obtained in this study are as follows:

(1) Better dividing of alumina circuit board 655μ m in thickness with Q-switched YAG laser is attained by the scribing of more than 100μ m depth.

(2) Higher repetition frequency of laser irradiation leads to smaller notch angle and lower breaking load.

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