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193 & 248 nm high power lasers for the micro and macro material processing

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Abstract

Recently infrared laser has faced resolution limit of finer micromachining requirement on especially semiconductor packaging like Fan-Out Wafer Level Package and Through Glass Via hole which are hard to process with less defect. In this study, we investigated process capabilities with deep ultra violet excimer laser to explore its possibilities of micromachining on organic and glass interposers. These results were observed with an optical microscopy and Scanning Electron Microscope.

We have succeeded 9 micron meter holes on organic and 100 micron meter aspect ratio 5 on glass interposer without any significant defects. As the ablation rates of both materials were quite affordable value, excimer laser is expected to be put in practical use for mass production.

Keywords: excimer laser, 193nm, 248nm, KrF laser, ArF laser, material processing, micromachining

1. Introduction

Infrared (IR) laser has been widely used for material processing, however, deep ultraviolet (DUV) excimer laser is considered to have a potential. We, Gigaphoton, have developed several kinds of excimer lasers to explore new laser processing. The excimer lasers at wavelength 193nm: ArF and 248nm: KrF (output power; up to 120W) have been used in semiconductor manufacturing for long years, and it is proved that they possess high stability and reliability. In addition to that, high power (>400W) wavelength 308nm: XeCl and 248nm excimer lasers are applied to annealing process of Flat Panel Display (FPD).

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We have been also developing hybrid excimer laser for high power 193nm coherent light source. Although the power itself is not so high, its solid state laser has high optical quality and can be amplified with our ArF excimer laser up to more than 100W [1][2].

Laser microfabrication is widely applied to manufacture various devices and systems. Higher density and lower size are required for processing organic and glass interposers on Fan-Out Wafer Level Package (FO-WLP) and Through Glass Via (TGV) hole in semiconductor packaging. As we mentioned above, IR laser is one of the most popular light sources for laser micromachining, but it cannot manufacture a hole smaller than 30μm and its processing quality is not high due to thermogenic effects. In order to remove that kind of effects, IR femtosecond (fs) laser is examined. However, IR fs lasers is not suitable for mass-production processing because of its low pulse energy and high cost. Another approach is to use a short wavelength laser such as excimer laser. Since DUV photon energy is much higher, excimer laser processing could reduce thermal effects and damage in a material by direct photon absorption. They also have high resolution capability by shorter wavelength, which is suitable for microfabrication process [3][4]. More than five thousands excimer lasers have been already installed and operating in factories of leading-edge semiconductor lithography process and FPD for poly-Si crystallization.

We have established an experimental facility to search material processing by high power excimer laser and started to evaluate both KrF/ArF capabilities for organic and glass interposers. In this paper, we would like to clarify potentials of excimer laser as an alternative to IR laser in micromachining.

2. Lasers & Experimental setup

To adopt laser ablation process in commercial manufacturing lines, it's important to know its ablation rate. And manufacturing costs can be estimated with laser photon costs and ablation volume rate. We have reported the affordable ablation rate in our previous report [5][6]. In this report, we try to make the via holes as small as possible. Figure 1 shows our experimental setup to make the via holes by DUV lasers. We used Gigaphoton's excimer lasers, both KrF and ArF. The major laser specifications are indicated in Table 1.

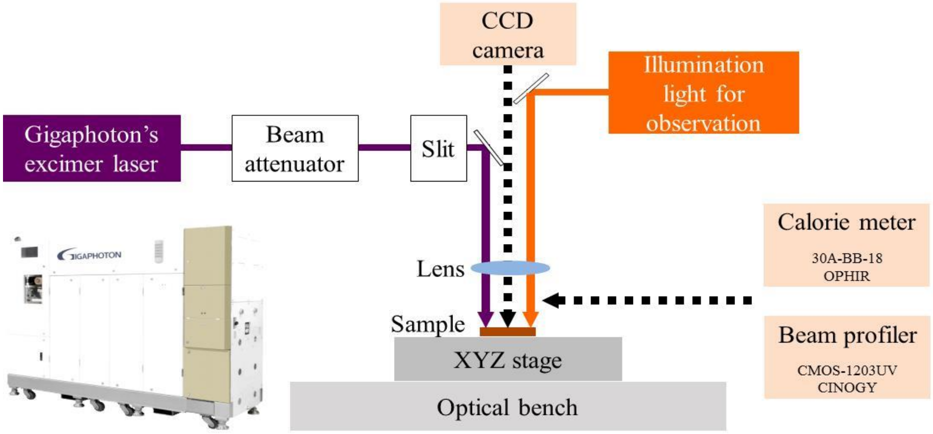
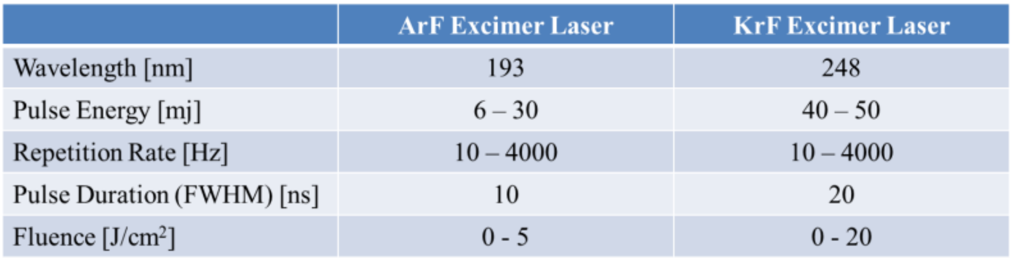


Fig. 1. Laser material processing test stand

Table 1. Specifications of KrF/ArF excimer laser for processing



	ArF Excimer Laser	KrF Excimer Laser
Wavelength [nm]	193	248
Pulse Energy [mj]	6 – 30	40 – 50
Repetition Rate [Hz]	10 – 4000	10 – 4000
Pulse Duration (FWHM) [ns]	10	20
Fluence [J/cm^2]	0 - 5	0 - 20

We adopted the laser repetition rate up to 100Hz in this study. The experiments were done in atmosphere, under the same conditions in practical use. We have already estimated it based on balances between its processing quality and fluence. The irradiated fluence was adjusted by internal laser pulse energy control system and attenuator. The beam shape was formed by a slit and reduction ratio was adjusted by lens. We used a CCD camera to monitor system operations, and measurement sensors to check laser parameters. The via hole shape measurement tools were used mainly two tools. The scanning electron microscope (SEM) was JCM-6000: JEOL and the optical microscope was OLP4000: OLYMPUS for observing outlook.

3. Results

3.1. Organic Film Interposer

The organic film is widely used in the semiconductor package for insulation layer. We have chosen Ajinomoto Buildup Film (ABF, material # GY50) that one of popular organic insulation film. The smaller (<30 μm) via hole process is one of critical issues for future generation process, because it is difficult to make via hole by the current processing technology. The current process is mainly using CO_2 laser. But it has limit around 40 μm hole, because the resolution limit by its wavelength (10 μm). We have chosen KrF laser for ABF film process from our previous results. The ablation process results are shown in Figure 2 by KrF laser. These pictures were taken just after the laser processing. The material thicknesses are 10 μm. They indicate minimum 9 μm via hole were clearly processed by KrF laser.

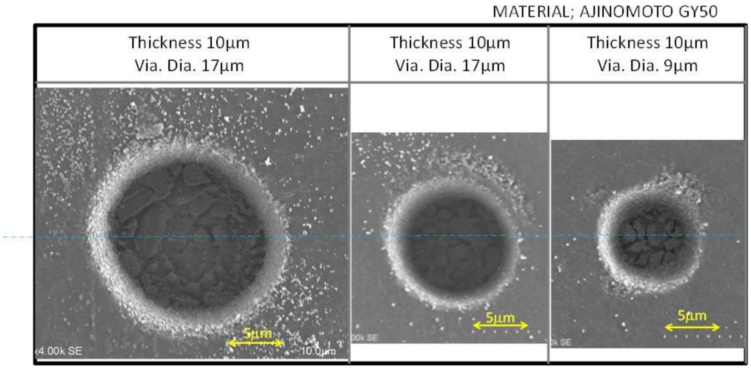
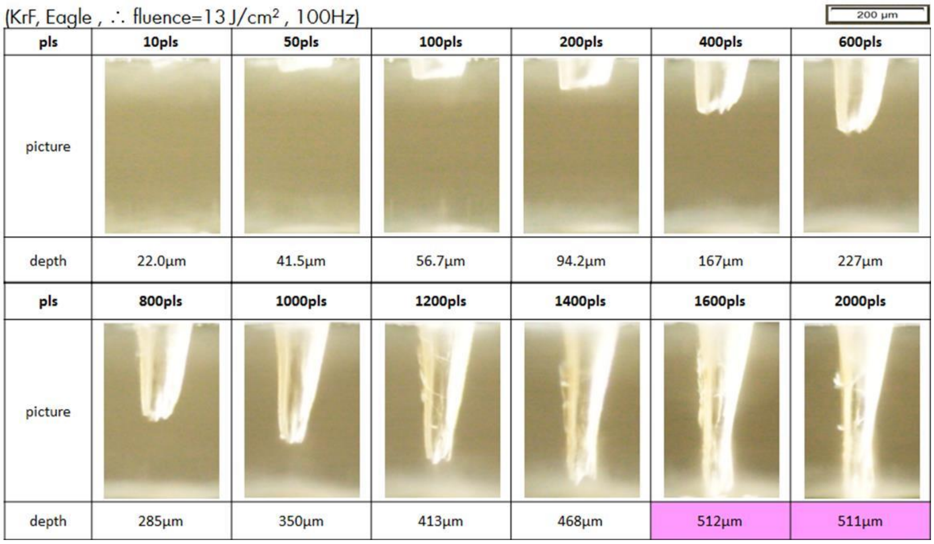


Fig. 2. Via hole on organic interposer material (ABF GY50, t = 10 μm)

3.2. Glass Interposer

For the TGV, we use the following setup. Laser: KrF/ArF, Rep. rate =100 Hz, Pulse duration = 20 nsec., Fluence: KrF:13 J/cm^2, ArF:5.5 J/cm^2. These laser conditions were optimized our previous study [7]. The beam spot size was 100 μm, which was first target size of TGV. We observed the abrasion process pulse by pulse until via through the glass sheet (thickness 500 μm).

Appearances measured by optical microscope are shown in Figure 3 by KrF and Figure 5 by ArF. The process result and hole depth are shown in Figure 4 by KrF and Figure 6 by ArF. The abrasion rate of KrF and ArF lasers are 0.30 μm/pulse at fluence 13 J/cm^2 and 0.12 μm/pulse at fluence 5.5 J/cm^2 respectively.



(KrF, Eagle , ∴ fluence=13 J/cm², 100Hz)

200 μm

pls	10pls	50pls	100pls	200pls	400pls	600pls
picture						
depth	22.0μm	41.5μm	56.7μm	94.2μm	167μm	227μm
pls	**800pls**	**1000pls**	**1200pls**	**1400pls**	**1600pls**	**2000pls**
picture						
depth	285μm	350μm	413μm	468μm	512μm	511μm

Fig. 3. Side view of via hole on glass processing by KrF laser (Corning Eagle Slim XG t=500μm)

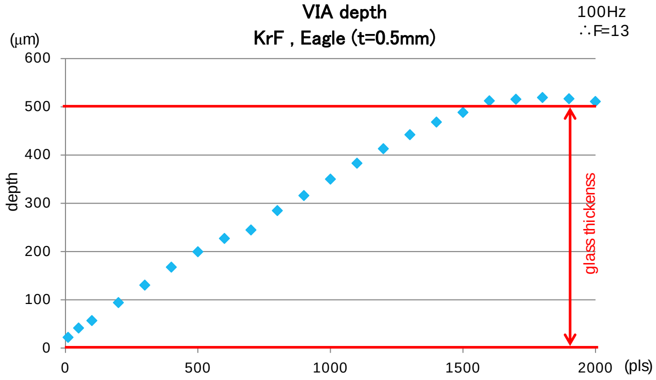


Fig. 4. Abrasion rate of glass by KrF laser, rep. rate = 100 Hz, Fluence = 13 J/cm^2

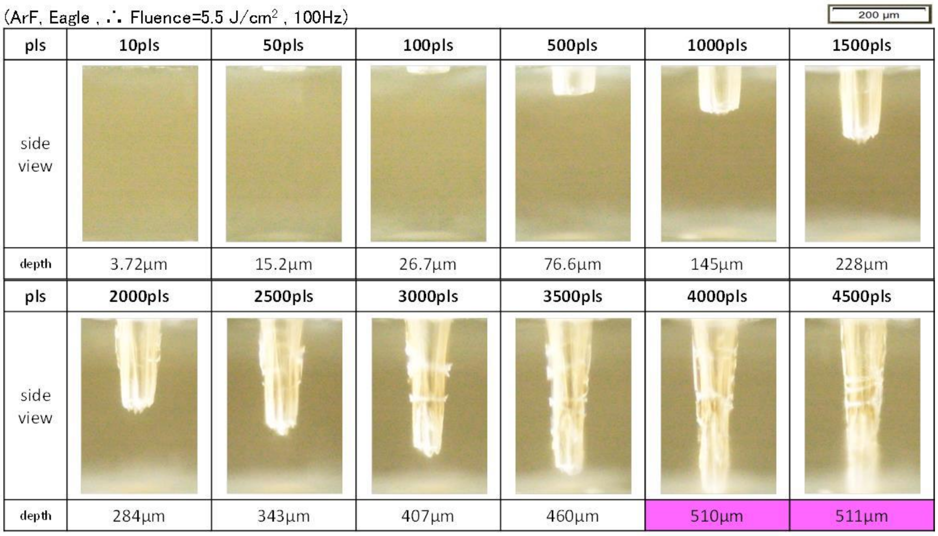


Fig. 5. Side view of via hole on glass processing by ArF laser (Corning Eagle Slim XG t=500μm)

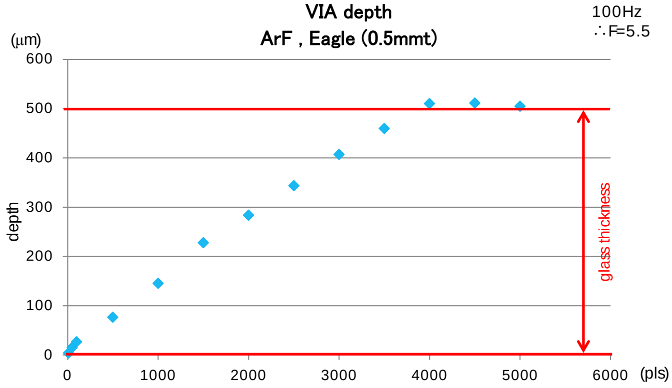


Fig. 6. Abrasion rate of glass by ArF laser, rep. rate = 100 Hz, Fluence = 5.5 J/cm^2

4. Summary

For organic interposer, we have achieved minimum via hole size 9 µm with 10 µm thickness. We indicate KrF excimer laser is applicable for the tool on next generation via hole design rule in FO-WLP. It may be also extend for smaller diameter via for future generation mass production of FO-WLP.

On the other hand, we have made holes of 100 µm in diameter and 5 of aspect ratio without any significant cracks on glass interposer. It shows KrF/ArF excimer lasers are applicable for TGV processing on wafer level packaging.

These results show excimer laser has great potential to be a useful tool for both of FO-WLP and TGV application in future generations. Because of Excimer laser is able to also easily deliver higher power even more than 100W.

5. Next steps

It seems that we can find good results for both of organic and glass interposers from their appearances. However, further investigations would be needed for quality verification in next process. We are planning next step as follows;

- Organic interposer: Further tests are required to evaluate processing quality in next process (ex; Cu plating). Our next target for via holes on FO-WLP is below 7 µm in diameter.
- Glass interposer: We will explore better conditions to get smoother surface without any micro cracks. More higher aspect ratio will be tried.

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