DUV high power lasers processing for glass and CFRP

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Masakazu Kobayashi, Kouji Kakizaki, Hiroaki,Oizumi, Toshio Mimura,
Junichi Fujimoto and Hakaru Mizoguchi
Gigaphoton Inc. Yokokura-shinden 400 Oyama Tochigi, 323-8558, JAPAN

ABSTRACT

A laser processing is widely applied to cutting, drilling, welding, bending and surface treatment in industry. Lasers with a wavelength of 1 μm are mainly used and the processing is realized by melting materials. This thermal process has a high productivity but the processed surface is hard to use for precision machining. This report is focusing on two materials which are classified in wide band gap. Ablation rate was measured with a laser microscope and an optical one.. Excimer laser is expected to be a useful tool for these materials

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

1. INTRODUCTION

Infrared (IR) laser has been widely used for material processing. Recently, in order to get finer processing surface, many researches on short-pulse lasers (femtosecond(fs) lasers) have been conducted. However most of them are the application to micro-machining because fs laser power is low for macro-machining.

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 influence in a material by direct photon absorption. It is also suitable for microfabrication process because of high resolution capability by shorter wavelength [1][2][3]. While material processing in DUV region is still in potential, we have developed several kinds of excimer lasers to explore new laser processing. The excimer lasers at 193nm and 248nm (power; up to 120W) have been used in the semiconductor manufacturing for long years, and have field-proven highly stability and reliability. The high power (>400W) 351nm and 248nm excimer lasers have been applied to the annealing process of FPD. An 193nm "hybrid" laser which is the combination of a solid-state laser seeder and an excimer laser amplifier are developing to make of wide band gap materials processing [4][5].

We have established an experimental facility to search material processing by high power excimer laser and started to evaluate both KrF/ArF capabilities for wide-band gap materials. In this paper, we would like to clarify potentials of excimer laser as an alternative to IR laser processing.

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2. LASERS & EXPERIMETAL SETUP

Figure 1 shows our experimental setup to measure laser ablation rate. We used Gigaphoton's excimer lasers, both KrF and ArF [6][7]. The major laser specifications are in Table 1. In order to remove thermal effects, we mainly adopted low repetition rate of 10Hz for ablation rate measurement. The experiments were done in atmosphere, under the same conditions in practical use. We have evaluated 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 mask and reduction ratio was adjusted by lens. We used a CCD camera to monitor system operations, and sensors to check laser parameters. Figs 2 and 3 show methods to measure via size and depth profile by three types of microscope which are optical (BX35 : OLYMPUS), laser (OLP4000 : OLYMPUS) and SEM (SU3500 : HITACHI, JCM-6000 : JEOL).

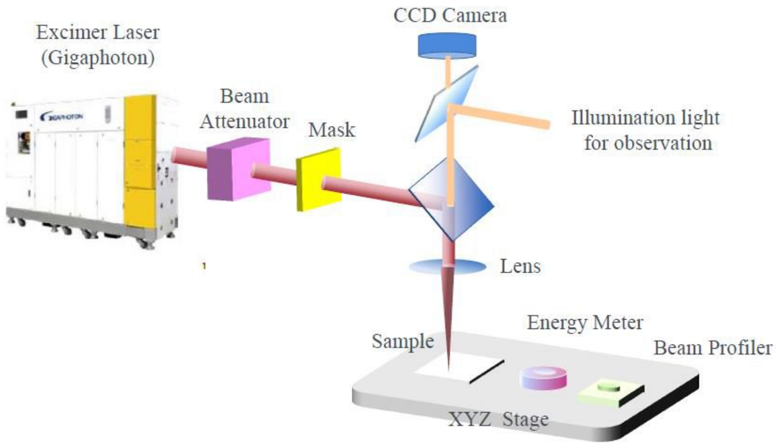


Figure 1. Test stand

Table 1. Specifications of KrF/ArF excimer laser

	units	ArF Excimer Laser	KrF Excimer Laser
Wavelength	nm	193	248
Pulse Energy	mJ	6-30	40-50
Repitation Rate	Hz	1-4000	1-4000
Pulse Duration (FWHM)	nsec	10	20
Fluence	J/cm^2	0-10	0-20

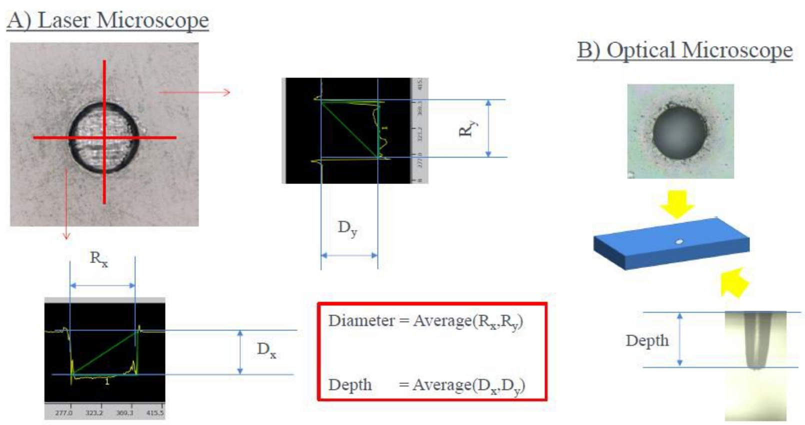


Figure 2. Via size and depth measurement

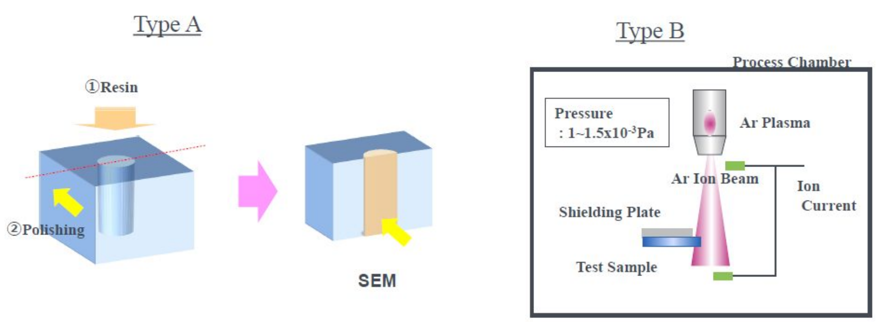


Figure 3. Cross-section observation

3. RESULTS

3.1 Glass for interposer

Glass and laser type in this experiment are shown in Table 2. Eagle XG Slim(by Corning) is a typical temped glass for interpose (TGV). The beam profile of each lasers, are shown in Figure 4. The beam spot size was 100 µm, which was a target size of TGV

Table 2. Glass for interposer material processing test condition

	Material (thickness)	Eagle XG Slim[*1] (300µm)	
Excimer laser	Type	KrF	ArF
	Wavelength (nm)	248	193
	Fluence (J/cm^2)	8-25	1-10
Process	Via Diameter	~ 100µm	

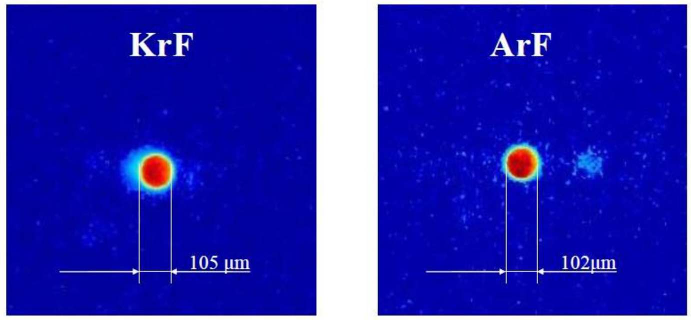


Figure 4. Beam profile for glass processing

We have measured the relation between fluence and ablation rate. The test was carried out in laser fluence from 1 to 10 J/cm2 by ArF and from 9 to 24 J/cm2 by KrF. We obtained rate of 1.15 µm /pls on KrF, 0.13 µm/pls on ArF at maximum in this experiment as shown in Figure 5. We conducted experiment under several different conditions of optical setup (reduction rate 1/10 and 1/4) and irradiated shape (circle and rectangle), and the results were almost same.

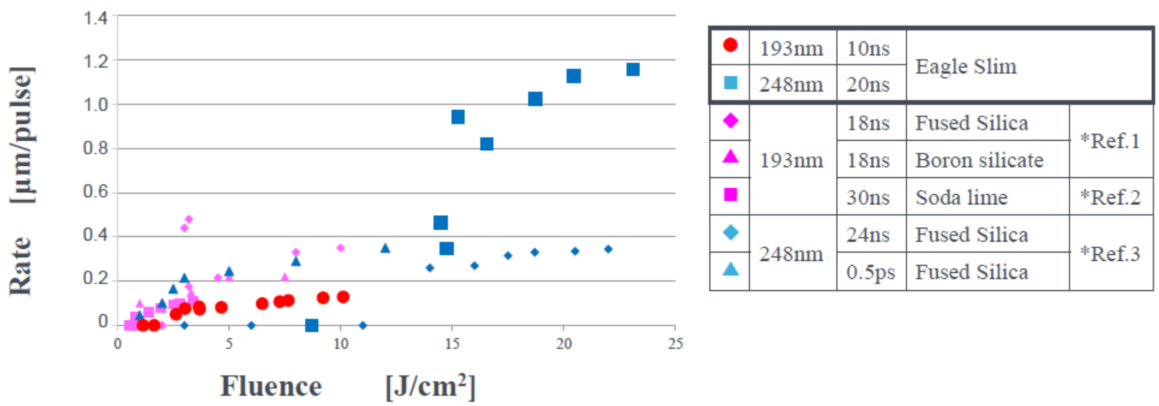


Figure 5. Ablation rate on Eagle (t=300µm) by ArF and KrF

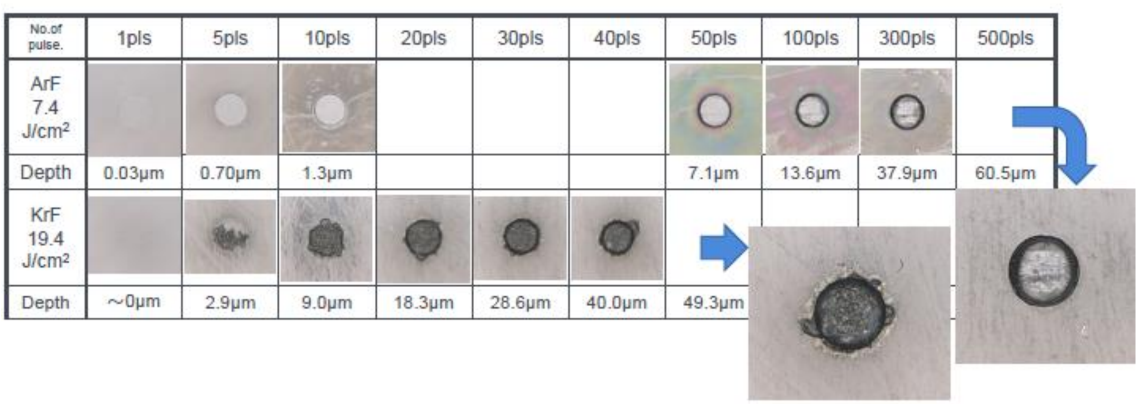


Figure 6. Via hole of Eagle by laser microscope

Figure 6 shows laser microscope observation. The results by ArF processing are slightly less damage.

A process of deeper hole(1<<depth/diameter) is required for TGV application.　The relations between depth and number of pulse are shown in Figure 7.　The measured depth is plotted in Figure 8(a) and the calculated average rates in Figure 8(b).　The average rate decreases rapidly in depth of less than 100 μm (almost equal to diameter) , but it is indicated to be able to process in depth of more than 300 μm.

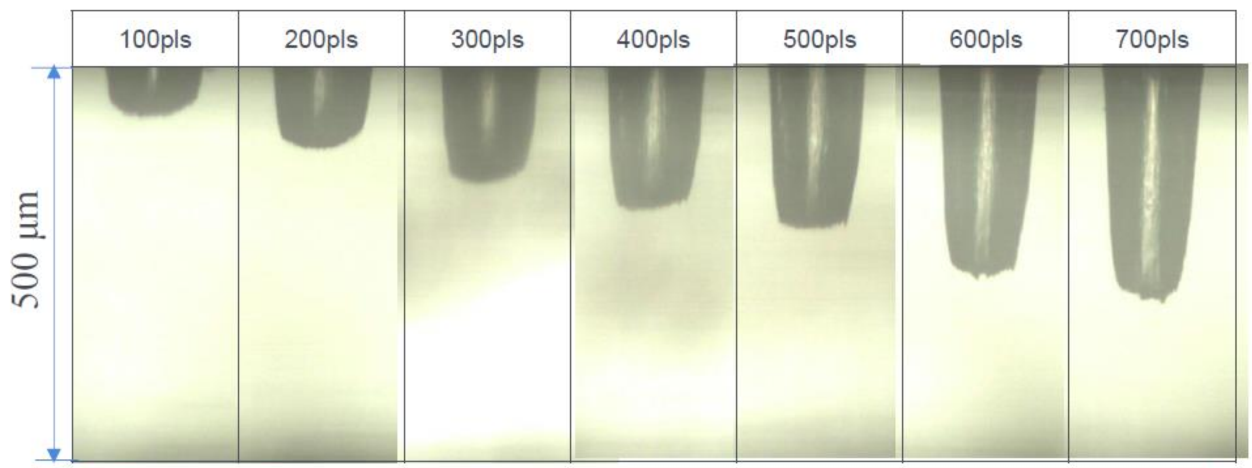
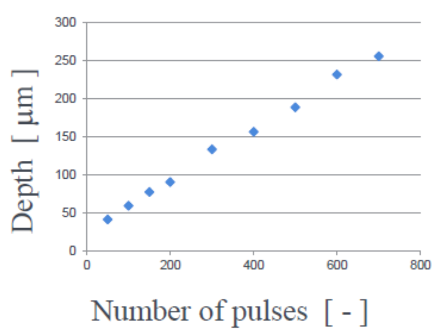


Figure 7　Microscope observation by number of pulse (KrF : Fluence 11.6 J/cm2)



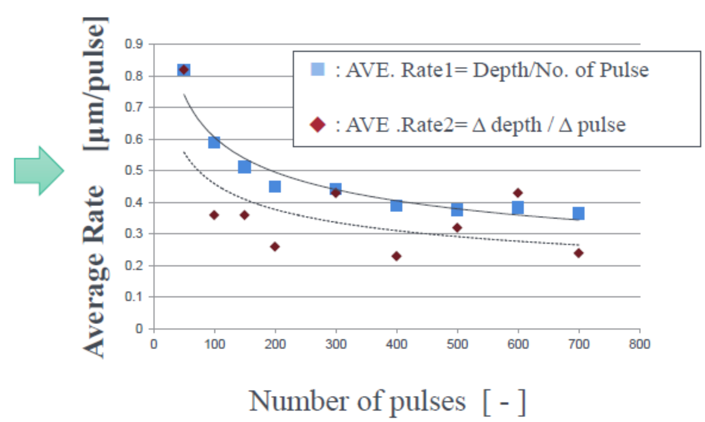


Figure 8(a) Depth measurement

Figure 8(b) Average rate of Eagle(t=0.5mm) by KrF

Appearances measured by SEM on through hole are shown in Figure 9.

In analysis with SEM, we could obtain positive results which are clear holes without any cracks. Differences between ArF and KrF cannot clearly be indicated by these results. We will investigate taper angels of holes as a next step.

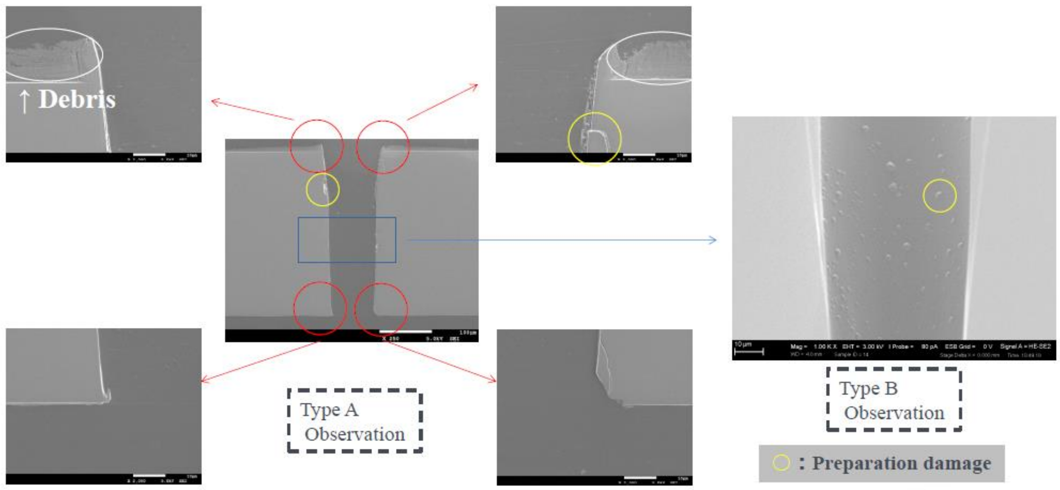


Figure 9(a). Appearance of via holes processed by ArF irradiation, hole size = 100µm

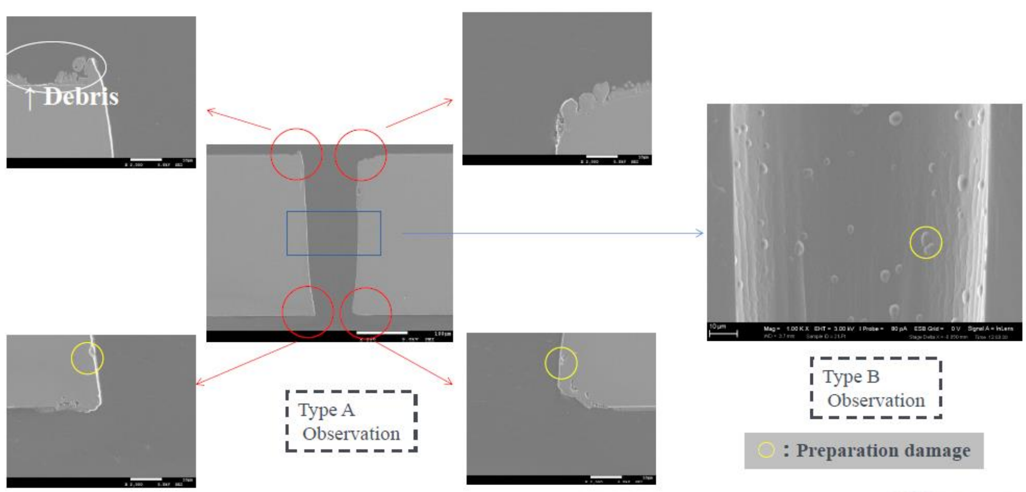


Figure 9(b). Appearance of via holes processed by KrF irradiation, hole size = 100µm

3.2 CFRP

CFRP is one of composite materials and hard to process with a few thermal damage by IR Laser. CFRP are made from resin and carbon fiber, and resin thickness in depth direction is different in location. In order to measure ablation rate of carbon fiber, excimer lasers are irradiated at position with thin thickness of resin. The irradiated surface observed by laser microscope and SEM are shown in Figure. 9. Resin is evaporated in a small of pulses and carbon fiber is ablated by ArF/KrF. Tips of processed fiber are thought to change in quality.

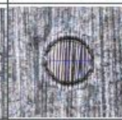
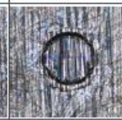
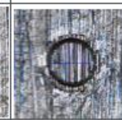
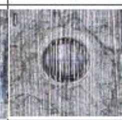
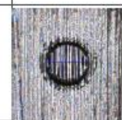
	1pls	5pls	10pls	30pls	50pls	100pls	200pls
KrF 13.4 J/cm^2 @ 100Hz							
Depth	3.11μm	3.85μm	8.52μm	22.5μm			
ArF 6.1 J/cm^2 @ 100Hz							
Depth	0.29μm	1.63μm	3.08μm		10.5μm	17.9μm	34.2μm

Figure 10(a) Via hole of CFRP by laser microscope

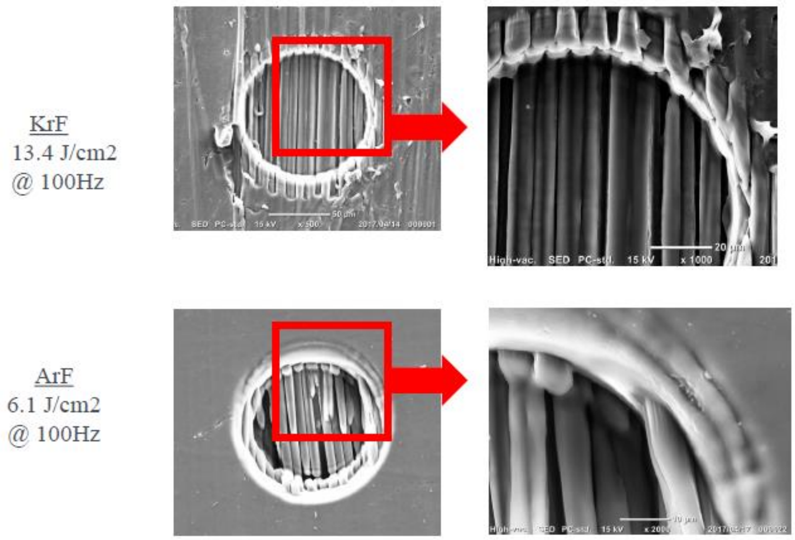


Figure 10(b). Via hole of CFRP by SEM

4. SUMMARY

We have made holes of 100 μm in diameter and 3 of aspect ratio without any significant cracks on glass interposer.
And, it is shown that excimer laser is able to process CFRP. We think the excimer laser has great potential to be a useful tool for glass and CFRP processing.

5. NEXT STEPS

We are planning next step as follows;

Glass : We will explore better conditions to get higher processing rate without any micro cracks under repetition more than 1kHz.

CFRP : Further tests are required to measure ablation rate and verify quality of process surface. And cutting speed will be evaluated with laser light or material scanning.

6. ACKNOWLEDGEMENT

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