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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 (FO-WLP) and Through Glass Via hole (TGV) which are hard to process with less defect. In this study, we investigated ablation rate with deep ultra violet excimer laser to explore its possibilities of micromachining on organic and glass interposers. These results were observed with a laser microscopy and Scanning Electron Microscope (SEM). 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).

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. 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.

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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. Figure 1 shows our experimental setup to measure laser ablation rate. We used Gigaphoton's excimer lasers, both KrF and ArF [5]. The major laser specifications are indicated in Table 1. In order to remove thermal effects, we adopted low repetition rate of 10Hz. 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 slit and reduction ratio was adjusted by lens. We used a CCD camera to monitor system operations, and measurement sensors to check laser parameters. Table 2 shows via hole shape measurement tools. The laser microscope was OLP4000: OLYMPUS for observing outlook and depth, and the surface profiler was Dektak 8: Veeco for caliblation of the laser microscopy measurement.

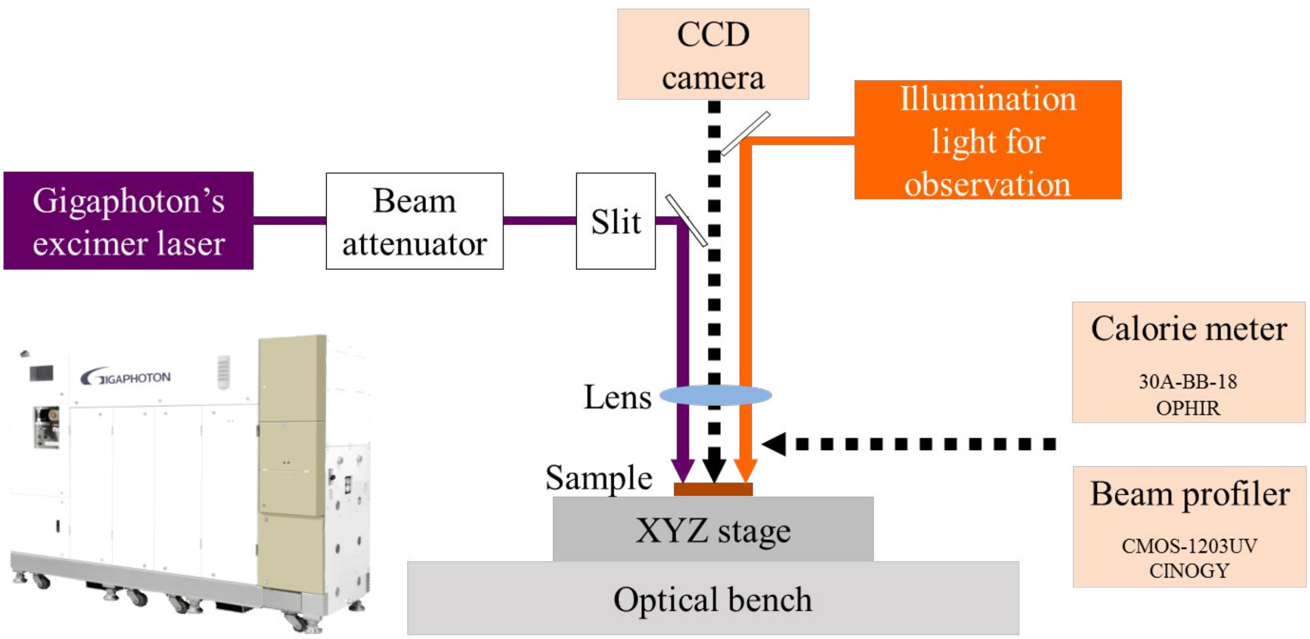
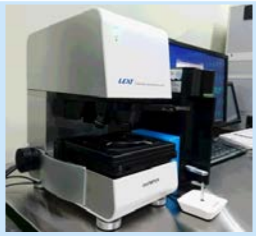
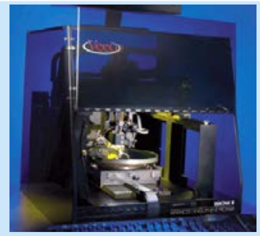


Figure 1. Laser material processing test stand

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

Table 2. Via hole size evaluation tools

Equipment	Laser microscope OLP4000 (OLYMPUS)	Surface profiler Dektak 8 (Veeco)
Specification	Plane resolution : < 0.60 μm	Plane resolution : < 0.51 μm
	Depth resolution : < 0.05 μm	Depth resolution : < 0.067 μm
Photograph		

Organic interposer and laser type in this experiment are shown in Table 3. We took the most popular organic interposer material (Ajinomoto Buildup Film (ABF) GX92 and GY50; AJINOMOTO Co. Inc.).

Table 3. Organic interposer material processing test condition

Materials (thickness)		GX92 (25μm)	GY50 (15μm)	GY50 (10μm)	GX92 (25μm)	GY50 (15μm)	GY50 (10μm)
Excimer laser	Type	KrF			ArF		
	Wave length (nm)	248			193		
	Fluence (mJ/cm^2)	400 - 1100			400 - 1000		
Process	Target (μm)	180	180	-	103	-	-

For glass interposer, the experimental outlook is shown in Table 4. Glass interposer requires more fluence compared to organic interposer. In this experiment, it needed around 4 to 25 times higher fluence. We had chosen Eagle Slim XG; Corning which was one of the most popular glass interposer.

Table 4. Glass for interposer material processing test condition

Material (thickness)		Eagle XG Slim (300 µm)	
Excimer laser	Type	KrF	ArF
	Wave length (nm)	248	193
	Fluence (J/cm^2)	8 - 25	1 - 4
Process	Target (µm)	105	102

3. RESULTS

3.1 Organic Film Interposer

The beam profile of each lasers are shown in Figure 2. Figure 3 shows ABF film structures.

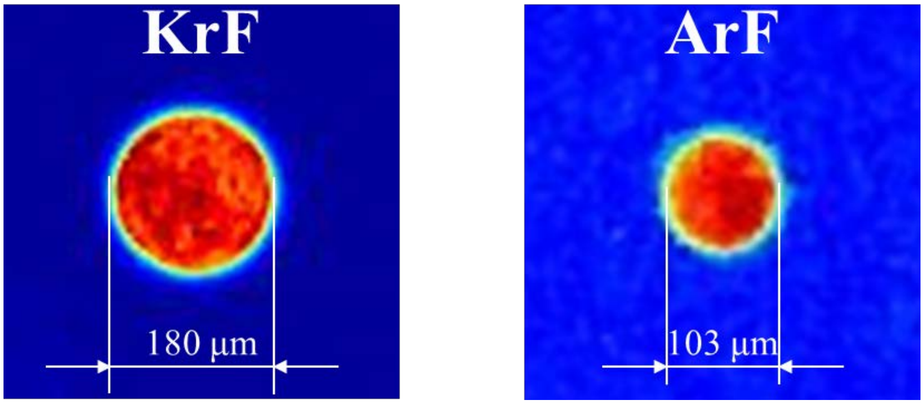


Figure 2. Beam profile for organic interposer

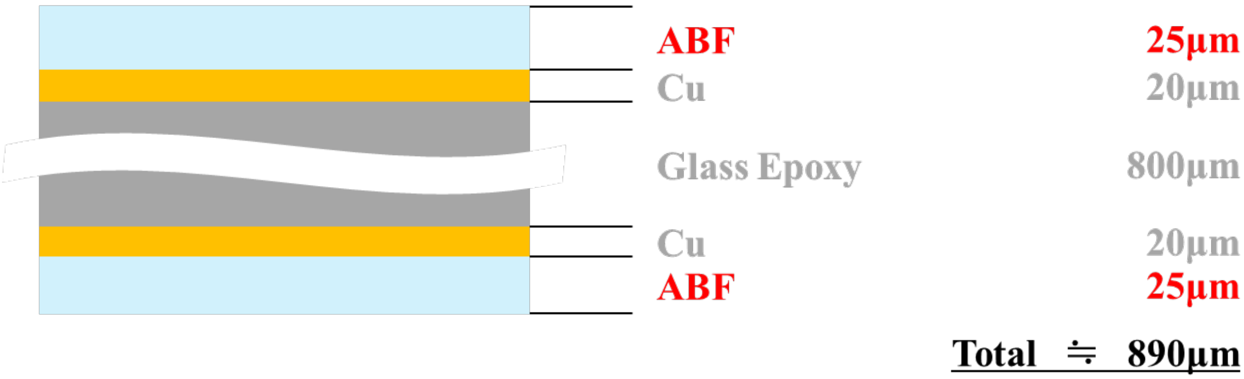


Figure 3. Structure of organic interposer (ABF)

The ablation process results are shown in Figure 4 (KrF) and Figure 5 (ArF) respectively. We have measured the relation between fluence and ablation rate. The test was carried out in laser fluence from 150 to 1140 mJ/cm^2 by KrF and from 90 to 1030 mJ/cm^2 by ArF.

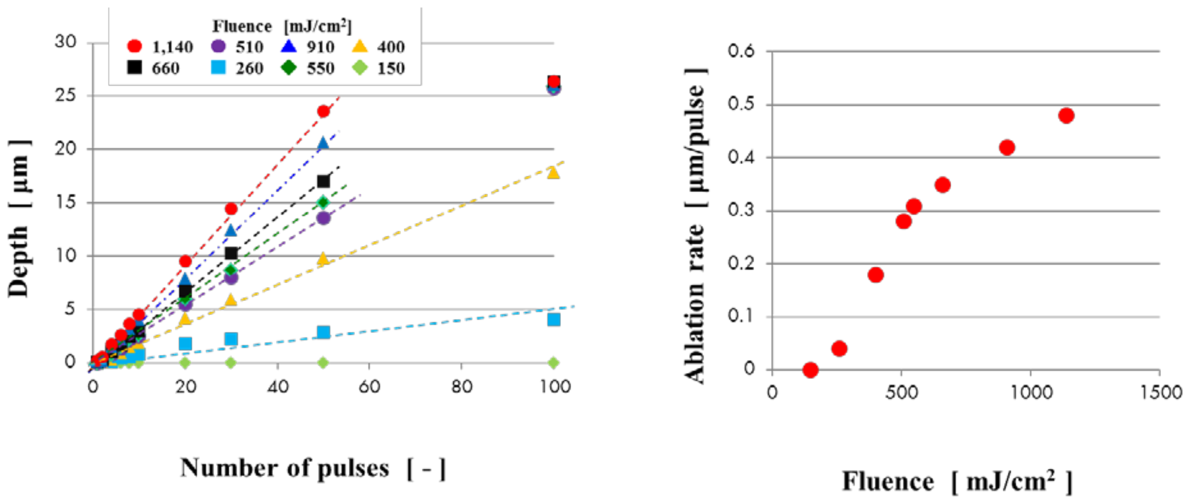


Figure 4. Ablation depth on ABF (GX92 t=25μm) by KrF

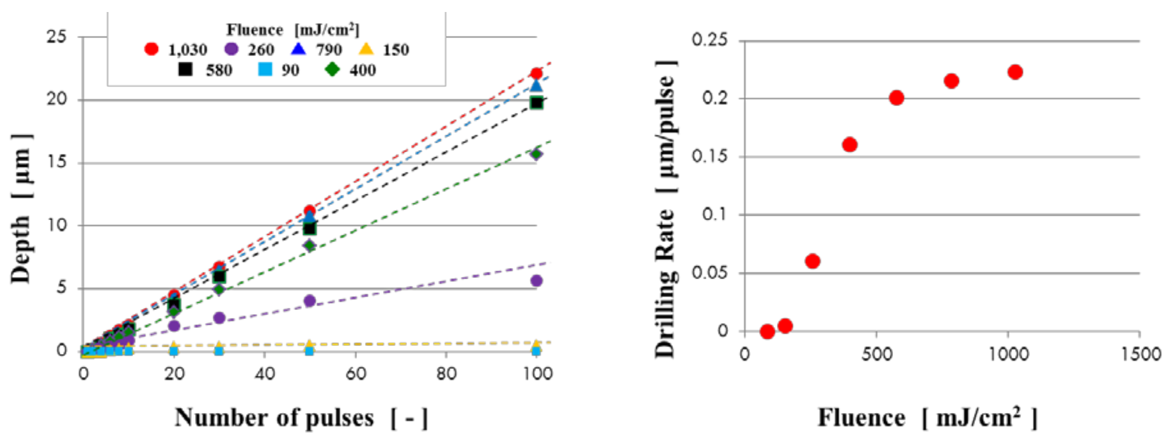


Figure 5. Ablation depth on ABF (GX92 t=25μm) by ArF

The ablation rate were obtained 0.35 μm/pls (most efficient condition (rate/energy)) and 0.48 μm/pls (maximum rate) by KrF. Also they were 0.20 μm/pls and 0.22 μm/pls by ArF respectively.

The appearances of via holes are indicated in Figure 6 (with laser microscopy) and 7 (with SEM). Cu layer is under the film layer. It seems that both KrF/ArF made via holes of right sizes and abrasion rates. Taper angles should be measured. We can find good conditions of Cu surface without residue after ablation of ABF both in Figure 6 and 7. We will conduct next investigations including optical experiments to verify quality difference between KrF and ArF. (Pictures enclosed in bold)

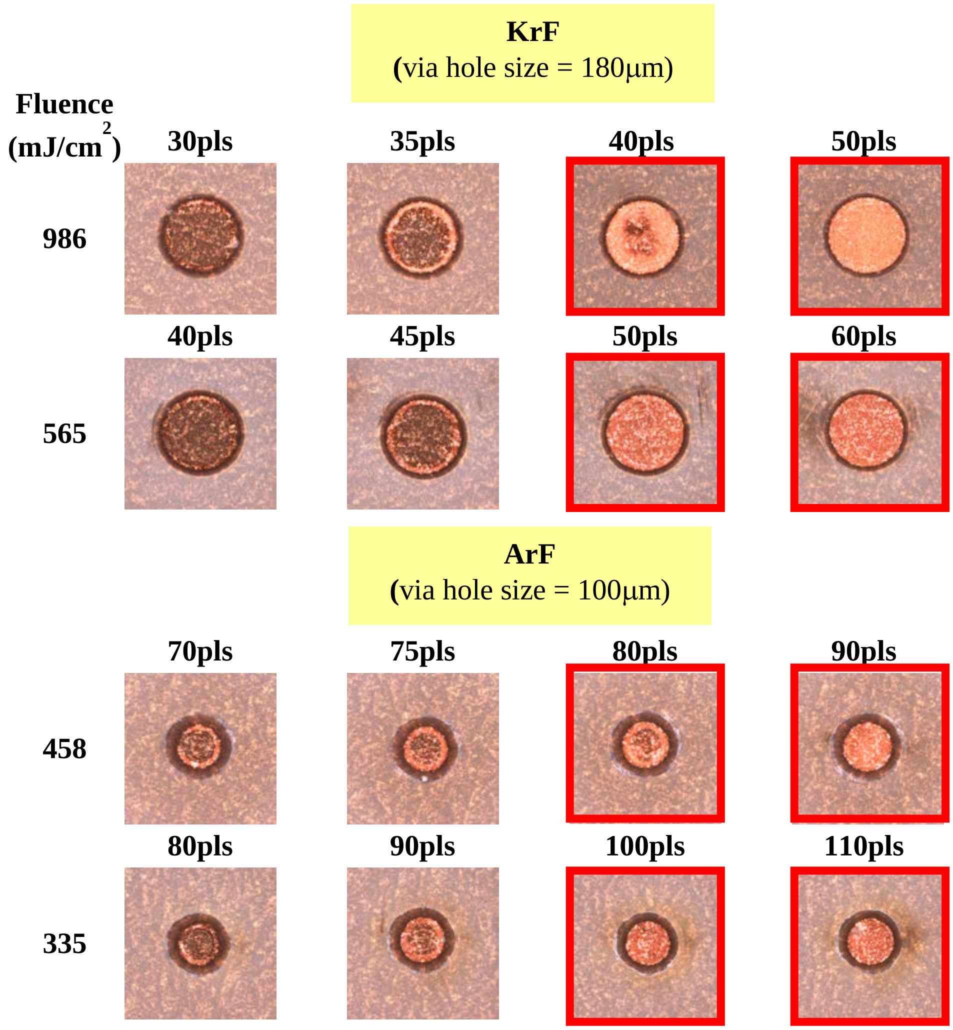


Figure 6. Via hole of organic interposer film (t=15µm, ABF GX92 by KrF, t=15µm GY50 by ArF) by laser microscope

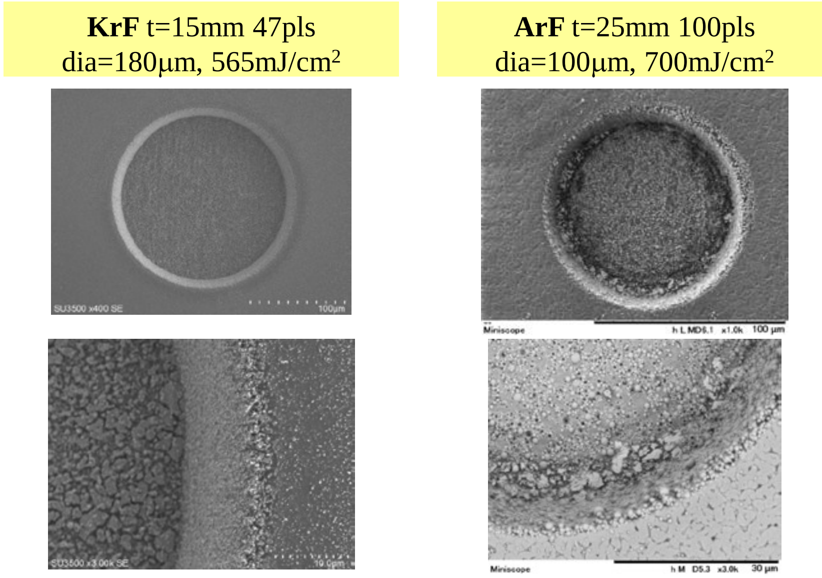


Figure 7. Appearance of organic via holes on ABF by SEM

3.2 Glass Interposer

Laser beam profiles used in the experiment are shown in Figure 8. The beam spot size was 100 μm, which was a target size of TGV. Ablation rate were also measured. We obtained rate of 1150 nm/pls on KrF, 128 nm/pls on ArF at maximum in this experiment as shown in Figure 9. We conducted experiment under several different conditions of optical setup (reduction rate 1/10 and 1/4), and the results were almost same.

Appearances measured by SEM are shown in Figure 10.

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

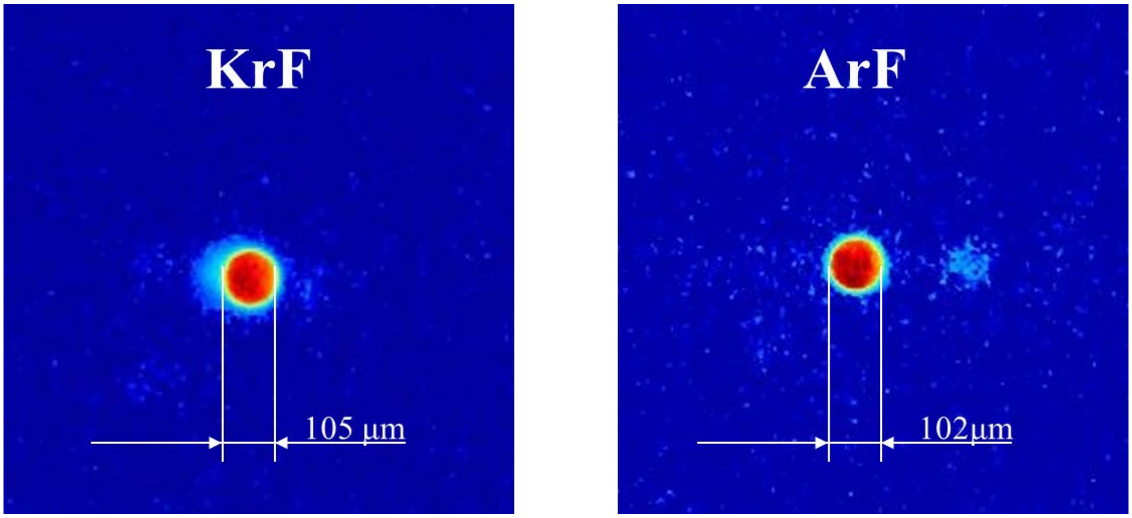


Figure 8. Beam prifile for Glass processing

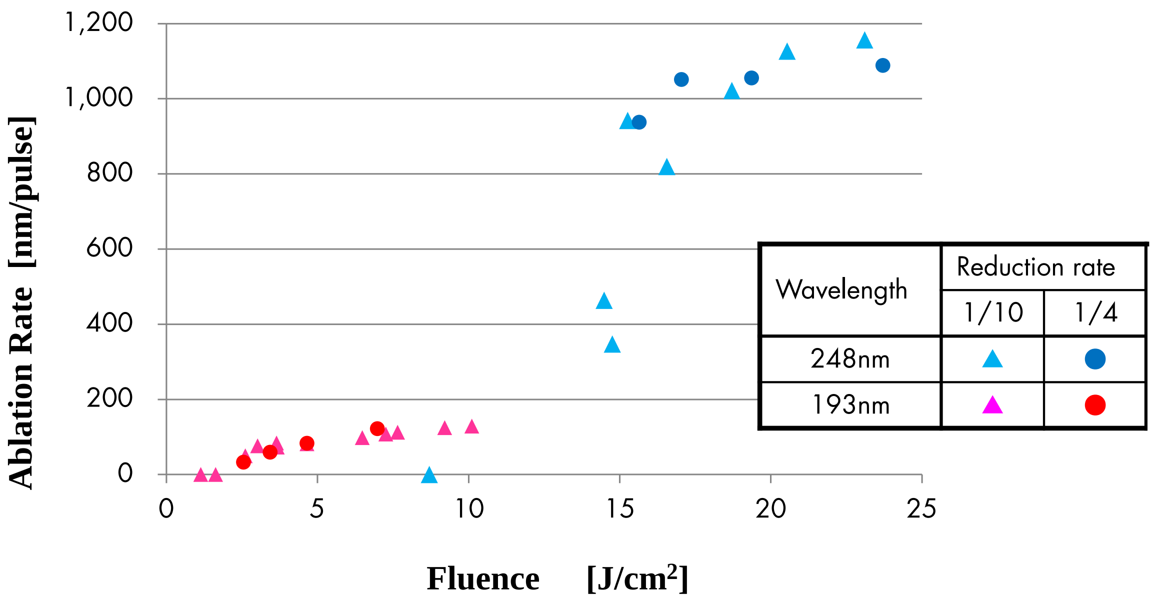


Figure 9. Glass Abration rate measurement of KrF/ArF

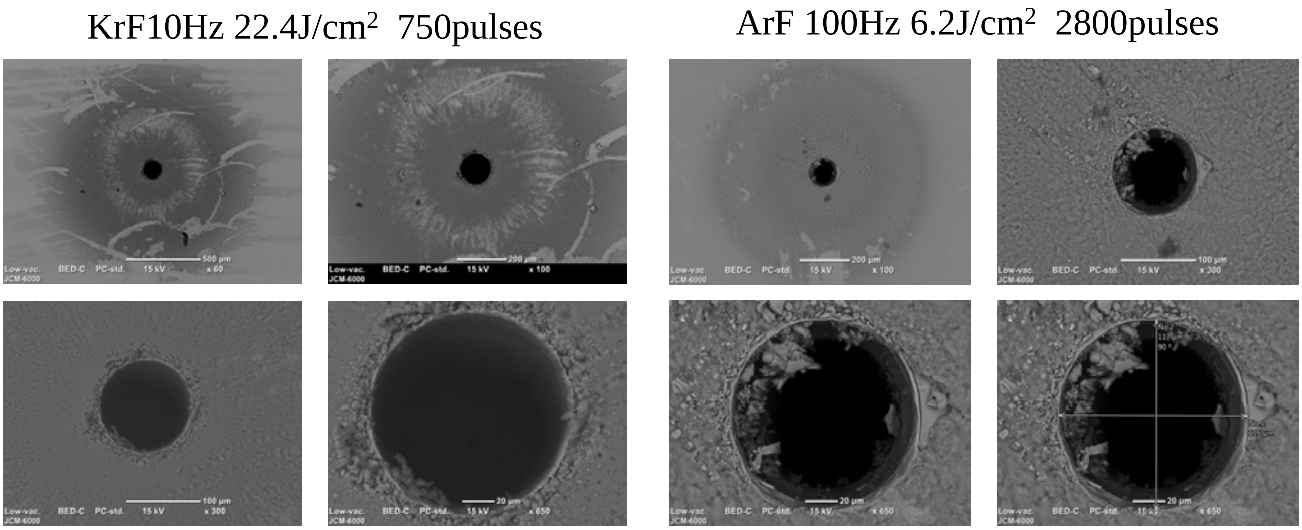


Figure 10. Appearance of via holes processed by KrF and ArF irradiation, hole size = 100μm

4. SUMMARY

For organic interposer, we have achieved both of affordable material processing rate (30μm/pls) and high quality (less smear) at the same time. Excimer laser is able to process small via hole (dia. 10μm and smaller) by shorter wavelength, and also easily deliver higher power even more than 100W.

On the other hand, we have made holes of 100 μm in diameter and 3 of aspect ratio without any significant cracks on glass interposer.

These results show excimer laser has great potential to be a useful tool for both of FO-WLP and TGV application in next generation.

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 10μm in diameter.
- Glass interposer: We will explore better conditions to get smoother surface without any micro cracks.

6. ACKNOWLEDGEMENT

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