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The micro via processing for semiconductor package by excimer lasers

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Abstract

Recently infrared/UV lasers have faced resolution limit of finer (<10μm) via hole size micromachining requirement on semiconductor package process. It will be required for multi die semiconductor package substrates by Fan-Out Wafer/Panel Level Package. The substrate materials are currently using the silicon wafer, organic build-up film. The glass substrate will be used high frequency signal transfer application like 5G tele-communication use. The glass via holes are hard to process with less defect. In this study, we investigated via hole quality by DUV laser ablation process by using deep ultra violet excimer lasers. The results show the possibilities of micromachining on the glass substrates. We have succeeded <30 μm holes aspect ratio 10 on glass substrate without any significant defects. Excimer lasers could be expected on manufacturing process for next generation semiconductor packages.

Keywords: excimer laser, deep ultraviolet, 193nm, ArF laser, interposer, non-alkali glass

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).

Laser microfabrication is widely applied to manufacture various devices and systems. Higher density and smaller size are required for processing organic and glass interposers on Fan-Out Wafer/Panel Level Package (FO-WLP/FO-PLP) 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 ϕ30μm 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 [1][2]. 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]. More than five thousand 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 non-alkali glass (glass) interposers. In this paper, we would like to clarify potentials of excimer laser as an alternative to IR/UV laser in micromachining.

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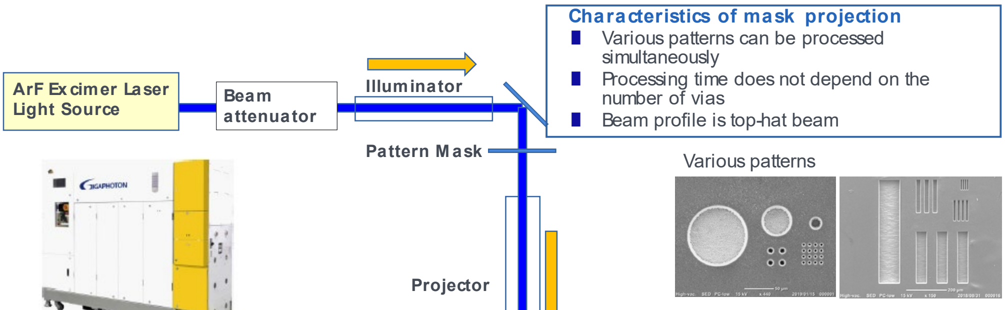
2. Lasers & Experimental setup

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. We have reported the affordable ablation rate in our previous report [4][5]. 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 also indicated.



	units	ArF excimer laser
Wavelength	nm	193
Pulse Energy	mJ	6 ~ 30
Repetition Rate	Hz	10 ~ 6000
Pulse Duration (FWHM)	nsec	10
Fluence	J/cm^2	1 ~ 5

Fig. 1. Laser material processing test stand

We adopted the laser repetition rate up to 1000Hz 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 beam 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 properties measurement tools were used mainly two tools. The 3D measuring optical laser microscope was OLS4000: OLYMPUS for observing outlook/distortion and Raman microscope inVia Qontor: RENISHAW for observing the structure of glass.

3. Results

In this study, we use ArF (Argon Fluoride; λ=193nm) excimer laser (specifications are shown Figure 1), and glass (Corning Eagle Slim XG). At first, we investigate the hole generation process by observing from the side of glass. The test conditions are laser repetition rare 1000Hz, fluence 11.9mJ/cm^2, beam spot/hole size ϕ30 μm. The hole reach to bottom after 1600 pulses irradiation (processing rate: 0.188μm/pls). The processing states are able to see by changing irradiation number of pulses [Figure 2].

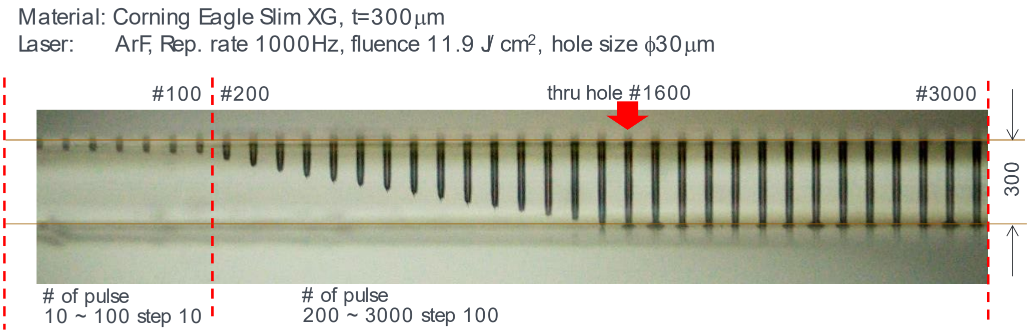
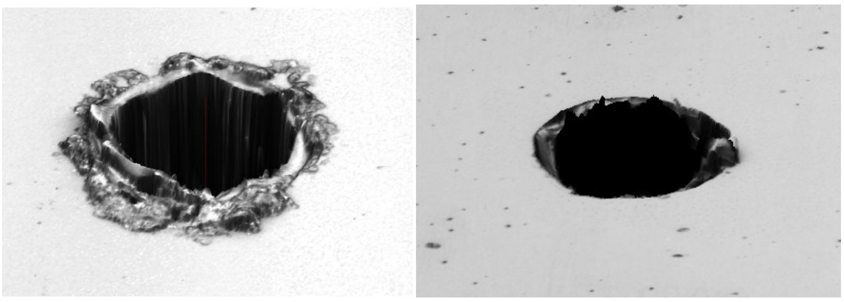


Fig. 2. Hole generation process in non-alkali glass ArF / KrF

We have observed the hole qualities by several measurement tools.

- Outlook: by laser microscope; brightfield
- Distortion: by laser microscope; differential interference contrast mode
- Structure: by confocal Raman microscope

Figure 3 shows the outlook of ϕ30μm holes just after laser processing Figure 3 a) and add debris removing process Figure 3 b). The debris were removed by hand polishing with compound. The measurements were carried out by the laser optical microscope “OLP4000”. The debris were removed by hand polishing with compounds. It shows the debris around hole is some by-products that was created abrasion process. Because those were removed easily in the hand polishing process.



a) HOLE after laser shot 3000 pls   b) HOLE after laser shot 3000 pls w/ debris removal process

Fig. 3. Outlook of processed holes before/after debris removal

To measure the distortion along the hole, we observed by laser microscope; differential interference contrast mode on OLP4000. No difference was observed after debris removal. It shows laser ablation may not be affect glass substrate.

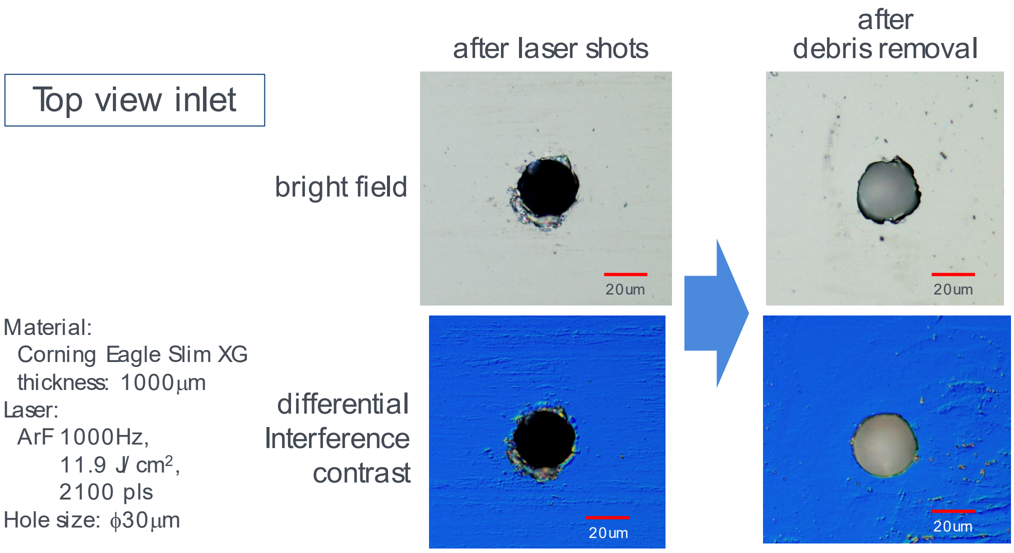


Fig. 4. Distortion along the holes by optical laser microscope, differential interference contrast mode

We also measured around hole by Raman microscope “inVia Qontor” to confirm the structure change. There is no change from 3μm and further area from the edge of hole. The edge has some by-products along the edge of hole, but we cannot measure any structure change by Raman microscope. There is Raman spectrum change in 0μm to 3μm. The peak shape changes and some peaks appear. It shows structure change from 0μm to 3μm along the edge of hole. We need further investigation the detail area analysis. We also need to check what kind of structure change was occurred by laser ablation.

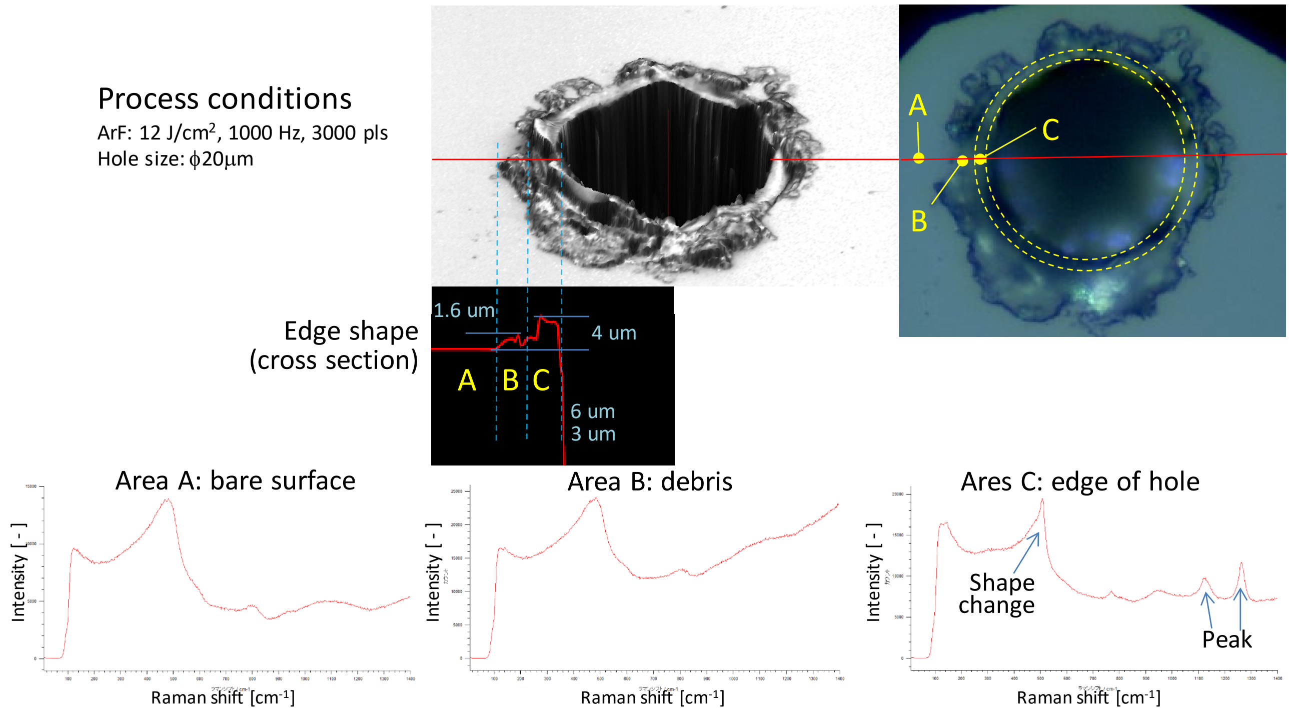


Fig. 5. Structure around edge of holes by Raman microscope

4. Summary

We have made holes of 30μm in diameter and 10 of aspect ratio without any significant distortion and structure change on glass. It shows ArF excimer lasers are applicable for TGV processing on wafer/panel level packaging.

This result shows excimer laser has great potential to be a useful tool for TGV application in future generations and related applications. Because of Excimer laser is able to also easily deliver higher power even more than 300W.

Acknowledgements

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References

[1] Ihlemann J., Wolff-Rottke B., “Excimer laser micro machining of inorganic dielectrics”, Applied Surface Science 106 (1996) 282-286

[2] Karstens R., Gödecke A., Prießner A., Ihlemann J., “Fabrication of 250-nm-hole arrays in glass and fused silica by UV laser ablation, Optics & Laser Technology 83 (2016) 16-20

[3] Mimura, T., Kakizaki, K., Oizumi, H., Kobayashi, M., Fujimoto, J., Matsunaga, T., and Mizoguchi, M., "High power DUV lasers for material processing", Proc. SPIE 1001603 (2016)

[4] Fujimoto J., Kobayashi M., Kakizaki K., Oizumi H., Mimura T., Matsunaga T., Mizoguchi H., “193nm high power lasers for the wide bandgap material processing", Proc. SPIE 10097,100970T (2017)

[5] Kobayashi M., Kakizaki K., OizumiH. , Mimura T., Fujimoto J., Mizoguchi H., “DUV High Power Laser Processing”, Abst. SPIE Optics+Optoelectonics, WS100-2 (2017)