EXCIMER LASER VIA-DRILLING - OPTIONS TO FURTHER CAPABILITIES OF NEXT GENERATION WAFER LEVEL PROCESSING DEVICES

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INTRODUCTION
SUSS MicroTec Photonic Systems (SMTPS) has extended its Excimer laser ablation expertise, and knowledge gained from close relationships with key advanced semiconductor material manufacturers, to Advanced Packaging’s top cutting-edge companies and research institutions (Figure 1).

By doing so, SUSS MicroTec has opened new and innovative avenues for industry-leaders to develop more capable and reliable Next Generation Wafer Level Processing (WLP) Devices. This article highlights SUSS’s Excimer Laser Via-Drilling technology and its role in shaping Next Generation WLP Devices.

BACKGROUND - INDUSTRY CHALLENGES
The explosive demand for increased cell phone capability and ever-shrinking form factor, has forced the hand held electronic device manufacturers into emergency reaction-mode with one mantra: “Smaller – Thinner – Lighter – Cheaper – Faster.” These are the common drivers for all of the major applications, including WLCSP, FOWLP, and flip-chip products (Figure 2). Since each of these drivers adds increased complexity and challenges to the fabrication process, it is understandable that the top-level demand by the industry is mitigating risks caused by the added complexity, while at the same time managing costs.

The traditional Photo Polymer Dielectrics used today (eg: PI, PBO, BCB, Epoxy) lack the necessary properties (thermal, mechanical, electrical) to mitigate Next GEN chip-failures as well as to drive down costs. Early industry trends indicate that new higher performance dielectric materials, such as Non-photo Polymers and Epoxy Mold Compounds (EMC) are favored as a means to combat the thermal/mechanical limitations of photo-dielectrics to help reduce these chip failures. The extensive benefits and improved reliability to be gained by these non-photoimagable materials are listed in Figure 3, below.

![Figure 1. SUSS MicroTec Photonic Systems is engaged in valuable JDA’s with IBM and Fraunhofer.](image1)

![Figure 2. Cell phones and handsets driving the need for smaller, thinner, lighter Next Gen Advanced Packages](image2)

![Figure 3. Next Generation WLP desired material properties](image3)

However, legacy photolithography and wet-etch patterning methods are barriers to material adoption of Non-Photo Polymers due to several technical and cost constraints:
1) More expensive processing  
2) Limited resolution  
3) Wet-etch limitations at high-pitch and  
4) Wet developing difficulties in small vias  

Consequently, there is considerable interest in using Excimer laser ablation in lieu of photolithography to form these vias (Figure 4) in dielectrics. Excimer ablation enables processing of reduced via dimensions and a broader range of dielectric materials, including inherently photosensitive and non-photosensitive options.

The laser ablation process provides improved feature resolution and reduced via opening sizes, resulting in significantly improved interconnect density.

**PROCESS COMPARISON**

Laser via drilling is a more simplified process compared to traditional photolithography methods. A reduction in process steps decreases overall costs and increases process yields. The traditional photolithography process consists of the following 6-steps: coat dielectric, soft bake, UV expose, develop, hard bake and plasma clean. In contrast, the Excimer laser drilling process consists of 4-steps: Coat dielectric, Hard bake/blanket expose, laser ablation and plasma descum/clean (Figure 5).

The examples in this paper will demonstrate how using laser via drilling can dramatically improve the design rules for next generation Vias and RDL layouts.

**LASER VIA DRILLING (ABLATION)**

Laser via ablation offers “state of the art” process results with improved feature resolution (~3 µm) and reduced via opening sizes (Typically 1:1 ratio). This laser process allows for designing significantly higher density interconnect layouts for underlying metal redistribution layers and metal pads.

Figures 6-9 present a test matrix of via and line dimensions in a 7 µm thick PBO dielectric. Via dimensions as small as 7.3 µm are demonstrated with an application desired sidewall angle of 60 degrees. The Excimer laser process also enables the ability to manipulate the sidewall via angle profile by simply adjusting the laser fluence and other settings. The typical sidewall angle range is generally between 50–82 degrees, depending on material type.

Figure 4. Mask based laser ablation optimizes throughput and pattern placement  
Figure 5. Comparison of the number of process step for photolithography (6) and laser ablation process (4).  
Figure 6. Via & L/S features ablated in 6µm PBO  
Figure 7. Square Via (~20µm) ablated in 6µm PBO
Excimer laser ablation is ideal for selectively removing materials, such as polymers; while stopping on a different material, such as a metal layer that is (> ~1 µm) thick. A thick metal pad acts as a natural stop layer for Excimer ablation of vias with no damage or metal removal occurring to the metal pad. Figure 10 demonstrates the ability to ablate to a copper surface without damaging or etching the copper layer. The red arrow illustrates the sidewall angle of ~75 degrees through a 14 µm thick dielectric layer. In addition, by controlling the fluence and other settings the Excimer ablation is able to stop at a certain depth in the dielectric without a metal backstop. The ability for laser drilling to stop on metal pads without damaging them is a critical requirement for Advanced Packaging applications. A comparison of Excimer and DPSS laser drilling results in polymer, down to a ~1.4 µm thick Al pad, are shown in Figure 11. The results clearly demonstrates that Excimer laser drilling is able to selectively stop on the Al pad without damaging it due to its flat top beam profile. In contrast, the DPSS laser results show significant damage to the Al pads.
The Authors

Matthew Gingerella is a seasoned applications engineer and solutions-based capital-equipment sales professional. His education includes a Bachelor’s Degree in Chemistry from CSUF and a two-year degree in Electronics Technology. His background encompasses manufacturing, industrial processes, regulatory compliance, sales, service, marketing and training.

He is presently an International Product Specialist for SUSS MicroTec Photonic Systems located in Corona, CA. He has spent over 7-years working closely with the scientists, researchers, engineers and management of top-tier high-technology companies to help develop and qualify SUSS MicroTec’s laser ablation and projection photolithography patterning solutions for their cutting-edge applications and processes. Gingerella is an application specialist for the following markets: Semiconductor Advanced Packaging, WLP/3D TSV/RDL, Biosensors, Diagnostic Sensors, Rigid & Flexible Displays, E-Paper, Photovoltaics, and Organic Electronics.

Matt Souter graduated in 1992 from CSULB in California with a BS in Mechanical Engineering. He joined Tamarack Scientific in 2001 and has been active in the role of VP of Sales and Marketing for both the Laser Ablation and Photolithography product lines. Much of his focus as of late, has been in the research and development of alternative patterning techniques using Excimer laser ablation as a means to not only meet next generation Advanced Packaging requirements, but also address a means to lower manufacturing costs. Matt has recently authored an exciting new laser process for the removal of metal seed layers in lieu of standard processing approaches, addressing both technical limitations as well as a reduction in manufacturing costs. This process is currently patent pending. With the recent acquisition, he currently works as Global Sales Director and Laser System Product Manager for SUSS MicroTec.

DESIGN IMPROVEMENT ENABLER

Since Excimer laser via ablation can produce smaller via dimensions compared to standard photolithography methods, using this innovative technology can dramatically improve the design rules for next generation RDL layouts. Excimer laser ablation enables three important advantages for flip-chip and other wafer-level packaging applications:

1) a larger quantity and reduced via dimensions to be placed on the device;
2) ability to utilize better performing polymers; and
3) enable manufacturing cost reductions. In fact, Excimer laser ablation could possibly reduce some two-layer RDL designs down to just one-layer, further simplifying the manufacturing process.

The following example demonstrates the ability to ablate a 10 µm via to a 10 µm RDL and shows successful subsequent plating (Figure 12).

To simplify its industry adoption, the Excimer laser via drilling process has been successfully and seamlessly integrated into a standard photolithography process flow. Excimer laser via drilling is an enabler for the use of “non-photosensitive” organic dielectrics. In contrast, photolithography with “non-photo” polymers would require additional processing steps and increase manufacturing costs. Excimer laser ablation is attractive because it provides superior patterning capabilities and reduces manufacturing costs.

The use of the latest “non-photo” dielectrics will improve mechanical and thermal properties in next generation device packaging – even as the bump diameters and pitches continue to shrink. The expected result is more capable WLP devices with improved product yield for next generation products.

Figure 12: Eximer laser ablated 10µm vias on 10µm RDL trace.
Pictures courtesy of FlipChip International