JPSA

Applications Note

advanced laser technology

Wafer Processing with Short-Pulse UV DPSS Lasers

Introduction

UV diode-pumped solid-state (DPSS) lasers are robust, production-capable systems used in a wide range of applications in microfabrication, surface treatment and materials processing. The potential of these lasers for semiconductor and other industries leads to the development of applications that often can not be performed by other mechanical, chemical or laser fabrication methods. DPSS lasers offer excellent beam quality and the highest repetition rate providing the smallest beam size for micro features. Typically the DPSS lasers used are vanadate (Nd:YVO4)-based and produce an IR beam at approximately 1 µm. Efficient frequency conversion allow use of these lasers at 355- and 266 nm with several watts of available power.

Micromachining is a wide area where DPSS lasers are used. Silicon, sapphire, CVD diamond, III-V semiconductors (gallium arsenide, indium phosphide, gallium phosphide) and III-nitrides such as gallium nitride and aluminum nitride, are materials routinely machined by DPSS lasers in applications such as structuring, via drilling, dicing and cutting. In addition, these lasers are also used for micromachining other ceramics, polymers and metals.

Recently, frequency-multiplied diode-pumped solid-state (DPSS) lasers have demonstrated fairly high pulse energies even at UV wavelengths and high kHz repetition rates. A focused beam spot with short pulse duration creates extremely high irradiance, resulting in instantaneous vaporization of materials during wafer scribing. In conventional laser scribing, a simple far field imaging technique is used, wherein the laser beam is sharply focused onto a small spot, and then delivered to a target wafer. However, the focused beam spot in the conventional far field imaging does not have sufficient flexibility to adjust for optimum intensity, which is determined by the light absorption properties of a particular target.

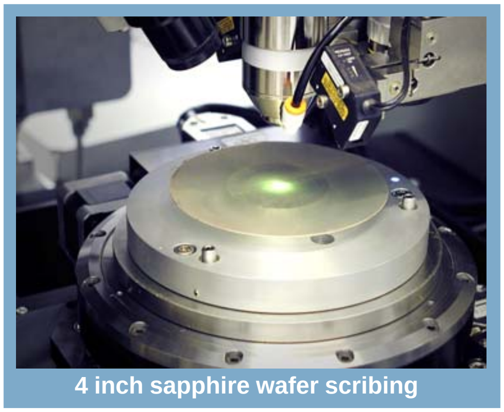
Optimum laser intensity is important to achieve the desired processing result, because either excessive or insufficient laser intensity will introduce imperfections into the laser scribing process. Furthermore, conventional laser scribing is limited in terms of the achievable minimum spot size of the focused beam, which is directly related to resolution of the scribing process. Consequently, there is a need for a laser scribing method that avoids the drawbacks of existing techniques. At JPSA we have developed adequate beam shaping/ delivery optics to adjust the laser intensity while minimizing the beam waist. Properly optimized laser intensity with a highly resolved beam spot dramatically increases semiconductor wafer scribing speed, while minimizing excessive heating and collateral material damage.

Improvements in short pulse width, short wavelength UV Diode-Pumped Solid State (DPSS) lasers in very recent times have resulted in robust, production-capable systems that offer a wide range of flexibility in terms of modifying pulse shape, repetition rate and beam quality. Harmonic generation allows the user to adequately choose the most appropriate wavelength for a wide range of materials processing applications.

DPSS Laser Applications

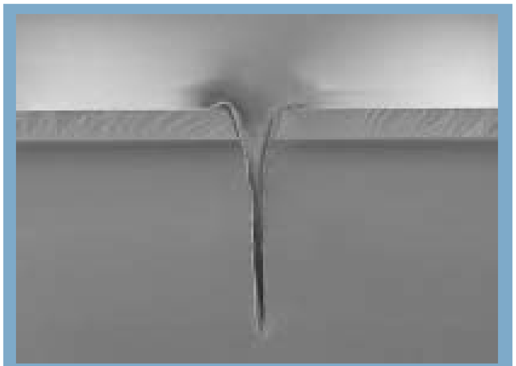
The development of high repetition rate UV DPSS lasers makes them particularly suitable for cutting, marking, scribing and via drilling applications. For a number of applications UV DPSS lasers are used at the focal point of the imaging lens on a direct writing technique. The use of CAD conversion software minimizes set up time for new parts and allows efficient and high quality machining. Sapphire, quartz, CVD diamond, and glass are materials cleanly cut up with high quality and narrow kerfs up to thicknesses of 500 microns using special processing techniques.

Via drilling with the DPSS laser is performed using different techniques, the choice of which is largely dependent upon via diameter and required accuracy. Percussion drilling is used to create small diameter vias (3 - 10 µm), while vias larger than the beam diameter can be machined using trepanning/helical drilling. In this technique, the spot beam is moved one or several times across a defined path until breakthrough is achieved. At JPSA a typical DPSS application is machining of small holes in fused silica films with diameters varying from 10 microns to several millimeters within the same wafer. For machining blind vias, with smooth flat-bottomed surfaces, or vias with minimal taper, excimer lasers are typically used, since a constant density distribution on target is required, rather than the quasi-Gaussian beam profile typical of DPSS lasers.



4 inch sapphire wafer scribing

Laser scribing is currently an area receiving special focus. We routinely use these lasers to scribe blue LED and sapphire wafers at speeds of 50- to 75 mm/sec, leading to a throughput of more than 10 wafers per hour (for standard 2 inch diameter wafer with die size of 350 µm by 350 µm) while creating a very narrow kerf (as narrow as 2.5µm). With its high throughput and minimal impact on LED performance, the process is tolerant of wafer warp and bow, and delivers much faster scribing speed than traditional mechanical methods. For III-V semiconductors, such as GaAs and InP, a cut depth of 40 µm is typically achieved at speeds of up to 150 mm/sec. Very high scribing speeds, with minimal affectation are also achieved for some metals, silicon and other ceramics.



Extremely narrow 2.5µm kerf in Sapphire wafer, higher die count

LED Wafer Scribing

The use of short-wavelength UV DPSS lasers have proven to increase die yields, without appreciable loss of brightness, in LED wafer scribing, and have proven superior to traditional diamond scribing methods not only in these terms but also in terms of throughput and long-term product reliability. These improvements are due, in part, to the nature of UV lasers, as well as their method of application to the scribe and break process (front side versus back side processing). Overall, the advantages are quite clear, but are also application and technology specific, which may explain some of the current misconceptions concerning UV laser scribe and break technology versus traditional methods – or even other laser scribing methods - that are currently circulating in the industry.

UV laser processing allows a much narrower scribe kerf width than other technologies. Coupled with front-side processing, this increases the number of usable die that can be produced per wafer, thus accelerating machine payback and increasing profits. An easy example involves a typical 2" blue LED wafer on sapphire, with 250µm x 250µm devices. Using traditional diamond scribing with typical 50µm streets (300µm die pitch), there will be ~24,400 die on the wafer; 22,200 usable die at a 90% die yield. Using UV laser scribing, the street width can be reduced to 20µm (a 270µm die pitch). At this die pitch the wafer contains ~27,750 die (a 14% increase due to narrower streets), and will produce 27,475 usable die at a 99% yield - a 24% total increase in usable die.

GaAs Wafer Scribing

Scribing GaAs wafers with DPSS (UV) lasers has emerged as an alternative method of scribing for separation for brittle compound semiconductor wafer materials. These lasers rapidly processes wafers with kerfs to <3 microns in thin or thick wafers without edge chipping in all the III-V materials, including "IV" materials such as Si and Ge, and straight, accurate, cleaner cuts particularly for GaAs wafers. GaAs wafers are expensive, so wafer real estate is valuable. The tighter, narrower, cleaner cuts achievable with UV laser scribing provide better die count per wafer and higher yields due to fewer damaged die. The laser scribing process operates within 20 micron streets or narrower.

Laser scribing has multiple advantages over traditional scribe and break processes. With the scribe and break process, PCM structures must be designed with through-dicing lanes. The diamond scribe does not scribe continuously through the structure. Due to this, the structure must be designed with dicing lanes. This creates issues for the testing of these structures. However, with laser scribing, PCM design is no longer an issue. The structures can be designed in a way that benefits the tests being completed, not to the requirements of the separation method. Laser scribing is not interrupted when there is no dicing lane.

With the traditional methods of separation, the dicing lanes must be free of thin films/metal. With the saw process, thin films/metal in the dicing lanes increases the wear on the blade thus reducing the life of the blade or possibly causing the blade to "blow" during the cutting process. With scribe and break, thin films/metal in the dicing lanes causes the diamond tool to skip/bounce creating areas that are not scribed. These areas therefore do not break, which can cause the rest of the wafer to break off the scribe lines. Thin films/metal in the dicing lanes does not limit laser scribing. This allows for higher yield, lowering the numbers of reworks during in line production, and does not cause wear to the laser. The ability to dice through thin/films also has ability to increase through put for the photo processes as well. Currently, all wafers must be patterned to the edge of the wafer, including partial fields, so that the street can be etched clean, creating a clean dicing lane to the edge of the wafer. When the wafers are not patterned to the edge, the yield takes a big hit.

Traditional methods of die separation require lots of time. For example: a 4 inch diameter wafer with a die size of 0.300mm x 0.360 mm has ~55,000 die. A wafer with this die count takes ~4 hours with the saw (saw speed = 6.5 mm/sec), ~2 hours with scribe and break (scribe speed = 12.8 mm/sec), and ~3 minutes with laser scribing (laser scribe speed = 150mm/sec).

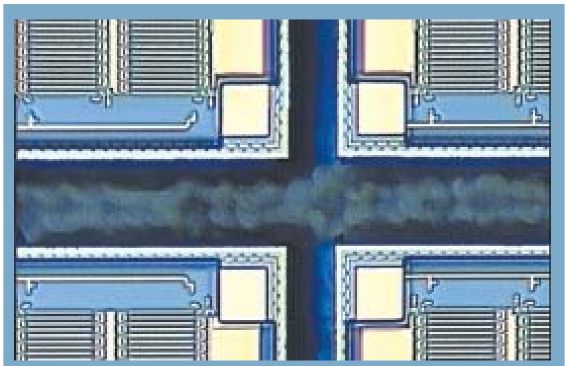
Laser scribing gives the added benefit of options when determining shipping methods. The scribe and break process requires that the wafers be scribed on a film frame and then transferred to a grip ring for shipping. Wafers that have been scribed must be stretched to prevent the die from "rubbing" together when the tape flexes. Many customers require the wafers to be on a film frame, or the customers have to make modifications so that the wafers can be received on a grip ring. The laser scribe gives the option of shipping wafers on a film frame. The die are separated through the active levels by the laser scribe. The die will only "rub" together in non-active material.

Current die separation methods loose yield due to chip outs. Chip outs are eliminated with laser scribing. This alone has a large impact on product yield.

Laser scribing will increase wafer through put on final automated wafer inspection. Currently, wafers must be stretched to prevent chip outs caused by the die "rubbing" together. The die do not stretch uniformly, causing inspection time to increase. Due to the non uniform stretch, each die must be aligned for the automatic inspection to be performed correctly. Occasionally the yield is impacted because the die will not align. Laser scribing allows for the wafers to be inspected on a film frame, which greatly reduces the time required for inspection. This allows all products to go through the auto inspection process.

Outlook

The demand for microfabrication, surface treatment and materials processing in the semiconductor industry is increasing. Short-pulsed UV DPSS lasers also continue to increase their average power, providing rugged industrial packages with longer working lives and hands-free operation. Currently, a major effort is underway to create reliable ultra-short (pico- and femtosecond) pulsed laser systems for industrial use. The ongoing development of laser systems, new machining techniques, improved beam delivery optical systems and enhanced knowledge of laser /material interactions will continue to advance the development of new applications in the future.



GaAs wafer, diced and expanded. Wafer dicing is well-suited for UV DPSS lasers with their highly focusable, pinpoint-bright beams

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