

## FLEXIBLE LASER SYSTEM FOR SEVERING SEMICONDUCTOR WAFERS

### Field of the Invention

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The present invention relates in general to severing semiconductor wafers, and in particular to severing semiconductor wafers that are made from a variety of materials and that have a range of thickness.

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### Background of the Invention

A plurality of semiconductor integrated circuits are formed on a semiconductor wafer with scribing lanes that separate the individual integrated circuits. A process known as singulation is employed to cut the wafer along the scribing lanes, thereby separating the individual integrated circuits, which are then individually packaged.

In the past, a rotating wafer sawing was used to cut the wafer, however today laser systems are used for cutting a semiconductor wafer along the scribing lanes. Primary advantages of using a laser system relative to the wafer saw method are the minimal generation of particles, the reduced cracking in the integrates circuits, narrower scribing lanes, and the ability to sever integrated circuits having a variety of shapes. While reduced particles and cracks relate to better more reliable integrated circuits, narrower scribing lanes are particularly attractive, as it will allow a larger portion of wafer real estate to be used for integrated circuits. Hence, the packing density per wafer may be increased, resulting in a lower unit cost per integrated circuit.

In addition, with the growing need for semiconductor packages for specific applications, the devices on integrated circuits may no longer be limited to devices having orthogonal sides. Here again the laser

allows flexibility over the conventional saw in that the laser can more readily sever non-orthogonal devices on a semiconductor wafer.

US patent no. 5214261 by Zappela, assigned to Rockwell International Corporation, teaches a dry laser system for severing semiconductor wafers using an ultraviolet excimer laser with a single  
5 angled laser light beam, and US patent no. 5641416 by Chadha, assigned to Micron Display Technology Inc., teaches a dry laser system for severing semiconductor wafers using an infrared Nd:YAG laser system with a laser light beam that is passed over the scribing lanes a  
10 number of times.

Each of these prior art dry laser systems are systems designed for severing specific types of semiconductor wafers, and to address specific requirements for the integrated circuits on the respective semiconductor wafer type. Hence, the type of laser that is used, the settings for the  
15 laser, and the method of applying the laser light beam are specific to the particular semiconductor wafer type and the devices thereon.

In a semiconductor packaging facility, particularly one in a contract manufacturing operation, there is a need for a flexible laser system that is capable of severing a variety of semiconductor wafers,  
20 where the wafers may be made of a variety of materials and have a variety of thickness.

### Brief Summary of the Invention

25 The present invention seeks to provide a method and apparatus for a laser system for severing semiconductor wafers, which overcomes, or at least reduces the abovementioned limitations of the prior art.

Accordingly, in one aspect, the present invention provides a laser system for severing at least one semiconductor wafer having a plurality  
30 of devices formed thereon with a plurality of scribing lanes between the plurality of devices, the laser system comprising:

a laser handler having at least two laser generators, the at least two laser generators operably coupled to provide at least one laser light beam;

an optical system handler for receiving the at least one laser light beam, the optical system handler having at least one optical element for manipulating the at least one laser light beam to produce a manipulated laser light beam, wherein the manipulated laser light beam for evaporating portions of the at least one semiconductor wafer along at least some of the plurality of scribing lanes by ablative photodecomposition;

a wafer handler having a movable mount, the movable mount for receiving and securing at least one wafer thereon, the wafer handler for positioning the mount such that at least one of the plurality of scribing lanes on the semiconductor wafer is substantially aligned with the manipulated laser light beam, and for moving the mount such that the semiconductor wafer travels with the manipulated laser light beam on the at least one of the plurality of scribing lanes; and

a controller coupled to the laser handler, the optical system handler and the wafer handler.

In another aspect, the present invention provides method for severing at least one semiconductor wafer having a plurality of devices formed thereon with a plurality of scribing lanes between the plurality of devices, the method comprising the steps of:

- a) providing a laser handler, an optical system handler and a wafer handler, and a controller coupled to the laser handler, the optical system handler and the wafer handler;
- b) inputting wafer specifications of the at least one semiconductor wafer to the controller;
- c) providing control signals from the controller to the laser handler to select at least one laser;
- d) providing control signals from the controller to the optical system handler to select at least one optical element;

- e) loading and aligning the at least one semiconductor wafer on the wafer handler;
  - f) severing the at least one semiconductor wafer with at least one laser light beam from the at least one laser, where the at least one laser
- 5 light beam has been manipulated by the at least one optical element.

### Brief Description of the Drawings

An embodiment of the present invention will now be more fully

10 described, by way of example, with reference to the drawings of which:

FIG. 1 shows a laser system in accordance with the present invention;

FIG. 2 shows a beam splitter configured by the optical system handler of the laser system in FIG. 1; and

15 FIG. 3 shows a flow chart detailing the operation of the laser system in FIG. 1

### Detail Description of the Drawings

20 The present invention, as will be described below, is a method and apparatus for a dry laser system for severing semiconductor wafers that are made from a variety of semiconductor materials, and where the semiconductor wafers have a range of thickness. The system incorporates a laser handler, which supports both an ultra-violet laser

25 and an infrared laser; an optical system handler which provides a configurable optical system; and a wafer handler for positioning and moving a semiconductor wafer relative to laser light beam(s) directed from the optical system handler onto the scribing lanes of a semiconductor wafer mounted on the wafer handler. A controller which

30 is coupled to the laser handler, the optical system handler, and the wafer handler; stores a variety of predetermined settings for a corresponding variety of semiconductor wafers types. Each of the

predetermined settings is optimized to sever a corresponding wafer type along the scribing lane, such that severed semiconductor integrated circuits meet their specific requirements.

In FIG. 1, a laser system 100 has a laser handler 115 which  
5 supports an ultraviolet laser source 120 and an infrared laser source 125. Each of the laser sources can be dedicated and optimized to operate within a particular range of wavelength. The ultra-violet and infrared laser sources 120 and 125 each can comprise one or more laser generators. The laser handler 100 comprises mounts (not shown)  
10 for mounting the laser sources 120 and 125 thereto, and has mechanical actuators (not shown) for moving the lasers sources 120 and 125. The mechanical actuators are coupled to receive control signals, and in response, move the laser sources 120 and/or 125 accordingly. A controller 130, which will be described in more detail  
15 later, provides the control signals.

In addition, the controller 130 also provides control signals to the laser sources 120 and 125 that control the operation of the laser sources 120 and 125, such as switching the power ON and OFF, and laser settings that include laser power, wavelength, and pulse repetition  
20 rate.

An optical system handler 135 is coupled to receive control signals from the controller 130. The optical system handler 135 provides a configurable arrangement of optical elements, and the arrangement of these elements is determined by control signals from the controller 130.  
25 For example, when only the ultra-violet laser source 120 is used and a single laser light beam is to be provided, the optical system handler aligns a convex lens with the ultra-violet laser source 120 to provide the single laser light beam. Another example is, when only the infrared laser source 125 is used and multiple laser light beams are to be  
30 provided, the optical system handler 135 provides a diffraction grating and a convex lens which are aligned with the infrared laser source 125.

When the laser source, either ultra-violet 120 or infrared 125, comprises more than one laser generator, the optical system handler 135 can be used to optically channel the laser light from the laser generators to produce a single laser light beam, when such is required.

5 Alternatively, the optical system handler 135 can direct laser light from multiple laser generators to multiple scribing lanes on a semiconductor wafer 145, simultaneously. Dotted lines 132 and 160 indicate the laser light beams travelling from the ultra-violet (UV) 120 and the infrared 125 sources respectively, to the optical system handler 135, while the

10 dotted lines 165 indicate the laser light beams directed by the optical system handler 135 at the scribing lanes on the semiconductor wafer 145. It will be appreciated that more than one UV laser generator may be employed to provide the UV laser light beam 120. Similarly, more than one infrared laser generator can be used to provide the infrared

15 laser light 160.

In selecting lasers, there are tradeoffs to be made as to which type of laser is preferred, however, such decisions are made when the wafer specifications are determined. For example, when a wafer is greater than a certain thickness, then the UV laser source 120 is less attractive

20 due to its lower power and the infrared laser source 125 with its higher power capability may be a better option. However, due consideration must be made for the type of devices on the semiconductor wafer and the more significant heat absorption that occurs when using the infrared laser source 125 as compared to a ultraviolet laser source 120.

25 The optical system handler 135 comprises a plurality of optical elements (not shown) for manipulating laser light 132 and 160 from the laser sources 120 and 125, and for directing and focussing the manipulated laser light beams 165 onto the scribing lanes on the semiconductor wafer 145. The optical elements are mounted on mounts

30 (not shown) and moved by programmable actuators (not shown) in accordance with control signals from the controller 130.

In FIG. 2 an arrangement 200 of optical elements by the optical system handler 135 provides a beam splitter. A laser light beam 205 from the laser sources 120 and/or 125 is directed to a prism 210 which reflects some of the laser light beam 205 as reflected laser light beam 220. Another portion of the laser light beam 205 is conducted through the prism 210 and emerges as laser light 225, which was subsequently reflected by reflective element 215. Thus, the laser light beam 205 is split into laser light beams 220 and 225. It will be appreciated that as the optical elements i.e. the prism 210 and the reflective element 215 are mounted on actuators (not show) the positions of these elements can be changed to provide the laser light beams 220 and 225 having a range of spacing between them, and the laser light beams 220 and 225 may be directed in accordance with settings from the controller 130, and/or user input. Each of the laser light beams 220 and 225 have individual focussing mechanisms 230 and 235, respectively, that focus the laser light beams 220 and 225 on scribing lanes on the semiconductor wafer 145.

Returning now to FIG. 1, a wafer handler 140 has a mount 142 on which is mounted the semiconductor wafer 145. The mount 142 is movable, and its position is programmed by control signals from the controller 130. Actuators (not shown) in the wafer handler 140 are programmed to move the mount 142, and thus the semiconductor wafer 145, along X and Y axes relative to the laser light beams 165 from the optical system handler 135. In addition, the wafer handler 140 can tilt the semiconductor wafer 145 in a plane orthogonal to the laser light beams 165. It is also anticipated that movement along the Z-axis may be useful, particularly when assisting in focussing the laser light beams 165 on the scribing lanes on the semiconductor wafer 145.

An image recognition system (IRS) 170 determines the location of the scribing lanes on the semiconductor wafer 145, and provides this information to the controller 130. One skilled in the art will be familiar with the operation of an image recognition system, and to the extent the

operation of the image recognition described herein is similar, to known systems, no further information on such known systems will be described herein.

The controller 130 uses the information from the IRS 170 to align  
5 the laser light beams 165 with the scribing lanes on the semiconductor wafer. This is accomplished by changing the position settings of the optical system handler 135 and/or changing the position of the semiconductor wafer 145 by changing the settings to the wafer handler 140. Circumstances may also require that the position of the laser  
10 sources be changed, and here settings to the laser handler 115 are affected by the controller 130.

In addition, during the scribing process, the IRS 170 monitors the laser light beams 165 as the wafer 145 is severed along the scribing lanes. The IRS 170 provides feed back in a closed loop position control  
15 system to ensure that the laser light beam is directed at the scribing lanes. Further, as the IRS 170 is able to determine the area on the wafer 145 on which the laser light beam is directed, the degree of focus of the laser light beam 165 can be controlled as the wafer 145 is moved by the wafer handler 140. Such image recognition systems are known to  
20 one skilled in the art.

The controller 130 has a memory 132 which stores a database of specifications for a variety of semiconductor wafers. The specifications include the type of material a wafer is made of, the thickness of the wafer, the size of the wafer i.e. diameter, and the type of device formed  
25 on the wafer. In addition, the database includes settings for the laser handler 115, the optical system handler 135, and the wafer handler 140. The laser handler settings include type of laser source, laser power, wavelength, and pulse repetition rate. The optical system settings include single or multiple beam, beam spacing, cutting width or  
30 kerf, etc., and the wafer handler settings include alignment, severing or cutting speed, and number of scans of the laser light beam per scribing

lane to cut through the wafer, etc. TABLE 1 shows an example of the information stored in the database.

| WAFER SPECIFICATIONS |                                |              |                           | HANDLER SETTINGS |                |               |
|----------------------|--------------------------------|--------------|---------------------------|------------------|----------------|---------------|
| Material<br>(Type)   | Thickness<br>( $\mu\text{m}$ ) | Size<br>(in) | Device                    | Laser            | Optics         | Wafer         |
| Silicon              | 280                            | 8            | CMOS<br>0.5 $\mu\text{m}$ | UV<br>etc.       | Single<br>etc. | Align<br>etc. |
|                      |                                |              |                           |                  |                |               |

TABLE 1

The information in the database is built up over time as each type of semiconductor wafer is added. To add a new type of semiconductor wafer to the database, a sample wafer is severed and the severed integrated circuits of the sample wafer are inspected. The various settings of the laser system 100 are manipulated until a set of settings is determined where the severed integrated circuit meets its specific requirements. Some modifications may be required, for example, when the speed at which a wafer is severed meets the specific requirements, but is below the speed that is required to maintain manufacturing throughput. In such an instance, more than one laser light beam may be configured for that particular wafer type, for example by having the optical system handler provide a beam splitter, as in FIG. 2.

Alternatively, when a new wafer is to be severed, the new wafer specifications can be entered via the user console 150 when the laser system 100 is in set-up mode. In this mode, the new wafer specifications are compared with those in the database and the closest matching wafer specifications found. The corresponding settings for the closest matching specifications are then presented to the user. The user may adopt the specifications, as presented, or make changes to the specifications. The user then proceeds, through several trials of severing the new wafer type, to fine tune the specifications for the new wafer

type. The finalized user selection of the specifications associated with the new wafer type is then saved in the database.

The controller 130 is a computer, such as an IBM compatible, and the memory 132 includes a data storage, such as a hard disk drive, in which the database is stored. The user console 150 is coupled to the controller 130, and this can comprise a video terminal and keyboard which provides a user interface to the laser system 100. In addition, the user console 150 can include a bar code reader which can be used in conjunction with bar code marking on semiconductor wafers to identify the different types of semiconductor wafers. The use of bar code marking simplifies inputting of wafer specifications, and makes it less prone to user errors caused by incorrect entry of wafer specifications.

With additional reference to FIG. 3, the process 300 for severing the semiconductor wafer 145 employing the laser system 100 starts 305 when specifications of the semiconductor wafer 145 are inputted 310 by a user on the user console 150. Alternatively, as described above, wafer specifications can also be provided via bar code marking. The wafer specifications include the material from which the semiconductor wafer 145 is made. Typically, this means the base material of the semiconductor wafer 145, which for the great majority of semiconductor wafers is silicon. In TABLE 1, silicon is used as an example. There are semiconductor wafers made from other materials, such as germanium, gallium arsenide, and sapphire.

The wafer specifications also include the thickness of the semiconductor wafer, as this is an important criterion when severing with a laser light beam. Laser light beam severing causes considerable heat to build up at the severing location that can damage the device(s) on the wafer. The laser light beam can be manipulated to control the resultant heat. One known method is to use multiple passes of the laser light beam over a scribing lane, thereby allowing time between passes for heat to dissipate. This method can be used for severing thicker

wafers. From TABLE 1 sample wafer thickness is 280 micrometers, often referred to as microns.

Another wafer specification is the size of the wafer 145 which typically is measured in terms of the diameter of a semiconductor wafer.

5 This specification is used to determine the working area on the mount 142 of the wafer handler 140 within which the laser beams 165 will need to operate. Yet another wafer specification is the type of device on the wafer 145, which includes the type of fabrication process used. This is important as this determines the level of heat absorption the wafer  
10 145 can take without damaging the devices. In TABLE 1, the example provides for a CMOS wafer that was fabricated using a 0.5 micron process.

After the wafer specifications have been entered, the controller 130 searches the database in the memory 132 for a match, and upon  
15 locating a match retrieves the corresponding settings in the database, and provides the settings to the laser handler 115, the optical system handler 135, and the wafer handler 140.

Upon receiving settings from the controller 130, the laser handler 115 selects 315 one of the laser sources 120 and/or 125 in accordance  
20 with the settings, and enables the selected laser source. For example, when the settings from the controller 130 indicate the ultra-violet laser source 120 is selected, the laser handler 115 provides power to the UV laser source 120. A UV laser generator, that forms part of the UV laser source 120, may then execute a set-up and diagnostic routine, and  
25 provide a response to the controller 130 indicating that the selected UV laser source 120 is operating properly. When more than one laser generator is selected, as indicated by the settings, the same set-up process occurs for each of the laser generators.

Next, the optical system selection 320 begins when the optical  
30 system handler 135 receives its settings from the controller 130. The settings indicate, for example, whether a single laser light beam 165 will be used or if several laser light beams 165 will be used. When only a

single laser light beam 165 is to be used, the optical elements, such as a single convex lens (not shown) that is required to direct and focus the single laser light beam, is arranged by the optical system handler 135 in accordance with the settings from the controller 130.

5        On the other hand, when multiple laser light beams are required, the optical elements 210 and 215 are arranged to manipulate and direct laser light provided from the selected laser light source 120 and/or 125 as laser light beams 220 and 225 onto the scribing lanes on the semiconductor wafer 145. In order to accomplish this, the distance  
10       between the multiple laser light beams 220 and 225 are precisely spaced to match the distance between the scribing lanes on the semiconductor wafer 145.

      The wafer 145 is then loaded 325 on the mount 142 and the image recognition system 170 activated. The image recognition system 170  
15       determines the location of predetermined reference marks on the semiconductor wafer 145, and provides this information to the controller 130. The controller 130 aligns 325 the laser beam or beams 165 by adjusting one or more of the following: the position of the laser sources 120 and/or 125; the position of the optical elements, such as  
20       210 and 215, in the optical system handler 135; and the position of the wafer 145.

      When alignment 325 has been completed, the laser source 120 and/or 125 starts severing 330 the semiconductor wafer 145 along the scribing lanes, and continues until the whole wafer 145 has been  
25       severed, in accordance with control signal from the controller 130. A determination 335 is then made as to whether another semiconductor wafer of the same type is to be severed. When there is another semiconductor wafer of the same type to be severed, then the process 300 jumps to step 325 where the new wafer is loaded and alignment  
30       performed, as before. However, when there are no further semiconductor wafers of the same type to be severed, a further determination 340 is made as whether a new wafer type is to be

severed. When there is, then the process 300 jumps to step 310 and the specifications of the new wafer type must be entered, and the process 300 proceeds as described earlier. However, when there is no new wafer type to be severed, the process 300 ends 345.

5        With the UV laser source 120 set to a wavelength of 355 nanometers, a pulse repetition rate of single shot to 100 kilohertz, a pulse width of less than 40 nanosecond, an average output power of greater than 1.5 watts at 15 kilohertz, and spatial mode of TEM<sub>00</sub>, a cutting width of 40 micrometers at a cutting speed of 10 nanometers per  
10       second has been achieved with 4 scans of the laser being required to sever a 280 micrometer thick silicon wafer.

      The present invention, as described, provides a method and apparatus for severing a variety of semiconductor wafers that are made from a variety of materials and that have a range of thickness.

15       This is accomplished by a laser system having a controller coupled to a laser handler, an optical system handler and a wafer handler that can be set-up to sever each of a variety of wafer types, and stores the corresponding handler settings for each of the wafer types in a database. Consequently, when wafer specifications of a wafer provided  
20       to the laser system match those in the database, the laser system can retrieve the corresponding settings for the handlers, and prepare the laser system to sever the wafer.

      The present invention therefore provides a method and apparatus for a laser system for severing semiconductor wafers, which overcomes,  
25       or at least reduces the limitations of the prior art.

      It will be appreciated that although only one particular embodiment of the invention has been described in detail, various modifications and improvements can be made by a person skilled in the art without departing from the scope of the present invention.

## Claims

1. A laser system for severing at least one semiconductor wafer having a plurality of devices formed thereon with a plurality of scribing  
5 lanes between the plurality of devices, the laser system comprising:

a laser handler having at least two different types of laser sources, the at least two different types of laser sources for providing at least one laser light beam;

an optical system handler for receiving the at least one laser light  
10 beam, the optical system handler having at least one optical element for manipulating the at least one laser light beam to produce a manipulated laser light beam, wherein the manipulated laser light beam for evaporating portions of the at least one semiconductor wafer along at least some of the plurality of scribing lanes by ablative  
15 photodecomposition;

a wafer handler having a movable mount, the movable mount for receiving and securing at least one wafer thereon, the wafer handler for positioning the mount such that at least one of the plurality of scribing lanes on the semiconductor wafer is substantially aligned with the  
20 manipulated laser light beam, and for moving the mount such that the semiconductor wafer travels with the manipulated laser light beam on the at least one of the plurality of scribing lanes; and

a controller coupled to the laser handler, the optical system handler and the wafer handler.

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2. A laser system in accordance with claim 1 wherein the at least two different types of laser sources comprises at least one ultra-violet laser generator.

30 3. A laser system in accordance with claim 1 wherein the at least two different types of laser sources comprise at least one infrared laser generator.

4. A laser system in accordance with claim 1 wherein the at least two different types of laser sources comprise at least one ultra-violet laser generator and at least one infrared laser generator.

5 5. A laser system in accordance with claim 1 wherein the optical system handler comprises at least one optical element.

6. A laser system in accordance with claim 5 wherein the at least one optical element is coupled to at least one actuator, and wherein the  
10 at least one actuator has an input for receiving control signals from the controller, the at least one actuator for positioning the at least one optical element in accordance with the control signals.

7. A method for severing at least one semiconductor wafer having a  
15 plurality of devices formed thereon with a plurality of scribing lanes between the plurality of devices, the method comprising the steps of:

- a) providing a laser handler having at least two different types of laser sources, an optical system handler and a wafer handler, and a controller coupled to the laser handler, the optical system handler  
20 and the wafer handler;
- b) inputting wafer specifications of the at least one semiconductor wafer to the controller;
- c) providing control signals from the controller to the laser handler to select at least one of the at least two different types of laser sources;
- 25 d) providing control signals from the controller to the optical system handler to select at least one optical element;
- e) loading and aligning the at least one semiconductor wafer on the wafer handler; and
- f) severing the at least one semiconductor wafer with at least one laser  
30 light beam from the at least one of the at least two different types of laser sources, where the at least one laser light beam is manipulated by the at least one optical element.

8. A method in accordance with claim 7 further comprising the step of determining whether at least another semiconductor wafer is substantially similar to the at least one semiconductor wafer.

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9. A method in accordance with claim 8 further comprising the step of repeating steps (e) and (f) when the at least another semiconductor wafer is substantially similar to the at least one semiconductor wafer.

10 10. A method in accordance with claim 8 further comprising the step of repeating steps (a) to (f) when the at least another semiconductor is not substantially similar to the at least one semiconductor wafer.