US 20050247894A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2005/0247894 A1
Watkins et al. (43) Pub. Date: Nov. 10, 2005

(54) SYSTEMS AND METHODS FOR FORMING APERTURES IN MICROFEATURE WORKPIECES

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(21) Appl. No.: **10/839,457**

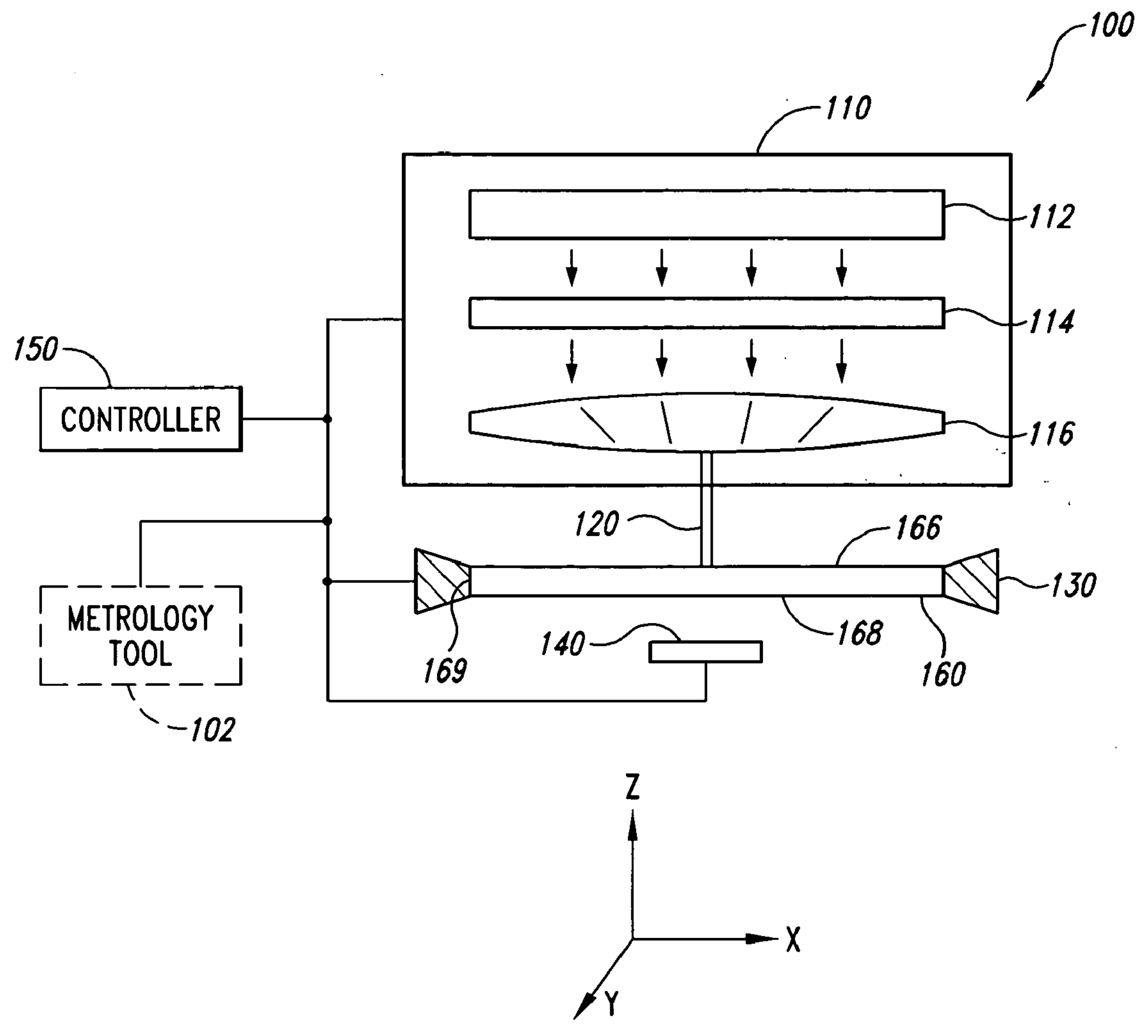
(22) Filed: **May 5, 2004**

**Publication Classification**

(51) Int. Cl.[7] .......................... **H01L 21/76**; G01N 21/86
(52) U.S. Cl. ....................................................... **250/559.13**

(57) **ABSTRACT**

Systems and methods for forming apertures in microfeature workpieces are disclosed herein. In one embodiment, a method includes directing a laser beam toward a microfeature workpiece to form an aperture and sensing the laser beam pass through the microfeature workpiece in real time. The method can further include determining a number of pulses of the laser beam and/or an elapsed time to form the aperture and controlling the laser beam based on the determined number of pulses and/or the determined elapsed time to form a second aperture in the microfeature workpiece.



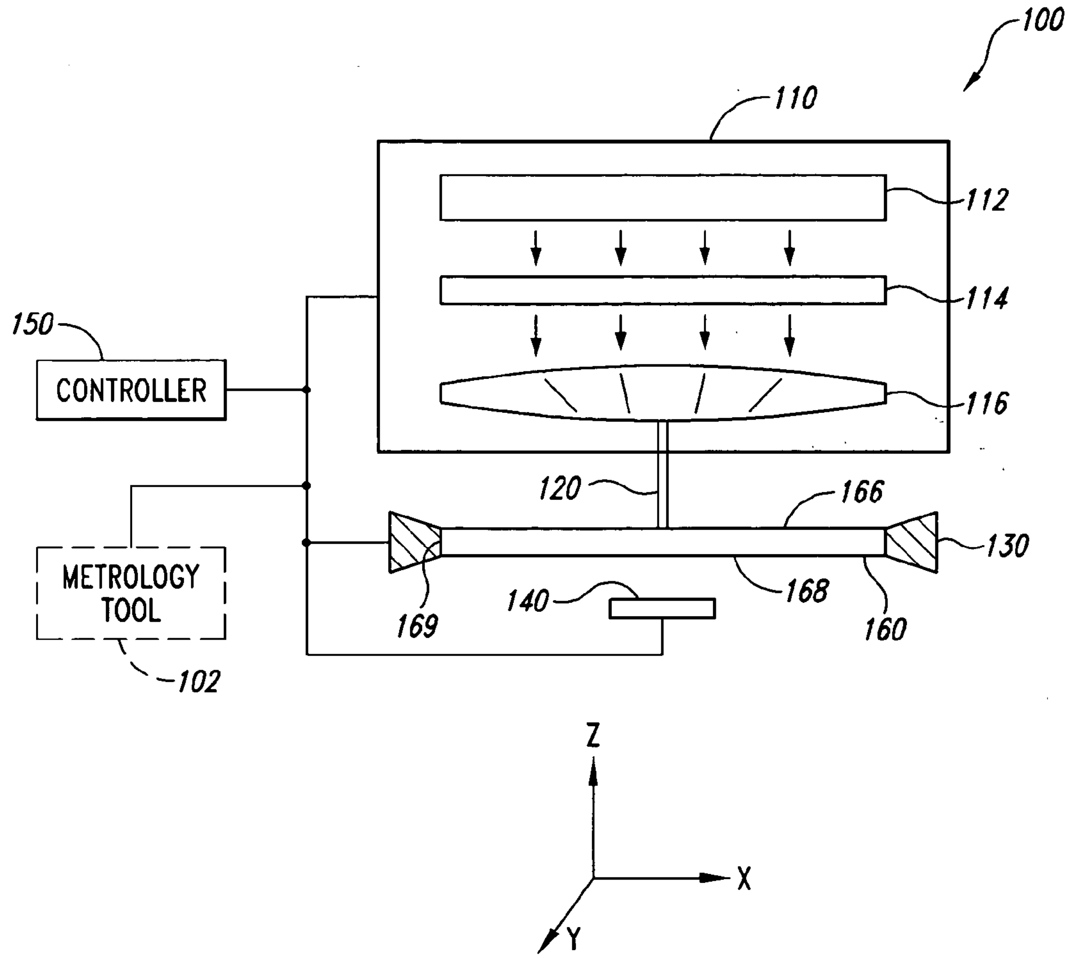

100
110
112
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*Fig. 1*

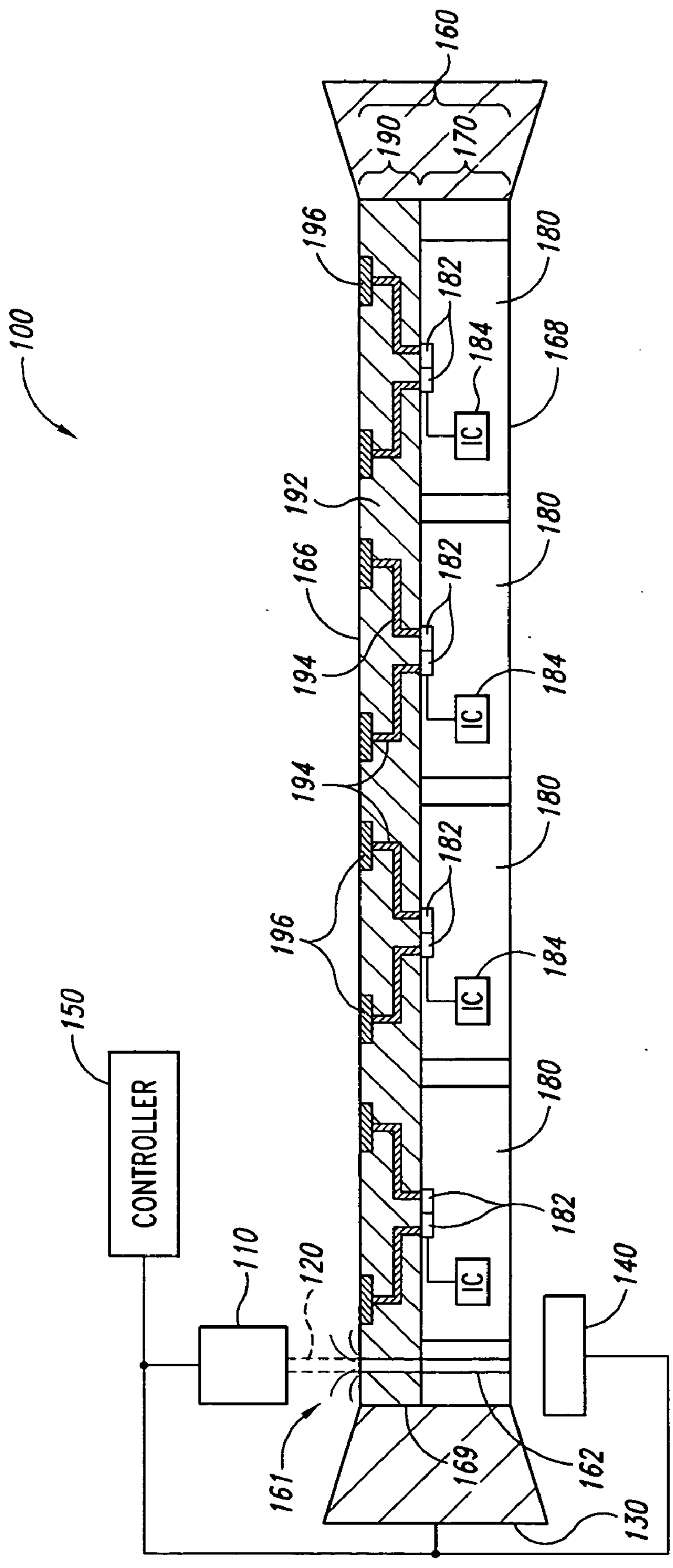
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*Fig. 2*

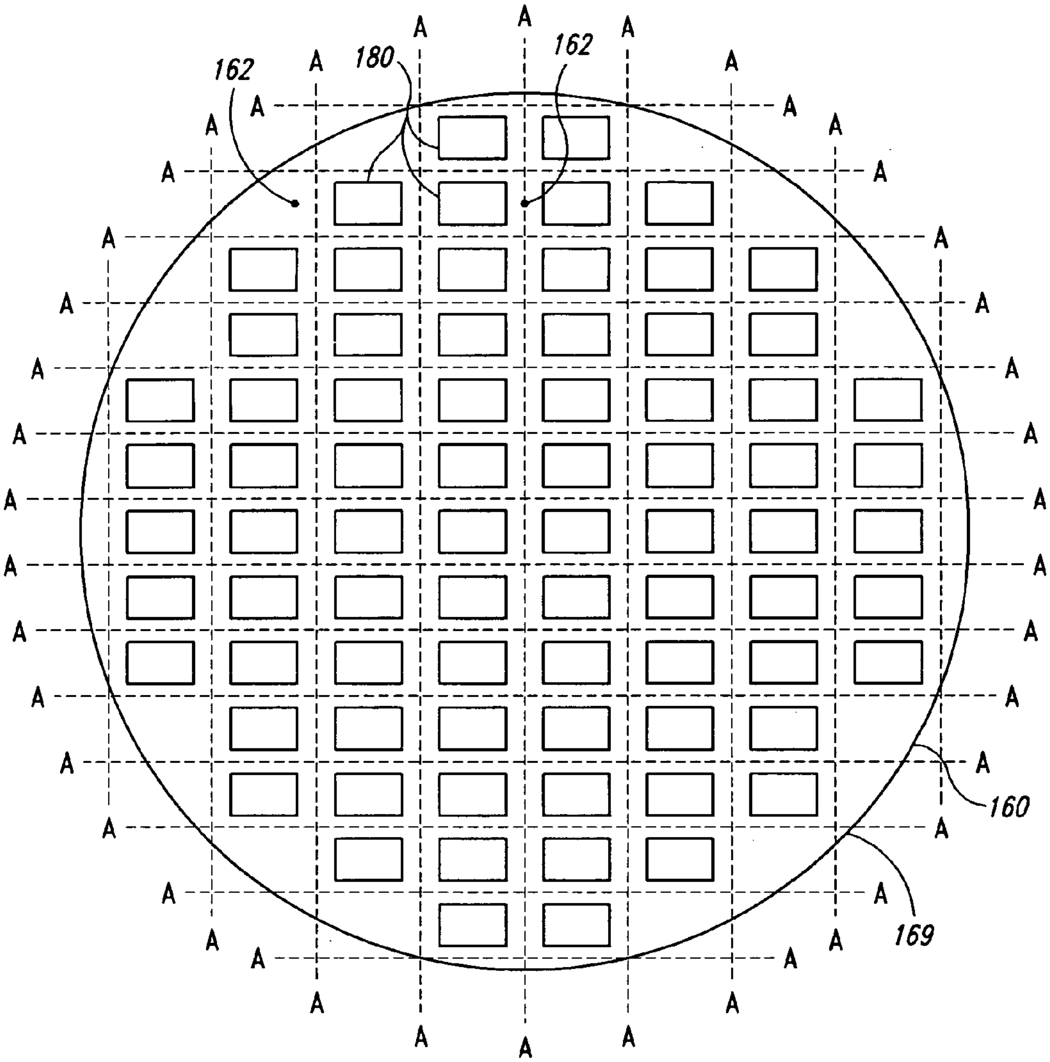
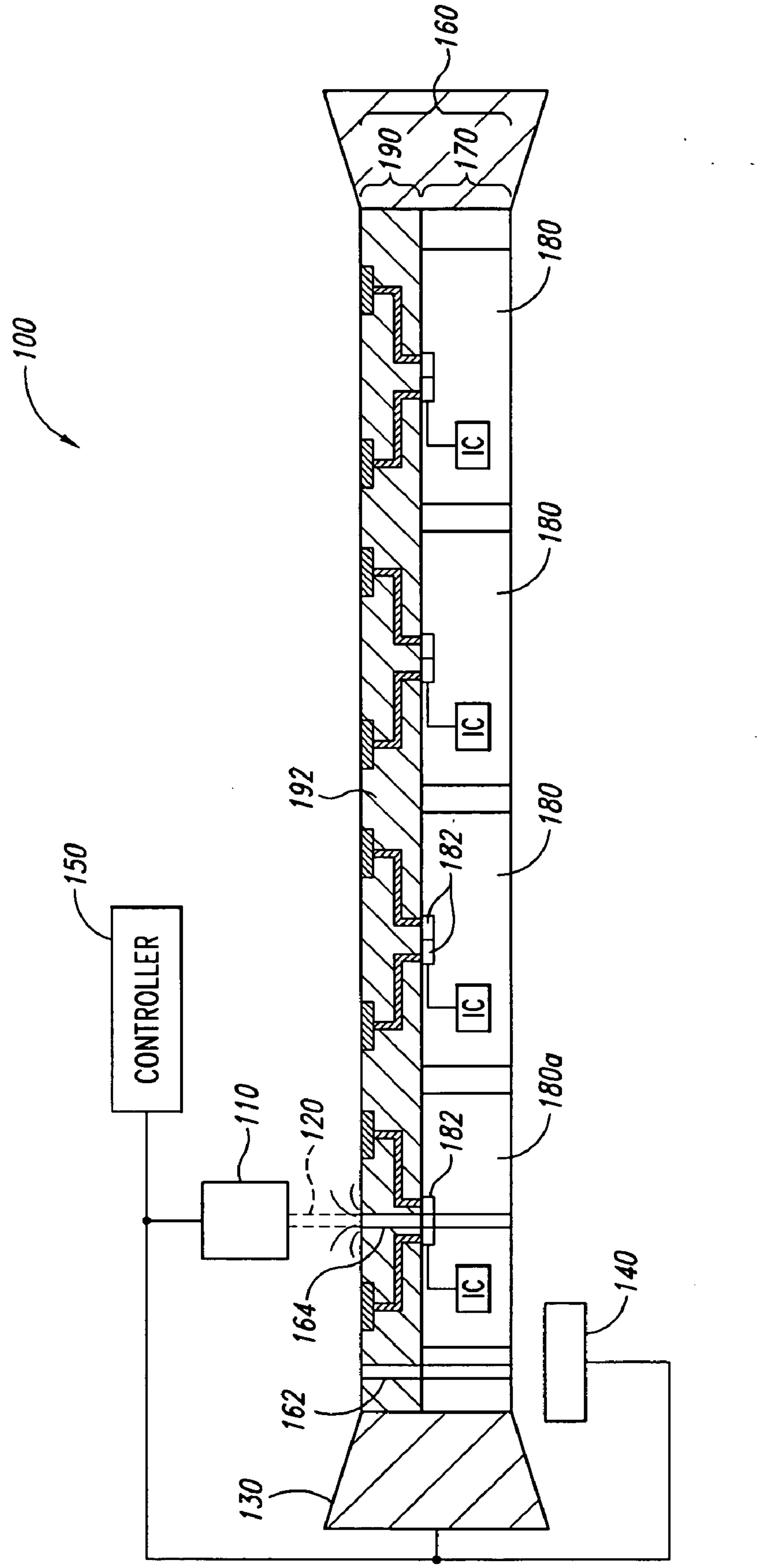



*Fig. 3*


100
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190
170
180
180
180
180a
182
182
192
IC
IC
IC
IC
150
CONTROLLER
110
120
164
162
130
140

*Fig. 4*

# SYSTEMS AND METHODS FOR FORMING APERTURES IN MICROFEATURE WORKPIECES

## TECHNICAL FIELD

**[0001]** The present invention is related to systems and methods for forming apertures in microfeature workpieces. More particularly, the invention is directed to systems and methods for forming apertures with laser beams.

## BACKGROUND

**[0002]** Microelectronic devices are used in cell phones, pagers, personal digital assistants, computers, and many other products. A die-level packaged microelectronic device can include a microelectronic die, an interposer substrate or lead frame attached to the die, and a molded casing around the die. The microelectronic die generally has an integrated circuit and a plurality of bond-pads coupled to the integrated circuit. The bond-pads are coupled to terminals on the interposer substrate or lead frame. The interposer substrate can also include ball-pads coupled to the terminals by conductive traces in a dielectric material. An array of solder balls is configured so that each solder ball contacts a corresponding ball-pad to define a "ball-grid" array. Packaged microelectronic devices with ball-grid arrays are generally higher grade packages that have lower profiles and higher pin counts than conventional chip packages that use a lead frame.

**[0003]** Die-level packaged microelectronic devices are typically made by (a) forming a plurality of dies on a semiconductor wafer, (b) cutting the wafer to singulate the dies, (c) attaching individual dies to an individual interposer substrate, (d) wire-bonding the bond-pads to the terminals of the interposer substrate, and (e) encapsulating the dies with a molding compound. Mounting individual dies to individual interposer substrates is time consuming and expensive. Also, as the demand for higher pin counts and smaller packages increases, it becomes more difficult to (a) form robust wire-bonds that can withstand the forces involved in molding processes and (b) accurately form other components of die-level packaged devices. Therefore, packaging processes have become a significant factor in producing semiconductor and other microelectronic devices.

**[0004]** Another process for packaging microelectronic devices is wafer-level packaging. In wafer-level packaging, a plurality of microelectronic dies are formed on a wafer and a redistribution layer is formed over the dies. The redistribution layer includes a dielectric layer, a plurality of ball-pad arrays on the dielectric layer, and a plurality of traces coupled to individual ball-pads of the ball-pad arrays. Each ball-pad array is arranged over a corresponding microelectronic die, and the traces couple the ball-pads in each array to corresponding bond-pads on the die. After forming the redistribution layer on the wafer, a stenciling machine deposits discrete blocks of solder paste onto the ball-pads of the redistribution layer. The solder paste is then reflowed to form solder balls or solder bumps on the ball-pads. After forming the solder balls on the ball-pads, the wafer is cut to singulate the dies. Microelectronic devices packaged at the wafer level can have high pin counts in a small area, but they are not as robust as devices packaged at the die level.

**[0005]** In the process of forming and packaging microelectronic devices, numerous holes are formed in the wafer and subsequently filled with material to form conductive lines, bond-pads, interconnects, and other features. One existing method for forming holes in wafers is reactive ion etching (RIE). In RIE, many holes on the wafer can be formed simultaneously. RIE, however, has several drawbacks. For example, RIE may attack features in the wafer that should not be etched, and the RIE process is slow. Typically, RIE processes have removal rates of from approximately 5 $\mu$/min to approximately 50 $\mu$/min. Moreover, RIE requires several additional process steps, such as masking and cleaning.

**[0006]** Another existing method for forming holes in wafers is laser ablation. A conventional laser ablation process includes forming a series of test holes in a test wafer to determine the time required to form various through holes in the test wafer. The test holes are formed by directing the laser beam to selected points on the wafer for different periods of time. The test wafer is subsequently inspected manually to determine the time required to form a through hole in the wafer. The actual time for use in a run of identical wafers is then calculated by adding an overdrill factor to the time required to drill the test holes to ensure that the holes extend through the wafer. A run of identical wafers is then processed based on the data from the test wafer. A typical laser can form more than 10,600 holes through a 750 Å wafer in less than two minutes.

**[0007]** Laser ablation, however, has several drawbacks. For example, the heat from the laser beam creates a heat-affected zone in the wafer in which doped elements can migrate. Moreover, because the wafer thickness is generally non-uniform, the laser may not form a through hole in thick regions of the wafer or the wafer may be overexposed to the laser beam and consequently have a large heat-affected zone in thin regions of the wafer. Accordingly, there exists a need to improve the process of forming through holes or deep blind holes in microfeature workpieces.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0008]** **FIG. 1** is a schematic view of a system for forming an aperture in a microfeature workpiece in accordance with one embodiment of the invention.

**[0009]** **FIG. 2** is a schematic side cross-sectional view of the system of **FIG. 1** with the laser directing a laser beam toward the microfeature workpiece.

**[0010]** **FIG. 3** is a top plan view of the microfeature workpiece without a redistribution layer.

**[0011]** **FIG. 4** is a schematic side cross-sectional view of the system of **FIG. 1** with the laser forming a production aperture in the microfeature workpiece.

## DETAILED DESCRIPTION

**[0012]** A. Overview

**[0013]** The present invention is directed toward systems and methods for forming apertures in microfeature workpieces. The term "microfeature workpiece" is used throughout to include substrates in or on which microelectronic devices, micromechanical devices, data storage elements, and other features are fabricated. For example, microfeature workpieces can be semiconductor wafers, glass substrates, insulated substrates, or many other types of substrates.

Several specific details of the invention are set forth in the following description and in **FIGS. 1-4** to provide a thorough understanding of certain embodiments of the invention. One skilled in the art, however, will understand that the present invention may have additional embodiments, or that other embodiments of the invention may be practiced without several of the specific features explained in the following description.

[**0014**] Several aspects of the invention are directed to methods for forming apertures in microfeature workpieces. In one embodiment, a method includes directing a laser beam toward a microfeature workpiece to form an aperture and sensing the laser beam pass through the microfeature workpiece in real time. In one aspect of this embodiment, the method further includes determining a number of pulses of the laser beam and/or an elapsed time to form the aperture and controlling the laser beam based on the determined number of pulses and/or the determined elapsed time to form a second aperture in the microfeature workpiece. In another aspect of this embodiment, an electromagnetic radiation sensor senses the laser beam. The method can further include positioning the microfeature workpiece between a laser and an electromagnetic radiation sensor before directing the laser beam.

[**0015**] In another embodiment, a method includes ablating a microfeature workpiece by directing pulses of a laser beam to form a test aperture in the microfeature workpiece and automatically determining a number of pulses of the laser beam and/or an elapsed time to form the test aperture. The method further includes automatically controlling the laser beam based on the determined number of pulses and/or the determined elapsed time to form a plurality of production apertures in the microfeature workpiece. In one aspect of this embodiment, automatically controlling the laser beam includes directing the laser beam toward the microfeature workpiece for an adjusted number of pulses and/or an adjusted time to form at least one of the production apertures. The adjusted number of pulses can be different from the determined number of pulses, and the adjusted time can be different from the determined elapsed time. For example, if the production aperture is a blind hole, the adjusted number of pulses can be less than the determined number of pulses and/or the adjusted time can be less than the determined elapsed time by an underdrill factor. Alternatively, if the production aperture is a through hole, the adjusted number of pulses can be greater than the determined number of pulses and/or the adjusted time can be greater than the determined elapsed time by an overdrill factor.

[**0016**] Another aspect of the invention is directed to systems for forming apertures in microfeature workpieces. In one embodiment, a system includes a laser configured to produce a laser beam along a beam path, an electromagnetic radiation sensor positioned along the beam path to sense the laser beam, and a workpiece carrier configured to selectively position a microfeature workpiece in the beam path before the electromagnetic radiation sensor to form an aperture in the microfeature workpiece. The system can further include a controller operably coupled to the laser, the electromagnetic radiation sensor, and the workpiece carrier. The controller can have a computer-readable medium containing instructions to perform any one of the above-described methods.

[**0017**] B. Embodiments of Systems for Forming Apertures in Microfeature Workpieces

[**0018**] **FIG. 1** is a schematic view of a system **100** for forming an aperture in a microfeature workpiece **160** in accordance with one embodiment of the invention. In the illustrated embodiment, the system **100** includes a laser **110**, a workpiece carrier **130**, a sensor **140**, and a controller **150**. The laser **110**, the workpiece carrier **130**, and the sensor **140** are operatively coupled to the controller **150**. The laser **110** selectively generates a laser beam **120** to form apertures in the microfeature workpiece **160** by ablating the workpiece material. The system **100** can also include a metrology tool **102** (shown schematically in broken lines) to determine the thickness of portions of the microfeature workpiece **160**.

[**0019**] The laser **110** can include an illumination source **112**, a galvo mirror **114**, and a telecentric lens **116**. In one embodiment, the laser **110** can be a solid-state laser that produces a laser beam with a wavelength of approximately 355 nm and a pulse frequency of approximately 10 kHz to approximately 75 kHz. In one aspect of this embodiment, the power generated by the laser **110** can be approximately 7 watts, and the laser beam can have a pulse frequency of approximately 20 kHz to approximately 30 kHz. In additional embodiments, other lasers may be used with different configurations.

[**0020**] The workpiece carrier **130** is configured to hold and properly position the microfeature workpiece **160**. More specifically, the workpiece carrier **130** positions the microfeature workpiece **160** relative to the laser **110** so that the laser beam **120** forms an aperture at a desired location on the workpiece **160**. The workpiece carrier **130** can be moveable along three orthogonal axes, such as a first lateral axis (X direction), a second lateral axis (Y direction), and/or an elevation axis (Z direction). In other embodiments, the workpiece carrier **130** may not be movable along all three orthogonal axes, and/or the laser **110** may be movable.

[**0021**] In the illustrated embodiment, the workpiece carrier **130** engages and supports the perimeter of the microfeature workpiece **160**. More specifically, the microfeature workpiece **160** has a first surface **166**, a second surface **168** opposite the first surface **166**, and a perimeter edge **169**. The workpiece carrier **130** can have an edge-grip end effector configured to engage the perimeter edge **169** of the microfeature workpiece **160** without contacting the first and second surfaces **166** and **168**. In other embodiments, the workpiece carrier **130** may contact a portion of the first and/or second surfaces **166** and/or **168** of the microfeature workpiece **160**. For example, the workpiece carrier **130** may engage the perimeter edge **169** and a perimeter region of the second surface **168** to carry the microfeature workpiece **160** without obscuring the laser beam **120** from passing through the desired points on the workpiece **160**.

[**0022**] The sensor **140** senses electromagnetic radiation to determine when the aperture has been formed in the microfeature workpiece **160**. More specifically, the sensor **140** detects when the laser beam **120** passes through the microfeature workpiece **160** and sends a signal to the controller **150** indicating that an aperture has been formed. The sensor **140** can be an electromagnetic radiation sensor, such as a photodiode, selected to respond to the wavelength of the laser beam **120**. The laser **110** and the sensor **140** can be arranged so that the workpiece carrier **130** can position the microfeature workpiece **160** between the laser **110** and the sensor **140**. The sensor **140** can be movable relative to the microfeature workpiece **160** to be aligned with the laser beam **120**. For example, the sensor **140** can be moveable along the three orthogonal axes X, Y and Z. In other embodiments, the sensor **140** can be fixed relative to the laser **110** such that they can move together.

[**0023**] **FIG. 2** is a schematic side cross-sectional view of the system **100** with the laser beam **120** directed toward the microfeature workpiece **160** (shown enlarged for illustrative purposes). In the illustrated embodiment, the microfeature workpiece **160** includes a substrate **170** having a plurality of microelectronic dies **180** and a redistribution layer **190** formed on the substrate **170**. Each microelectronic die **180** can have an integrated circuit **184** (shown schematically) and a plurality of bond-pads **182** coupled to the integrated circuit **184**. The redistribution layer **190** includes a dielectric layer **192** and a plurality of ball-pads **196** in the dielectric layer **192**. The ball-pads **196** are arranged in ball-pad arrays relative to the microelectronic dies **180** such that each die **180** has a corresponding array of ball-pads **196**. The redistribution layer **190** also includes a plurality of conductive lines **194** in or on the dielectric layer **192** to couple the bond-pads **182** of the microelectronic dies **180** to corresponding ball-pads **196** in the ball-pad arrays. In other embodiments, the microfeature workpiece **160** may not include microelectronic dies **180** and/or the redistribution layer **190**. For example, the microfeature workpiece **160** can be a circuit board or other substrate.

[**0024**] C. Embodiments of Methods for Forming Apertures in Microfeature Workpieces

[**0025**] **FIG. 2** also illustrates an embodiment of a method for forming apertures in microfeature workpieces. The controller **150** generally contains computer operable instructions that generate signals for controlling the laser **110**, the workpiece carrier **130**, and the sensor **140** to form a single aperture or a plurality of apertures in the microfeature workpiece **160**. In one embodiment, the controller **150** controls the laser **110** to form a test aperture **162** in the microfeature workpiece **160** and determines the number of pulses of the laser beam **120** and/or the time required to form the test aperture **162**. In this embodiment, the laser **110** directs the laser beam **120** toward the first surface **166** of the microfeature workpiece **160** at a test location to form the test aperture **162**. The laser beam **120** locally ablates the workpiece material and produces a vapor **161** that can be convected away from the region adjacent to the test aperture **162**. The laser **110** directs the laser beam **120** toward the microfeature workpiece **160** until the sensor **140** senses the laser beam **120**. The sensor **140** detects the laser beam **120** when the test aperture **162** extends through the microfeature workpiece **160**. When the sensor **140** detects the laser beam **120**, it sends a signal to the controller **150** which in turn sends a control signal to the laser **110** to stop generating the laser beam **120**. The controller **150** stores the elapsed time and/or the number of pulses of the laser beam **120** required to form the test aperture **162**.

[**0026**] The test aperture **162** can be formed in a noncritical portion of the microfeature workpiece **160**. For example, **FIG. 3** is a top plan view of the microfeature workpiece **160** without the redistribution layer **190**. Referring to **FIGS. 2 and 3**, test apertures **162** can be formed in a perimeter region of the microfeature workpiece **160** proximate to the perimeter edge **169** and/or along the singulation lines A-A (**FIG. 3**) where the workpiece **160** is cut to separate the packaged microelectronic dies **180**. Accordingly, in the illustrated embodiment, the portion of the microfeature workpiece **160** that includes the test aperture(s) **162** is not used for circuitry or other components of the dies **180** or workpiece **160**. A plurality of test apertures are generally formed in a microfeature workpiece, but in many applications only a single test aperture may be formed in a workpiece. In other embodiments, not every workpiece in a run of workpieces needs to include a test aperture.

[**0027**] **FIG. 4** is a schematic side cross-sectional view of the system **100** with the laser **110** forming a production aperture **164** in the microfeature workpiece **160**. Based on the data gathered from forming the test aperture **162**, the controller **150** and/or an operator develops a recipe to form the production aperture **164**. The controller **150** can use the number of pulses of the laser beam **120** and/or the elapsed time to form the test aperture **162** in forming the production aperture **164**. For example, the controller **150** can calculate an expected number of pulses of the laser beam **120** required to form the production aperture **164** based on the stored number of pulses required to form the test aperture **162**. Additionally, the controller **150** can calculate an expected time required to form the production aperture **164** based on the stored elapsed time to form the test aperture **162**.

[**0028**] In one embodiment, the expected number of pulses of the laser beam **120** and the expected time required to form the production aperture **164** are determined by multiplying the stored number of pulses and the stored elapsed time to form the test aperture **162** by a correction factor. The correction factor can adjust for differences in the thickness across the microfeature workpiece **160**. For example, the metrology tool **102** (**FIG. 1**) can measure the thickness of the workpiece **160** at the test aperture **162** location and at the production aperture **164** location. The correction factor can account for the difference in the thickness of the workpiece **160** at the two locations. The correction factor can also adjust for differences in the workpiece material at the test aperture **162** location and at the production aperture **164** location. For example, in the illustrated embodiment, the test aperture **162** is formed through material adjacent to a first die **180***a*, and the production aperture **164** is formed through the first die **180***a* including the bond-pads **182**. The correction factor can also increase the reliability of the process. For example, if the production aperture is a through hole, the correction factor can include an overdrill factor to increase the likelihood that the production aperture is formed completely through the microfeature workpiece.

[**0029**] After the controller **150** calculates the expected number of pulses of the laser beam **120** and/or the expected time required to form the production aperture **164**, the system **100** forms the production aperture **164** in the microfeature workpiece **160**. The workpiece carrier **130** properly positions the microfeature workpiece **160** relative to the laser **110**, and then the laser **110** directs the laser beam **120** toward the workpiece **160** for the expected number of pulses of the laser beam **120** and/or for the expected time required to form the production aperture **164**. In this embodiment, the sensor **140** does not need to be aligned with the production aperture **164** because the controller **150** controls the laser **110** based on the data gathered from forming the test aperture **162**. However, in other embodiments, the system **100** may form the production aperture **164** without first forming the test aperture **162**. In these embodiments, the sensor **140** can be aligned with the production aperture **164** to signal the controller **150** when the production aperture **164** has been formed, as described above with reference to **FIG. 2**. In any of these embodiments, the system **100** can form a plurality of production apertures in the microfeature workpiece **160**.

[**0030**] In additional embodiments, the system **100** can also form blind apertures that do not extend completely through the microfeature workpiece **160**. In these embodiments, the controller **150** can calculate the expected number of pulses and/or the expected time required to form the blind production aperture based on the data gathered from forming the test aperture **162** in a process similar to that described above. More specifically, the expected number of pulses of the laser beam **120** and the expected time required to form the blind production aperture can be determined by multiplying the stored number of pulses and the stored elapsed time to form the test aperture **162**, respectively, by a correction factor. The correction factor in this application can adjust for differences in the workpiece material and thickness as described above to underdrill the workpiece for forming a blind production aperture. The correction factor also adjusts for the difference between the depth of the test aperture **162** and the desired depth of the blind production aperture. In other embodiments, the correction factor can also adjust for other factors.

[**0031**] One feature of the system **100** of the illustrated embodiment is that it provides good control of the exposure time that the microfeature workpiece **160** is subject to the laser beam **120**. The laser beam **120** can be shut off after an aperture is formed because either the sensor **140** provides real-time feedback to the controller **150** or the controller **150** is able to accurately predict when the aperture has been formed. An advantage of this feature is that the heat-affected zone in the microfeature workpiece **160** is mitigated because the laser beam **120** is shut off in a timely manner. In prior art systems, the laser beam continues to pulse even after an aperture is formed and consequently increases the size of the heat-affected zone in the workpiece; such sizable heat-affected zones are detrimental to microelectronic devices because doped elements can migrate within the zone. Another advantage of the illustrated system **100** is that it enables high throughput using lasers and prolongs the life of the laser **110** because the number of pulses of the laser beam **120** required to form the apertures is reduced.

[**0032**] Another feature of the system **100** of the illustrated embodiment is that the system **100** consistently forms accurate apertures in the microfeature workpiece **160**. An advantage of this feature is that apertures are consistently formed with a desired depth. The ability of the system **100** to more precisely determine the number of pulses of the laser beam **120** and/or the elapsed time to form a through hole allows the system **100** to avoid overdrilling and underdrilling.

[**0033**] From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration but that various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.

I/We claim:

**1**. A method for forming an aperture in a microfeature workpiece, the method comprising:

directing a laser beam toward the microfeature workpiece to form the aperture; and

sensing the laser beam pass through the microfeature workpiece in real time.

**2**. The method of claim 1, further comprising determining a number of pulses of the laser beam and/or an elapsed time to form the aperture.

**3**. The method of claim 1 wherein the aperture is a first aperture, and wherein the method further comprises:

determining a number of pulses of the laser beam and/or an elapsed time to form the first aperture; and

controlling the laser beam based on the determined number of pulses and/or the determined elapsed time to form a second aperture at another location in the microfeature workpiece.

**4**. The method of claim 1, further comprising positioning the microfeature workpiece between a laser and an electromagnetic radiation sensor before directing the laser beam, wherein directing the laser beam occurs while the microfeature workpiece is positioned between the laser and the electromagnetic radiation sensor.

**5**. The method of claim 1 wherein sensing the laser beam comprises sensing the laser beam with an electromagnetic radiation sensor.

**6**. The method of claim 1 wherein:

the microfeature workpiece comprises a first die and a second die adjacent to the first die; and

directing the laser beam comprises forming the aperture between the first and second dies.

**7**. The method of claim 1 wherein:

the microfeature workpiece comprises a perimeter region; and

directing the laser beam comprises forming the aperture in the perimeter region of the microfeature workpiece.

**8**. The method of claim 1 wherein directing the laser beam comprises forming a through hole in the microfeature workpiece.

**9**. The method of claim 1 wherein:

the microfeature workpiece includes a first surface and a second surface opposite the first surface; and

the method further comprises supporting the microfeature workpiece with a workpiece carrier so that a center region of the first surface and a center region of the second surface do not contact the workpiece carrier while directing the laser beam.

**10**. The method of claim 1 wherein the aperture is a first aperture, wherein the microfeature workpiece comprises a first die and a second die adjacent to the first die, wherein directing the laser beam comprises forming the first aperture between the first and second dies, and wherein the method further comprises:

determining a number of pulses of the laser beam and/or an elapsed time to form the first aperture; and controlling the laser beam based on the determined number of pulses and/or the determined elapsed time to form a second aperture at another location in the microfeature workpiece.

**11**. The method of claim 1 wherein the aperture is a first aperture, and wherein the method further comprises:

determining a first thickness of the microfeature workpiece at a first location, the first location being the location of the first aperture;

determining a second thickness of the microfeature workpiece at a second location different than the first location; and

controlling the laser beam based on the difference between the first thickness and the second thickness to form a second aperture at the second location.

**12**. A method for forming a plurality of production apertures in a microfeature workpiece, the method comprising:

ablating the microfeature workpiece by directing pulses of a laser beam to form a test aperture in the microfeature workpiece;

automatically determining a number of pulses of the laser beam and/or an elapsed time to form the test aperture; and

automatically controlling the laser beam based on the determined number of pulses and/or the determined elapsed time to form a plurality of production apertures in the microfeature workpiece.

**13**. The method of claim 12 wherein automatically determining the number of pulses and/or the elapsed time comprises sensing the laser beam pass through the microfeature workpiece in real time.

**14**. The method of claim 12 wherein ablating the microfeature workpiece comprises forming a through hole.

**15**. The method of claim 12 wherein automatically controlling the laser beam comprises:

selecting an adjusted number of pulses by changing the determined number of pulses according to a correction factor; and

directing the laser beam toward the microfeature workpiece for the adjusted number of pulses to form at least one of the production apertures.

**16**. The method of claim 12 wherein automatically controlling the laser beam comprises:

selecting an adjusted time by changing the determined elapsed time according to a correction factor; and

directing the laser beam toward the microfeature workpiece for the adjusted time to form at least one of the production apertures.

**17**. The method of claim 12 wherein:

the production apertures comprise a plurality of blind holes; and

automatically controlling the laser beam comprises controlling the laser beam based on a selected depth of the blind holes.

**18**. The method of claim 12, further comprising positioning the microfeature workpiece between a laser and an electromagnetic radiation sensor before directing the laser beam, wherein ablating the microfeature workpiece occurs while the microfeature workpiece is positioned between the laser and the electromagnetic radiation sensor.

**19**. The method of claim 12 wherein automatically determining the number of pulses and/or the elapsed time comprises sensing the laser beam with an electromagnetic radiation sensor.

**20**. The method of claim 12 wherein:

the microfeature workpiece comprises a first die and a second die adjacent to the first die; and

ablating the microfeature workpiece comprises forming the test aperture between the first and second dies.

**21**. The method of claim 12 wherein:

the microfeature workpiece comprises a perimeter region; and

ablating the microfeature workpiece comprises forming the test aperture in the perimeter region of the microfeature workpiece.

**22**. The method of claim 12 wherein:

the microfeature workpiece includes a first surface and a second surface opposite the first surface; and

the method further comprises supporting the microfeature workpiece with a workpiece carrier so that a center region of the first surface and a center region of the second surface do not contact the workpiece carrier while directing the laser beam.

**23**. The method of claim 12, further comprising:

determining a first thickness of the microfeature workpiece at a first location, the first location being the location of the first aperture; and

determining a second thickness of the microfeature workpiece at a second location different than the first location, the second location being the location of one of the plurality of production apertures;

wherein automatically controlling the laser beam comprises controlling the laser beam based on the difference between the first thickness and second thickness.

**24**. A method for forming a plurality of apertures in a microfeature workpiece, the method comprising:

impinging a laser beam upon the microfeature workpiece to form a first aperture;

sensing the laser beam pass through the microfeature workpiece with a sensor; and

forming a second aperture by controlling the laser beam based on a determined number of pulses of the laser beam to form the first aperture and/or a determined elapsed time to form the first aperture.

**25**. The method of claim 24 wherein forming the second aperture comprises automatically determining the number of pulses of the laser beam and/or the elapsed time to form the first aperture.

**26**. The method of claim 24 wherein forming the second aperture comprises:

selecting an adjusted number of pulses by changing the determined number of pulses according to a correction factor; and directing the laser beam toward the microfeature workpiece for the adjusted number of pulses to form the second aperture.

**27**. The method of claim 24 wherein forming the second aperture comprises:

selecting an adjusted time by changing the determined elapsed time according to a correction factor; and

directing the laser beam toward the microfeature workpiece for the adjusted time to form the second aperture.

**28**. The method of claim 24 wherein:

the second aperture comprises a blind hole; and

forming the second aperture comprises controlling the laser beam based on a selected depth of the blind hole.

**29**. The method of claim 24 wherein:

the microfeature workpiece includes a first surface and a second surface opposite the first surface; and

the method further comprises supporting the microfeature workpiece with a workpiece carrier so that a center region of the first surface and a center region of the second surface do not contact the workpiece carrier while directing the laser beam.

**30**. A method for forming an aperture in a microfeature workpiece, the method comprising:

positioning the microfeature workpiece between a laser and an electromagnetic radiation sensor;

directing a laser beam from the laser toward the microfeature workpiece to form the aperture in the microfeature workpiece while the microfeature workpiece is positioned between the laser and the electromagnetic radiation sensor; and

sensing the laser beam pass through the microfeature workpiece with the electromagnetic radiation sensor.

**31**. The method of claim 30, further comprising determining a number of pulses of the laser beam and/or an elapsed time to form the aperture.

**32**. The method of claim 30 wherein the aperture is a test aperture, and wherein the method further comprises:

determining a number of pulses of the laser beam and/or an elapsed time to form the test aperture; and

controlling the laser beam based on the determined number of pulses and/or the determined elapsed time to form a plurality of production apertures in the microfeature workpiece.

**33**. The method of claim 30 wherein:

the microfeature workpiece includes a first surface and a second surface opposite the first surface; and

the method further comprises supporting the microfeature workpiece with a workpiece carrier so that a center region of the first surface and a center region of the second surface do not contact the workpiece carrier while directing the laser beam.

**34**. A system for forming an aperture in a microfeature workpiece, the system comprising:

a laser configured to produce a laser beam along a beam path;

an electromagnetic radiation sensor positioned along the beam path to sense the laser beam; and

a workpiece carrier configured to selectively position the microfeature workpiece in the beam path before the electromagnetic radiation sensor to form the aperture in the microfeature workpiece.

**35**. The system of claim 34 wherein:

the microfeature workpiece includes a first surface and a second surface opposite the first surface; and

the workpiece carrier is configured to carry the microfeature workpiece without contacting a center region of the first surface and a center region of the second surface of the microfeature workpiece.

**36**. The system of claim 34 wherein the workpiece carrier is configured to engage a perimeter region of the microfeature workpiece to support the workpiece.

**37**. The system of claim 34 wherein the workpiece carrier does not obscure the beam path.

**38**. A system for forming an aperture in a microfeature workpiece, the system comprising:

a laser configured to produce a laser beam along a beam path;

an electromagnetic radiation sensor positioned along the beam path to sense the laser beam;

a workpiece carrier configured to selectively position the microfeature workpiece in the beam path before the electromagnetic radiation sensor; and

a controller operably coupled to the laser, the electromagnetic radiation sensor, and the workpiece carrier, the controller having a computer-readable medium containing instructions to direct the laser beam toward the microfeature workpiece to form the aperture, and sense the laser beam pass through the microfeature workpiece in real time.

**39**. The system of claim 38 wherein:

the microfeature workpiece includes a first surface and a second surface opposite the first surface; and

the workpiece carrier is configured to carry the microfeature workpiece without contacting a center region of the first surface and a center region of the second surface of the microfeature workpiece.

**40**. The system of claim 38 wherein the workpiece carrier is configured to engage a perimeter region of the microfeature workpiece to support the workpiece.

**41**. The system of claim 38 wherein the computer-readable medium contains further instructions to determine a number of pulses of the laser beam and/or an elapsed time to form the aperture.

**42**. The system of claim 38 wherein the aperture is a test aperture, and wherein the computer-readable medium contains further instructions to determine a number of pulses of the laser beam and/or an elapsed time to form the test aperture, and control the laser beam based on the determined number of pulses and/or the determined elapsed time to form a plurality of production apertures in the microfeature workpiece.

**43**. A system for forming a plurality of production apertures in a microfeature workpiece, the system comprising:

a laser configured to produce a laser beam along a beam path;

an electromagnetic radiation sensor positioned along the beam path to sense the laser beam;

a workpiece carrier configured to selectively position the microfeature workpiece in the beam path before the electromagnetic radiation sensor; and

a controller operably coupled to the laser, the electromagnetic radiation sensor, and the workpiece carrier, the controller having a computer-readable medium containing instructions to perform a method comprising—

ablating the microfeature workpiece by directing pulses of a laser beam to form a test aperture in the microfeature workpiece;

determining a number of pulses of the laser beam and/or an elapsed time to form the test aperture; and

controlling the laser beam based on the determined number of pulses and/or the determined elapsed time to form the plurality of production apertures in the microfeature workpiece.

**44**. The system of claim 43 wherein:

the microfeature workpiece includes a first surface and a second surface opposite the first surface; and

the workpiece carrier is configured to carry the microfeature workpiece without contacting a center region of the first surface and a center region of the second surface of the microfeature workpiece.

**45**. The system of claim 43 wherein the workpiece carrier is configured to engage a perimeter region of the microfeature workpiece to support the workpiece.

**46**. A system for forming an aperture in a microfeature workpiece, the system comprising:

a laser configured to produce a laser beam along a beam path;

an electromagnetic radiation sensor positioned along the beam path to sense the laser beam;

a workpiece carrier; and

a controller operably coupled to the laser, the electromagnetic radiation sensor, and the workpiece carrier, the controller having a computer-readable medium containing instructions to perform a method comprising—

positioning the microfeature workpiece in the beam path with the workpiece carrier;

directing the laser beam toward the microfeature workpiece to form the aperture in the microfeature workpiece; and

sensing the laser beam pass through the microfeature workpiece with the electromagnetic radiation sensor.

**47**. The system of claim 46 wherein:

the microfeature workpiece includes a first surface and a second surface opposite the first surface; and

the workpiece carrier is configured to carry the microfeature workpiece without contacting a center region of the first surface and a center region of the second surface of the microfeature workpiece.

**48**. The system of claim 46 wherein the workpiece carrier is configured to engage a perimeter region of the microfeature workpiece to support the workpiece.

**49**. The system of claim 46 wherein the computer-readable medium contains instructions to perform the method further comprising determining a number of pulses of the laser beam and/or an elapsed time to form the aperture.

**50**. The system of claim 46 wherein the aperture is a test aperture, and wherein the computer-readable medium contains instructions to perform the method further comprising:

determining a number of pulses of the laser beam and/or an elapsed time to form the test aperture; and

controlling the laser beam based on the determined number of pulses and/or the determined elapsed time to form a plurality of production apertures in the microfeature workpiece.

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