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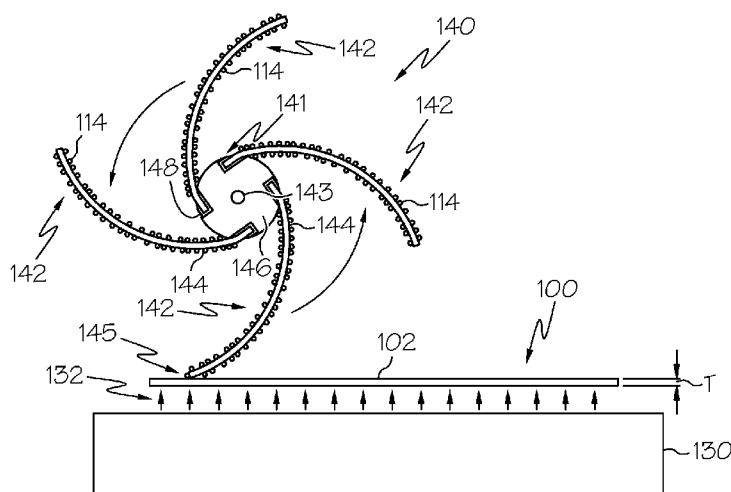


FIG. 4

(57) Abstract: Methods for mechanically forming crack initiation defects in thin glass substrates are described. In one embodiment, a method for separating a glass substrate into a plurality of substrates includes directing a flow of carrier fluid having abrasive material entrained therein onto the surface of the glass substrate to form an initiation defect in the surface of the glass substrate. The initiation defect does not extend through a thickness of the glass substrate. Thereafter, the initiation defect is heated with a laser source and subsequently cooled with a cooling fluid such that a crack initiates from the initiation defect. The crack extends through the thickness of the glass substrate and propagates across the glass substrate such that the glass substrate is separated into a plurality of substrates.



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METHODS FOR MECHANICALLY FORMING CRACK INITIATION DEFECTS IN THIN GLASS SUBSTRATES

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority under 35 U.S.C. § 119 of U.S. Provisional Application Serial No. 61/475,409 filed on April 14, 2011, the content of which is hereby incorporated by reference.

BACKGROUND

Field

[0002] The present specification generally relates to laser separation of thin glass substrates and, more specifically, to methods for mechanically forming crack initiation defects for use in separating thin glass substrates using laser separation techniques.

Technical Background

[0003] Glass substrates such as those utilized in flat panel displays and other electronic devices are generally formed from a large glass substrate which is segmented into a plurality of smaller glass substrates that are incorporated into individual devices. A variety of separation techniques may be used to separate the large glass substrate into a plurality of smaller glass substrates including laser cutting techniques. In order to separate a glass substrate by laser cutting, an initiation defect or vent crack is first formed in the glass substrate using a scoring wheel. To form the initiation defect the scoring wheel is brought into contact with the glass substrate and a force which is normal to the surface of the glass substrate is then applied to the scoring wheel, pressing the scoring wheel into the surface of the glass substrate as the scoring wheel is traversed over the surface a short distance. The force exerted on the scoring wheel creates an initiation defect that extends partially through the thickness of the glass substrate. Thereafter, the initiation defect is heated and rapidly cooled to propagate a through vent from the initiation defect to separate the glass substrate.

[0004] However, as the thickness of glass substrates decreases, forming initiation defects in the surface of the glass substrate as described above generally results in the formation of a series of cracks in the surface of the glass substrate rather than a localized defect due to the large magnitude of the normal force necessary to form the defect with the scoring wheel. Even in situations where only a single crack is formed, this single crack generally extends through the thickness of the glass substrate. Such cracks can be easily and uncontrollably propagated across the width of the glass substrate, often resulting in the catastrophic failure of the glass substrate prior to laser separation.

[0005] Accordingly, a need exists for alternative methods and apparatuses for creating crack initiation defects in thin glass substrates to facilitate separating the thin glass substrates into a plurality of individual glass substrates by laser separation.

SUMMARY

[0006] The embodiments described herein relate to methods for forming crack initiation defects in the surface of thin glass substrates without puncturing the thin glass substrates or initiating uncontrolled crack propagation in the thin glass substrates and thereby facilitate separating the thin glass substrates into a plurality of individual substrates. Also disclosed are apparatuses for performing the methods.

[0007] According to one embodiment, a method for separating a glass substrate into a plurality of substrates without puncturing the thin glass substrate or initiating uncontrolled crack propagation in the glass substrate includes providing a glass substrate and directing a flow of carrier fluid having abrasive material entrained therein onto a surface of the glass substrate to form the initiation defect in the surface of the glass substrate. Thereafter, the initiation defect may be heated with a laser source and subsequently cooled with a cooling fluid such that a crack initiates from the initiation defect. The crack extends through a thickness of the glass substrate and propagates across the glass substrate to separate the glass substrate into the plurality of substrates.

[0008] In another embodiment, a method for separating a glass substrate into a plurality of individual substrates without puncturing the thin glass substrate or initiating uncontrolled crack propagation in the glass substrate includes providing a glass substrate and contacting a surface of the glass substrate with an abrading fiber comprising an abrasive material.

Thereafter, the abrading fiber is traversed over the surface of the glass substrate such that the abrasive material of the abrading fiber forms an initiation defect in the surface of the glass substrate.

[0009] In another embodiment, a method for separating a glass substrate into a plurality of individual substrates without puncturing the thin glass substrate or initiating uncontrolled crack propagation in the glass substrate includes providing a glass substrate and compliantly supporting the glass substrate proximate a rotating abrasive wheel. A surface of the glass substrate is then contacted with the rotating abrasive wheel such that a primary component of a force exerted by the rotating abrasive wheel against the glass substrate is substantially parallel to the surface of the glass substrate to minimize flexure of the glass substrate, wherein the abrasive wheel abrades the initiation defect in the surface of the glass substrate.

[0010] Additional features and advantages of the invention will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the embodiments described herein, including the detailed description which follows, the claims, as well as the appended drawings.

[0011] It is to be understood that both the foregoing general description and the following detailed description describe various embodiments and are intended to provide an overview or framework for understanding the nature and character of the claimed subject matter. The accompanying drawings are included to provide a further understanding of the various embodiments, and are incorporated into and constitute a part of this specification. The drawings illustrate the various embodiments described herein, and together with the description serve to explain the principles and operations of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 schematically depicts a method for forming a crack initiation defect in a thin glass substrate with abrasive material entrained in a carrier fluid, according to one or more embodiments shown and described herein;

[0013] FIG. 2 schematically depicts a plurality of crack initiation defects formed in a surface of a glass substrate utilizing the method depicted in FIG. 1;

[0014] FIG. 3 schematically depicts an enlarged view of the plurality of crack initiation defects of FIG. 2;

[0015] FIG. 4 schematically depicts an abrading apparatus being used to form one or more crack initiation defects in a surface of a thin glass substrate according to another embodiment shown and described herein;

[0016] FIG. 5 schematically depicts an abrading apparatus being used to form one or more crack initiation defects in a surface of a thin glass substrate according to another embodiment shown and described herein;

[0017] FIGS. 6A and 6B schematically depict crack initiation defects formed in a surface of a thin glass substrate with an abrading apparatus according to one or more embodiments shown and described herein;

[0018] FIG. 7 schematically depicts an embodiment of an abrading apparatus for forming crack initiation defects in a thin glass substrate;

[0019] FIG. 8 schematically depicts a plurality of crack initiation defects formed in a surface of a thin glass substrate with the abrading apparatus of FIG. 7;

[0020] FIG. 9 schematically depicts another embodiment of a method for forming a crack initiation defect with an abrading fiber;

[0021] FIG. 10 schematically depicts a method for forming a crack initiation defect in a thin glass substrate with a rotating abrasive wheel according to one or more embodiments shown and described herein;

[0022] FIG. 11 schematically depicts a method for forming a crack initiation defect in a thin glass substrate with a rotating abrasive wheel according to one or more embodiments shown and described herein;

[0023] FIG. 12 schematically depicts a crack initiation defect formed in the surface of the thin glass substrate utilizing the method depicted in FIG. 11; and

[0024] FIGS. 13A and 13B schematically depict a method for laser separating a glass substrate from a crack initiation defect according to one or more embodiments shown and described herein.

DETAILED DESCRIPTION

[0025] Reference will now be made in detail to embodiments of methods for mechanically forming crack initiation defects in thin glass substrates, examples of which are illustrated in the accompanying drawings. Whenever possible, the same reference numerals will be used throughout the drawings to refer to the same or like parts. One embodiment of a method for forming crack initiation defects in the surface of glass substrates is schematically depicted in FIG. 1. The method generally comprises directing abrasive material entrained in a flow of carrier fluid onto a surface of a glass substrate to form a plurality of localized crack initiation defects. Various embodiments of methods and apparatuses for forming crack initiation defects in glass substrates will be described herein with specific reference to the appended drawings.

[0026] Cover glasses for use in electronic devices, such as flat panel displays, smart phones and the like, may be formed from thin glass substrates with thicknesses of 0.2 mm or less. These thin glass substrates are generally formed as a large sheet or ribbon of glass which is subsequently segmented into a plurality of individual glass substrates by laser separation techniques. It has now been determined that conventional techniques for forming crack initiation defects in thin glass substrates to facilitate laser separation may result in uncontrolled separation of the thin glass substrates, puncturing the thin glass substrates or, in worst case scenarios, the catastrophic failure of the thin glass substrates due to the high normal force used to form the crack initiation defects. Thus, forming crack initiation defects in the thin glass substrates can be a source of loss and high cost. Described herein are methods and apparatuses for forming crack initiation defects in glass substrates that mitigate the aforementioned difficulties.

[0027] Referring now to FIG. 1, one method of forming a crack initiation defect in the surface 102 of a thin glass substrate 100 (i.e., a glass substrate having a thickness T which is less than or equal to about 0.2mm) is schematically depicted. The crack initiation defect is formed in the surface of the glass substrate with abrasive material 114 entrained in a flow of carrier fluid 112, such as, for example, compressed air or a similar carrier gas. In alternative embodiments, the flow of carrier fluid 112 may be a liquid, such as water, in which the abrasive material 114 is entrained. In the embodiments described herein, the abrasive material 114 is entrained in a flow of compressed air emitted from a nozzle 110. The flow of carrier fluid 112 with the

entrained abrasive material 114 is directed onto the surface 102 of the glass substrate 100 to abrade an area of the surface thereby creating localized crack initiation defects.

[0028] In the embodiments described herein the abrasive material 114 has a mesh size from about 400 mesh to about 600 mesh in order to form crack initiation defects having a size suitable to propagate a crack therefrom. However, it should be understood that these values for the mesh size of the abrasive material are exemplary and that abrasive materials with larger or smaller mesh sizes may also be utilized to form crack initiation defects in the surface of the glass substrate utilizing this method.

[0029] Various types of abrasive materials may be utilized in the flow of carrier fluid 112 in order to form the crack initiation defects. For example, in one embodiment the abrasive material 114 entrained in the flow of carrier fluid 112 is aluminum oxide. However, it should be understood that other suitable abrasive materials may be used as well including, without limitation, silicon carbide, boron nitride, diamond and similar abrasive materials.

[0030] The flow of carrier fluid 112 with entrained abrasive material 114 is directed onto the surface of the glass substrate 100 with a pressure suitable to cause localized erosion of the surface 102 of the glass substrate 100 without causing excessive damage to the glass substrate (i.e., without creating holes through the thickness of the glass substrate 100). In one embodiment, the flow of carrier fluid 112 with entrained abrasive material 114 is directed onto the surface of the glass substrate at a pressure that is less than or equal to about 60 psi. For example, the flow of carrier fluid 112 with entrained abrasive material 114 may be directed onto the surface 102 of the glass substrate 100 with a pressure greater than or equal to about 30 psi and less than or equal to about 60 psi. Maintaining the pressure of the flow of carrier fluid 112 to less than 60 psi helps to mitigate excessive damage and erosion of the glass substrate 100 which may lead to the formation of through holes or, alternatively, uncontrolled crack propagation. While it is desirable to maintain the pressure of the flow of carrier fluid 112 to less than 60 psi to mitigate excessive damage, it should be understood that pressures less than about 30 psi or greater than about 60 psi may also be used to form crack initiation defects in the glass substrate.

[0031] The nozzle 110 and glass substrate 100 are positioned relative to one another such that the flow of carrier fluid 112 with entrained abrasive material 114 has a contact spot 118

(shown in FIG. 3) with a diameter D of less than 1 inch (25.4 mm), preferably less than or equal to 0.75 inch (19 mm), within which the localized crack initiation defects 116 are formed. Maintaining the contact spot 118 to less than 1 inch (25.4 mm) minimizes the formation of crack initiation defects in undesired areas which could lead to the initiation of uncontrolled separation and mitigates damage to the glass substrate in the so-called "quality areas" of the glass substrate which should remain free from damage. In one embodiment described herein, the contact spot 118 has a diameter D greater than or equal to about 0.25 inch (6.35 mm) and less than or equal to about 0.75 inch (19 mm).

[0032] The glass substrate 100 may be positioned such that the area of the glass substrate opposite the contact spot 118 of the carrier fluid is compliantly supported, such as when the glass substrate 100 is cantilevered beneath the carrier fluid 112. Such an arrangement is shown in FIG. 1 where the glass substrate 100 is positioned on a support 109 such that at least a portion of the glass substrate 100 is cantilevered from the end of the support 109. In this arrangement the glass substrate 100 is compliantly supported such that the glass substrate 100 flexes as the flow of carrier fluid 112 and abrasive material 114 impact the surface 102 of the glass substrate 100 and the depth of the initiation defects caused by the abrasive material are minimized. Accordingly, it should be understood that the phrase "compliantly supported" means that at least a portion of the glass substrate is free to flex or recoil away from the crack initiation mechanism as the crack initiation defects are formed.

[0033] Alternatively, the glass substrate 100 may be compliantly supported on a compliant surface as the flow of carrier fluid 112 with entrained abrasive material 114 is directed onto the surface 102 of the glass substrate 100. For example, the compliant surface may be a foam pad or similar cushion on which the glass substrate 100 is positioned as the flow of carrier fluid 112 is directed onto the surface 102 of the glass substrate 100. In another embodiment, the compliant surface may be an air bearing, such as a Bernoulli chuck or similar air flotation device, on which the glass substrate 100 is positioned in order to cushion the glass substrate 100 as the flow of carrier fluid is directed on to the surface 102 of the glass substrate 100. The compliant surface compliantly supports and cushions the glass substrate 100 and allows the glass substrate 100 to recoil slightly as the flow of carrier fluid 112 and abrasive material 114 impacts the surface 102 of the glass substrate 100 such that the depth of the localized

initiation defects caused by the abrasive material are minimized. Exemplary embodiments of compliant surfaces, specifically air bearings, are schematically depicted in FIGS. 4 and 5 and described in further detail herein.

[0034] Referring now to FIGS. 2 and 3, the flow of carrier fluid 112 with entrained abrasive material 114 may be utilized to form at least one crack initiation defect 116 in a localized area on the surface 102 of the glass substrate 100 which corresponds to the position of the contact spot 118 of the flow of carrier fluid 112. More specifically, the abrasive material 114 entrained in the flow of carrier fluid 112 forms a plurality of crack initiation defects 116 within the contact spot 118 of the flow of carrier fluid 112. The surface density of the crack initiation defects 116 (i.e., the number of crack initiation defects per unit area) may be controlled by the dwell time of the flow of carrier fluid 112 at a specific location on the surface 102 of the glass substrate 100. Accordingly, longer dwell times yield higher crack initiation defect surface densities. For a given contact spot 118, any one of the plurality of crack initiation defects 116 located in the contact spot 118 may be utilized to initiate a separation vent or crack using laser separation techniques, as will be described in more detail herein.

[0035] Referring now to FIG. 4, another embodiment of a method for mechanically forming an initiation defect in a surface 102 of a glass substrate 100 is schematically depicted. As described above, the glass substrate has a thickness T which is less than or equal to 0.2 mm. In this embodiment, the crack initiation defect is formed utilizing an abrading apparatus 140. The abrading apparatus 140 generally comprises a drum member 141 and one or more abrading fibers 142. The drum member 141 is generally cylindrical in shape with a central axis of rotation 143 which generally corresponds to the long-axis of the drum member 141. The one or more abrading fibers 142 (four depicted in FIG. 4) extend from the surface 146 of the drum member 141 such that, as the drum member 141 is rotated about the axis of rotation 143, the abrading fibers 142 are rotated with the drum member 141 about the axis of rotation 143.

[0036] In the embodiments described herein, the abrading fibers 142 are fixed in individual receiving ports 148 formed in the surface 146 of the drum member 141 and secured in their respective receiving ports with an epoxy or another suitable material. The abrading fibers 142 comprise a filament 144 which is coated with an abrasive material 114. In the embodiments

described herein, the filaments 144 have a diameter from about 0.15 mm to about 0.22 mm and are formed from steel wire. However, it should be understood that the filaments can be formed from other materials including, without limitation, polymeric materials, carbon fiber or other metallic materials. Moreover, it should also be understood that the filaments may be formed with diameters which are greater than about 0.22 mm or less than 0.15 mm.

[0037] In the embodiments described herein, the angle α between the glass substrate 100 and the abrading fibers 142 as the abrading fibers 142 initiate contact with the glass substrate 100 is sufficiently small to prevent the fibers from lifting the glass substrate as they contact the glass substrate 100. For example, in one embodiment, the angle α between the abrading fibers 142 and the glass substrate 100 is less than or equal to about 45 degrees. To facilitate the desired angle α between the abrading fibers 142 and the glass substrate 100 upon initial contact, the filaments 144 forming the abrading fibers 142 may be curved, as depicted in FIG. 4. Alternatively or additionally, the abrading fibers 142 may be positioned in the drum member 141 such that the abrading fibers are tangential to the surface of the wheel, as depicted in FIG. 4.

[0038] In the embodiments described herein, the abrasive material applied to the filaments is diamond with a mesh size of greater than or equal to about 600 and less than or equal to about 1000 mesh. However, it should be understood that other abrasive materials may be used to coat the filaments including, without limitation, aluminum oxide, silicon carbide, or boron nitride. It should also be understood that other mesh sizes could also be used.

[0039] The abrading apparatus 140 may be coupled to a motor (not shown), such as a variable speed electric motor, to facilitate rotating the drum member 141 and the abrading fibers 142 about the axis of rotation 143 of the drum member. In the embodiments described herein rotational rates suitable for forming crack initiation defects in a glass substrate with the abrading apparatus 140 include the range from about 60 rpm to about 2000 rpm. However, it should be understood that rates of rotation outside the range from about 60 rpm to about 2000 rpm may also be used.

[0040] Still referring to FIG. 4, in one embodiment, the glass substrate 100 is positioned on a compliant surface 130 as the crack initiation defects are formed in the glass substrate with the abrading apparatus 140. The compliant surface 130 may comprise a foam material, as

described above, or alternatively, the compliant surface 130 may be an air bearing, as depicted in FIG. 4. In this embodiment, the compliant surface 130 (i.e., the air bearing) supports the glass substrate 100 on an air cushion 132 as the abrading apparatus 140 is brought into contact with the glass substrate 100. The air cushion 132 compliantly supports the glass substrate 100 as the abrading fibers 142 contact the surface 102 of the glass substrate 100, cushioning the glass substrate 100 and absorbing excess force applied to the glass substrate 100 thereby preventing catastrophic damage to the glass substrate 100.

[0041] While FIG. 4 depicts one arrangement for compliantly supporting the glass substrate, it should be understood that other arrangements are possible. For example, in an alternative embodiment, the glass substrate 100 may be compliantly supported by positioning the glass substrate on a support such that the end of the glass substrate 100 which is contacted by the abrading fibers is cantilevered from an end of the support, as depicted in FIG. 1. In this arrangement the glass substrate 100 is compliantly supported such that the glass substrate 100 flexes as the abrading fibers 142 impact the surface 102 of the glass substrate 100 such that the depth of the initiation defects caused by the abrading fibers is minimized.

[0042] In order to form a crack initiation defect in the surface 102 of the glass substrate 100, the abrading fibers 142 are brought into contact with the surface 102 of the glass substrate 100 and traversed over the surface by rotating the abrading apparatus 140 such that the abrading fibers 142 are rotated about the axis of rotation 143 of the drum member 141, and, as such, the abrading fibers 142 are rotated about an axis of rotation which is substantially perpendicular (i.e., $90 \text{ degrees} \pm 10 \text{ degrees}$) to the long axis of each abrading fiber. In one embodiment, the abrading apparatus 140 is positioned proximate the surface 102 of the glass substrate 100 such that the axis of rotation 143 of the drum member 141 is spaced apart from the surface 102 of the glass substrate 100 and only the tip portion 145 of each abrading fiber 142 contacts the surface 102 of the glass substrate 100 as the abrading fibers are rotated (i.e., the abrading fiber 142 makes a point contact with the surface 102). The abrasive material located on the tip portion 145 of each abrading fiber 142 abrades a crack initiation defect in the surface 102 of the glass substrate 100 as the abrading apparatus is rotated. Positioning the abrading apparatus 140 such that only the tip portion 145 of each abrading fiber 142 makes a point contact with the surface 102 of the glass substrate 100 minimizes the length of the crack

initiation defect abraded into the surface 102 of the glass substrate 100 and also ensures that the resultant crack initiation defect does not extend through the thickness of the glass substrate 100. One embodiment of a crack initiation defect 116 formed with the abrading apparatus utilizing the aforementioned technique is schematically depicted in FIG. 6A. In this embodiment the crack initiation defect 116 is offset from the edge of the glass substrate by positioning the abrading apparatus 140 relative to the glass substrate such that the tips of the abrading fibers contact the surface 102 of the glass substrate without first contacting the edge of the glass substrate. However, it should be understood that, in other embodiments, the crack initiation defect 116 may extend from the edge of the glass substrate 100, as will be described in further detail herein.

[0043] Referring to FIG. 5, in another embodiment, the rotating abrading apparatus 140, specifically the axis of rotation 143 of the abrading apparatus 140, is spaced apart from the surface 102 of the glass substrate 100 such that the abrading fibers 142 first contact the edge of the substrate and, thereafter, make more than a single point contact (i.e., a line contact) with the surface 102 of the glass substrate 100. More specifically, in this embodiment the rotating abrading apparatus 140 is positioned relative to the glass substrate 100 such that, as the abrading fibers 142 are rotated, the abrading fibers 142 flex against the surface 102 of the glass substrate 100 and a partial length of the abrading fiber proximate the tip portion 145 of the abrading fiber 142 makes a line contact with the surface 102 of the glass substrate 100, thereby increasing the length of the resultant crack initiation defect formed in the surface 102 of the glass substrate 100 with the abrading fibers 142. In some embodiments described herein, the portion of the abrading fibers 142 which make a line contact with the glass substrate 100 may be less than or equal to about 0.25 inches (6.35 mm). FIG. 6B schematically depicts a crack initiation defect 116 formed in the surface 102 of a glass substrate 100 using the aforementioned technique. In this embodiment, the crack initiation defect 116 extends from the edge of the glass substrate 100 as the abrading fibers make initial contact with the edge of the glass substrate 100 before moving across the surface 102 of the glass substrate 100.

[0044] Referring now to FIG. 7, one embodiment of an abrading apparatus 140 is schematically depicted. In this embodiment, the abrading fibers 142 are positioned on the drum member 141 to obtain a predetermined pattern of initiation defects on the surface 102 of

a glass substrate 100. In particular, FIG. 7 depicts an embodiment of an abrading apparatus 140 in which a plurality of abrading fibers 142 are arranged in rows 170 that extend in an axial direction on the surface 146 of the drum member 141. The abrading fibers 142 within each row 170 are equidistantly spaced apart by a distance s in the axial direction. A plurality of rows of abrading fibers 142 are equidistantly spaced on the surface 146 of the drum member 141 in the circumferential direction.

[0045] Referring now to FIG. 8, a glass substrate 100 is depicted in which a pattern of crack initiation defects 116 have been formed utilizing the abrading apparatus of FIG. 7. Each of the crack initiation defects 116 is spaced apart by a distance S which corresponds to the spacing of the abrading fibers 142 on the abrading apparatus 140 of FIG. 7. Accordingly, it should be understood that the abrading apparatus 140 can be constructed with a plurality of abrading fibers arranged to produce multiple crack initiation defects 116 in the surface 102 of a glass substrate with only a single pass of the abrading apparatus. Moreover, the abrading fibers 142 may be arranged on the drum member 141 of the abrading apparatus 140 to achieve a desired pattern of crack initiation defects 116 on the surface 102 of a glass substrate 100 which, in turn, may be utilized to segment the glass substrate into a plurality of individual glass substrates having the desired dimensions. In these embodiments it is desirable that the plurality of abrading fibers form a wide zone 117 of crack initiation defects 116, as depicted in FIG. 8. The zone 117 of multiple initiation defects 116 facilitates faster alignment of a laser with at least one of the defects in the zone during a subsequent laser separation process.

[0046] While the embodiments described hereinabove utilize rotating abrading fibers to form a crack initiation defect in the surface of the glass substrate, it should be understood that abrading fibers may be utilized to form a crack initiation defect in the surface of a glass substrate by moving the glass substrate relative to the abrading fibers. Referring to FIG. 9 by way of example, another embodiment of a technique for creating a crack initiation defect in the surface 102 of a glass substrate 100 with an abrading fiber 142 is schematically depicted. In this embodiment the abrading fiber is held in a fixed position. The abrading fiber 142 is traversed over the surface 102 of the glass substrate 100 by moving the glass substrate 100 in a direction indicated by arrow 200 such that the abrading fiber 142 contacts the surface 102 of the glass substrate 100 as the glass substrate is moved. As noted hereinabove, abrading fiber

142 is positioned such that the contact angle α between the abrading fiber 142 and the surface of the glass substrate 100 is minimized (i.e., less than or equal to 45 degrees) to prevent the abrading fiber 142 from lifting the glass substrate 100.

[0047] Based on the foregoing, it should be understood that the abrading fiber may be traversed over the surface of the glass substrate by rotating the abrading fibers relative to the glass substrate or moving the glass substrate relative to a fixed abrading fiber.

[0048] Referring now to FIG. 10, another embodiment of a method for forming a crack initiation defect in the surface of a glass substrate is schematically depicted. In this embodiment a rotating abrasive wheel 150 is utilized to form the crack initiation defect in the surface of the glass substrate 100. The abrasive wheel 150 generally comprises an abrasive material, such as silicon carbide, aluminum oxide diamond, or the like, which has a mesh of less than about 1000. For example, in some embodiments the abrasive material may have a mesh greater than or equal to about 300 or less than or equal to about 1000. In other embodiments the abrasive material may have a mesh greater than or equal to about 400 and less than or equal to about 600. In yet another embodiment the abrasive material may have a mesh from about 300 to about 400.

[0049] In one embodiment, the glass substrate 100 is positioned on a compliant surface 130 as the crack initiation defects are formed in the glass substrate with the abrasive wheel 150. The compliant surface 130 may comprise a foam material, as described above, or alternatively, the compliant surface 130 may be an air bearing, as depicted in FIG. 10. The air cushion 132 compliantly supports the glass substrate 100 as the abrasive wheel 150 contacts the surface 102 of the glass substrate 100, cushioning the glass substrate 100 and absorbing excess force applied to the glass substrate 100 and preventing damage to the glass substrate 100.

[0050] While FIG. 10 depicts one arrangement for compliantly supporting the glass substrate, it should be understood that other arrangements are possible. For example, in an alternative embodiment, the glass substrate 100 may be compliantly supported by positioning the glass substrate on a support such that the end of the glass substrate 100 which is contacted by the abrasive wheel is cantilevered from an end of the support, as is depicted in FIG. 1. In this arrangement the glass substrate 100 is compliantly supported such that the glass substrate 100

flexes as the abrasive wheel contacts the surface 102 of the glass substrate 100 such that the depth of the initiation defect caused by the abrasive wheel is minimized.

[0051] The rotating abrasive wheel 150 is brought into contact with the glass substrate 100 to abrade a crack initiation defect into the surface 102 of the glass substrate 100 in a manner which reduces flexure of the glass substrate 100. For example, referring specifically to FIG. 10, in one embodiment, the abrasive wheel 150 is rotated about an axis of rotation 154 which is parallel to the surface 102 of the glass substrate 100. The rotating abrasive wheel 150 is then brought into contact with the surface 102 of the glass substrate 100. Because the abrasive wheel 150 is rotating, the major component of the force exerted on the glass substrate 100 by the abrasive wheel 150 is tangential to the abrasive wheel and, as such, in the direction of the plane of the glass substrate 100 (i.e., parallel to the plane of the glass substrate) which reduces flexure in the glass substrate. The minor component of the force exerted on the glass substrate 100 by the abrasive wheel 150 is perpendicular to the glass substrate 100. However, because the glass substrate is compliantly supported on the compliant surface 130, the minor component of the force results in the displacement of the glass substrate 100 on the compliant surface thus minimizing damage to the glass substrate and preventing the abrasive wheel 150 from puncturing the glass substrate.

[0052] Referring now to FIG. 11, in another embodiment, the abrasive wheel 150 is rotated about an axis of rotation 154 which is non-parallel to the surface 102 of the glass substrate 100 in order to minimize the normal force exerted on the glass substrate 100 by the abrasive wheel 150 as the abrasive wheel 150 contacts the glass substrate. For example, in one embodiment the interior angle (i.e., the smallest angle) between the axis of rotation 154 of the abrasive wheel 150 and the surface 102 of the glass substrate is greater than 45 degrees and less than 90 degrees such that a force exerted on the glass substrate 100 by the abrasive wheel 150 is predominantly parallel to the plane of the glass substrate 100 rather than normal to the plane of the glass substrate 100. More specifically, arrow 160 in FIG. 11 is indicative of the magnitude of the component of the force exerted on the glass substrate by the abrasive wheel 150 in a direction parallel to the plane of the glass substrate 100 while arrow 162 is indicative of the magnitude of the component of the force exerted on the glass substrate in a direction normal to the plane of the glass substrate 100.

[0053] As indicated, rotating the abrasive wheel 150 about an axis of rotation 154 which is non-parallel to the surface 102 of the glass substrate 100, particularly at an angle greater than about 45 degrees and less than 90 degrees, results in the primary component of the force (i.e., the component of the force with the greatest magnitude) exerted on the glass substrate 100 being in the plane of the glass substrate 100 (i.e., parallel to the plane of the glass substrate) rather than normal to the surface 102 of the glass substrate 100. This minimizes the amount of flexure in the glass substrate 100 due to contact with the rotating abrasive wheel 150 as the abrasive wheel 150 and the glass substrate 100 are brought into contact to form a crack initiation defect by abrasion.

[0054] In either of the aforementioned embodiments, the normal force (i.e., the force indicated by arrow 162) exerted by the abrasive wheel 150 against the surface 102 of the glass substrate 100 is generally greater than or equal to about 0.1 Newton and less than or equal to about 24 Newtons. In one embodiment, the normal force exerted by the abrasive wheel is greater than or equal to about 1 Newton and less than or equal to about 10 Newtons.

[0055] In some embodiments the normal force exerted by the abrasive wheel 150 against the surface 102 of the glass substrate 100 is dependent on the mesh of the abrasive grit of the abrasive wheel 150. For example, a mesh of about 1000 may be used in conjunction with a normal force from about 0.1 Newton to about 10 Newtons. However, when the mesh is in a range greater than or equal to 400 and less than or equal to 600, the normal force exerted by the abrasive wheel 150 against the surface 102 of the glass substrate 100 is from about 1 Newton to about 24 Newtons.

[0056] The abrasive wheel 150 may be rotated at various rotational speeds in order to form the crack initiation defect. In general, the rotational speed of the abrasive wheel 150 may be in a range from about 200 rpm to about 40,000 rpm.

[0057] In another embodiment, the abrasive wheel 150 is rotated about an axis of rotation 154 which varies from an orientation wherein the axis of rotation 154 is parallel to the surface 102 of the glass substrate to an orientation wherein the axis of rotation 154 is non-parallel to the surface 102 of the glass substrate 100, or from an orientation wherein the axis of rotation 154 is non-parallel to the surface 102 of the glass substrate to an orientation wherein the axis of rotation 154 is parallel to the surface 102 of the glass substrate 100, or from an orientation

wherein the axis of rotation 154 is non-parallel to the surface 102 of the glass substrate to another orientation wherein the axis of rotation 154 is non-parallel to the surface 102 of the glass substrate 100. The axis of rotation 154 may be repeatedly varied, wherein the axis of rotation 154 makes repeated changes. The effect of the variation is to vary an orientation of a plane of the abrasive wheel 150 relative to the glass substrate 100 and thereby the contact location between the abrasive wheel and the glass substrate in a direction perpendicular to the axis of rotation 154 and create a wider defect region on the surface of the glass substrate. In other words, a direction of a normal to the plane of the abrasive wheel varies. The abrasive wheel 150 is said to wobble.

[0058] Such wobble can be achieved in other ways. For example, in an alternative embodiment, the abrasive wheel 150 may be mounted on an axle in an orientation such that a plane of the abrasive wheel 150 is not perpendicular to the axle. Thus, while the axis of rotation 154 does not vary, the orientation of the plane of the abrasive wheel 150 varies relative to the glass substrate 100 and a position of contact between the abrasive wheel 150 and the glass substrate 100 varies in a direction perpendicular to the axis of rotation (e.g. perpendicular to the axle), again creating a wider defect region. In other words, a direction of a normal to the plane of the abrasive wheel varies. Accordingly, wobble is a variation of the plane of the abrasive wheel 150 relative to the glass substrate 100 as the abrasive wheel rotates.

[0059] Referring to FIG. 12, a crack initiation defect 116 formed by the abrasive wheel 150 is schematically depicted. The crack initiation defect 116 does not extend through the thickness of the glass substrate 100. However, the depth of the crack initiation defect 116 may be dependent on the thickness of the glass substrate. For example, in some embodiments, the depth of the initiation defect is $0.1 \times T$, where T is the thickness of the glass substrate 100. The crack initiation defect 116 may have a length of 8 mm or less. For example, in some embodiments, the length of the crack initiation defect is greater than or equal to about 2 mm and less than or equal to about 8 mm. In other embodiments the crack initiation defect has a nominal length of about 5 mm.

[0060] Referring now to FIGS. 13A and 13B, the crack initiation defects formed utilizing the methods described herein may be used to form and propagate a through vent (i.e., a crack) in a

glass substrate along a desired separation line to separate the thin glass substrate into a plurality of substrates using laser separation techniques. For example, after a crack initiation defect is formed in the surface 102 of the glass substrate 100 utilizing one of the methods described herein, a laser source 180 is utilized to heat the crack initiation defect 116, and the volume of glass surrounding the crack initiation defect 116, by directing a beam 182 of the laser source 180 onto the surface 102 of the glass substrate 100. In the embodiment shown in FIGS. 13A and 13B, the beam 182 of the laser source 180 has a beam spot 190 on the surface 102 of the glass substrate 100 with dimensions large enough to encompass the crack initiation defect 116. The beam spot 190 is positioned on the crack initiation defect 116 to heat the defect.

[0061] Once the glass substrate 100 has reached the necessary temperature by laser heating, a cooling jet 186 of cooling fluid, such as water, air, or another suitable cooling fluid, is projected onto the crack initiation defect 116 with a cooling nozzle 184. The cooling jet 186 generally forms a cooling spot 192 on the surface 102 of the glass substrate 100 with dimensions large enough to encompass the crack initiation defect 116. The rapid cooling of the glass surrounding the crack initiation defect 116 causes a crack to develop from the crack initiation defect and propagate through the thickness T of the glass substrate 100. To propagate the crack over a desired line of separation 196 in the crack propagation direction 194, the glass substrate may be moved relative to the cooling jet 186 and the beam 182 of the laser source 180 in the direction indicated by arrow 188 or, alternatively, the cooling jet 186 and the beam spot may be traversed over the surface 102 of the glass substrate along the line of desired line of separation 196 such that the crack propagates along the desired line of separation, ultimately separating the thin glass substrate 100 into a plurality of smaller glass substrates.

[0062] It should now be understood that the methods and apparatuses described herein may be used to mechanically form a crack initiation defect in a thin glass substrate to facilitate laser separation of the glass substrate into a plurality of individual glass substrates. The techniques for forming the crack initiation defect described herein facilitate forming the crack initiation defect with a relatively low amount of normal force applied to the glass substrate and, as such, such techniques prevent uncontrolled cracking or puncturing of the glass substrate,

particularly when the glass substrate has a thickness of less than about 0.2 mm. However, it should also be understood that the techniques described herein may also be effectively used to form crack initiation defects in substrates having thicknesses greater than about 0.2 mm.

[0063] Accordingly, exemplary, non-limiting embodiments include:

[0064] C1. A method for forming an initiation defect in a glass substrate to facilitate separating the glass substrate into a plurality of substrates, the method comprising: providing the glass substrate; directing a flow of carrier fluid having abrasive material entrained therein onto a surface of the glass substrate to form the initiation defect in the surface of the glass substrate; heating the initiation defect with a laser source; and cooling the initiation defect with a cooling fluid such that a crack initiates from the initiation defect, the crack extending through a thickness of the glass substrate and propagating across the glass substrate to separate the glass substrate into the plurality of substrates.

[0065] C2. The method of C1, wherein the flow of carrier fluid comprises compressed air and the abrasive material has a mesh size of 400 to 600.

[0066] C3. The method of C1 or C2, wherein: the initiation defect comprises a plurality of initiation defects; and the plurality of initiation defects are located within a diameter of a contact spot of the flow of carrier fluid on the surface of the glass substrate.

[0067] C4. The method of C3, wherein the diameter of the contact spot is less than about 0.75 inches (19 mm) on the surface of the glass substrate.

[0068] C5. A method for forming an initiation defect in a glass substrate to facilitate separating the glass substrate into a plurality of substrates, the method comprising: providing the glass substrate; contacting a surface of the glass substrate with an abrading fiber comprising an abrasive material; and traversing the abrading fiber over the surface of the glass substrate such that the abrasive material of the abrading fiber forms the initiation defect in the surface of the glass substrate.

[0069] C6. The method of C5, wherein the abrading fiber makes a point contact with the surface of the glass substrate.

[0070] C7. The method of C5, wherein the abrading fiber makes a line contact with the surface of the glass substrate.

[0071] C8. The method of any one of C5 to C7, wherein a contact angle between the abrading fiber and the surface of the glass substrate is less than or equal to 45 degrees.

[0072] C9. The method of any one of C5, wherein the abrading fiber is traversed over the surface of the glass substrate by moving the glass substrate relative to the abrading fiber as the abrading fiber contacts the surface of the glass substrate.

[0073] C10. The method of any one of C5, wherein the abrading fiber is traversed over the surface of the glass substrate by rotating the abrading fiber about an axis of rotation substantially perpendicular to a long axis of the abrading fiber.

[0074] C11. The method of any one of C5 to C10, further comprising compliantly supporting the glass substrate as the abrading fiber contacts the surface of the glass substrate.

[0075] C12. The method of any one of C5 to C11, wherein the glass substrate is compliantly supported on an air bearing.

[0076] C13. A method for forming an initiation defect in a glass substrate to facilitate separating the glass substrate into a plurality of substrates, the method comprising: providing the glass substrate; compliantly supporting the glass substrate proximate a rotating abrasive wheel; and contacting a surface of the glass substrate with the rotating abrasive wheel such that a primary component of a force exerted by the rotating abrasive wheel against the glass substrate is parallel to the surface of the glass substrate to minimize flexure of the glass substrate, wherein the abrasive wheel abrades the initiation defect in the surface of the glass substrate.

[0077] C14. The method of C13, wherein an axis of rotation of the rotating abrasive wheel is parallel with the surface of the glass substrate.

[0078] C15. The method of C13, wherein an axis of rotation of the rotating abrasive wheel is non-parallel with the surface of the glass substrate.

[0079] C16. The method of C15, wherein an angle between the axis of rotation of the rotating abrasive wheel and the surface of the glass substrate is greater than 45 degrees and less than 90 degrees.

[0080] C17. The method of any one of C13 to C16, wherein a depth of the initiation defect is $0.1 \times T$, wherein T is a thickness of the glass substrate.

[0081] C18. The method of any one of C13 to C17, wherein the force exerted by the rotating abrasive wheel against the glass substrate is greater than or equal to about 0.1 Newton and less than or equal to about 10 Newtons and the rotating abrasive wheel is coated with material having a mesh of about 1000.

[0082] C19. The method of any one of C13 to C17, wherein the force exerted by the rotating abrasive wheel against the glass substrate is greater than or equal to about 1 Newton and less than or equal to about 24 Newtons and the rotating abrasive wheel is coated with material having a mesh of greater than or equal to about 400 and less than or equal to about 600.

[0083] C20. The method of any one of C13 to C19, wherein the glass substrate is compliantly supported on an air bearing.

[0084] C21. The method of any one of C13 to C20, wherein the rotating abrasive wheel is wobbled.

[0085] C22. The method of C21, wherein an axis of rotation of the rotating abrasive wheel varies.

[0086] C23. The method of C21, wherein an axis of rotation of the rotating abrasive wheel does not vary.

[0087] It will be apparent to those skilled in the art that various modifications and variations can be made to the embodiments described herein without departing from the spirit and scope of the claimed subject matter. Thus, it is intended that the specification cover the modifications and variations of the various embodiments described herein, provided such modification and variations come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A method for forming an initiation defect in a glass substrate to facilitate separating the glass substrate into a plurality of substrates, the method comprising:
 - providing the glass substrate;
 - directing a flow of carrier fluid having abrasive material entrained therein onto a surface of the glass substrate to form the initiation defect in the surface of the glass substrate;
 - heating the initiation defect with a laser source; and
 - cooling the initiation defect with a cooling fluid such that a crack initiates from the initiation defect, the crack extending through a thickness of the glass substrate and propagating across the glass substrate to separate the glass substrate into the plurality of substrates.
2. The method of claim 1, wherein the flow of carrier fluid comprises compressed air and the abrasive material has a mesh size of 400 to 600.
3. The method of claim 1, wherein:
 - the initiation defect comprises a plurality of initiation defects; and
 - the plurality of initiation defects are located within a diameter of a contact spot of the flow of carrier fluid on the surface of the glass substrate.
4. The method of claim 3, wherein the diameter of the contact spot is less than about 0.75 inches (19 mm) on the surface of the glass substrate.
5. A method for forming an initiation defect in a glass substrate to facilitate separating the glass substrate into a plurality of substrates, the method comprising:
 - providing the glass substrate;
 - contacting a surface of the glass substrate with an abrading fiber comprising an abrasive material; and

traversing the abrading fiber over the surface of the glass substrate such that the abrasive material of the abrading fiber forms the initiation defect in the surface of the glass substrate.

6. The method of claim 5, wherein the abrading fiber makes a point contact with the surface of the glass substrate.

7. The method of claim 5, wherein the abrading fiber makes a line contact with the surface of the glass substrate.

8. The method of claim 5, wherein a contact angle between the abrading fiber and the surface of the glass substrate is less than or equal to 45 degrees.

9. The method of claim 5, wherein the abrading fiber is traversed over the surface of the glass substrate by moving the glass substrate relative to the abrading fiber as the abrading fiber contacts the surface of the glass substrate.

10. The method of claim 5, wherein the abrading fiber is traversed over the surface of the glass substrate by rotating the abrading fiber about an axis of rotation substantially perpendicular to a long axis of the abrading fiber.

11. The method of claim 5, further comprising compliantly supporting the glass substrate as the abrading fiber contacts the surface of the glass substrate.

12. The method of claim 5, wherein the glass substrate is compliantly supported on an air bearing.

13. A method for forming an initiation defect in a glass substrate to facilitate separating the glass substrate into a plurality of substrates, the method comprising:
providing the glass substrate;

compliantly supporting the glass substrate proximate a rotating abrasive wheel; and contacting a surface of the glass substrate with the rotating abrasive wheel such that a primary component of a force exerted by the rotating abrasive wheel against the glass substrate is parallel to the surface of the glass substrate to minimize flexure of the glass substrate, wherein the abrasive wheel abrades the initiation defect in the surface of the glass substrate.

14. The method of claim 13, wherein an axis of rotation of the rotating abrasive wheel is parallel with the surface of the glass substrate.

15. The method of claim 13, wherein an axis of rotation of the rotating abrasive wheel is non-parallel with the surface of the glass substrate.

16. The method of claim 15, wherein an angle between the axis of rotation of the rotating abrasive wheel and the surface of the glass substrate is greater than 45 degrees and less than 90 degrees.

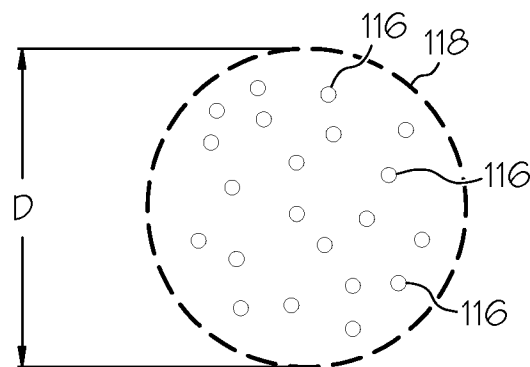
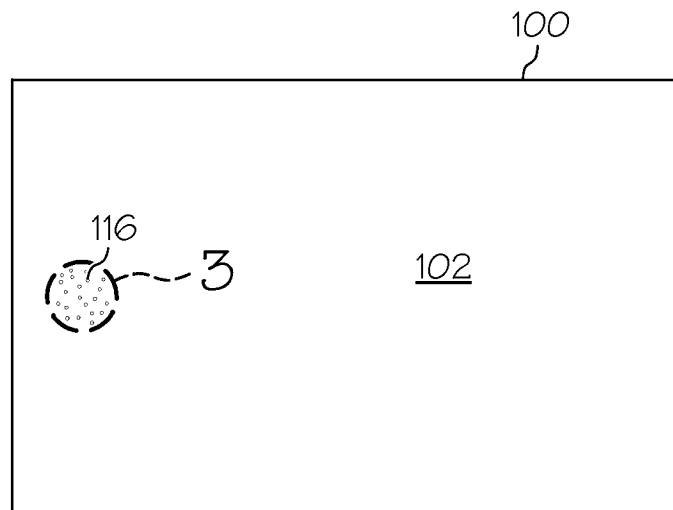
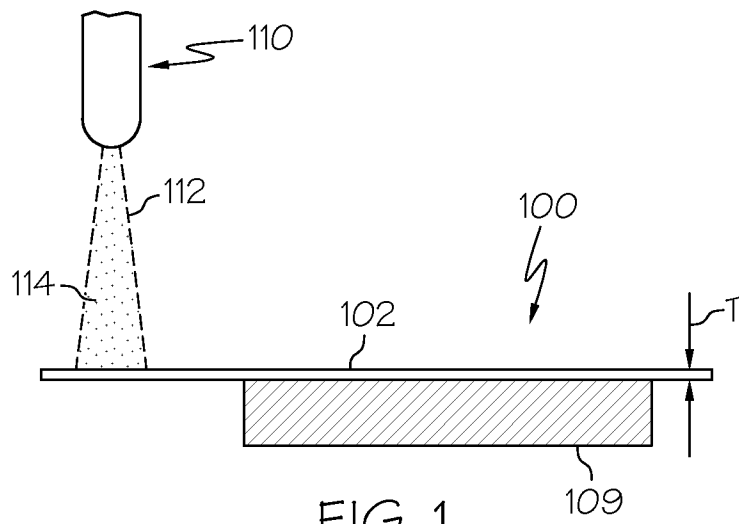
17. The method of claim 13, wherein a depth of the initiation defect is $0.1 \times T$, wherein T is a thickness of the glass substrate.

18. The method of claim 13, wherein the force exerted by the rotating abrasive wheel against the glass substrate is greater than or equal to about 0.1 Newton and less than or equal to about 10 Newtons and the rotating abrasive wheel is coated with material having a mesh of about 1000.

19. The method of claim 13, wherein the force exerted by the rotating abrasive wheel against the glass substrate is greater than or equal to about 1 Newton and less than or equal to about 24 Newtons and the rotating abrasive wheel is coated with material having a mesh of greater than or equal to about 400 and less than or equal to about 600.

20. The method of claim 13, wherein the glass substrate is compliantly supported on an air bearing.

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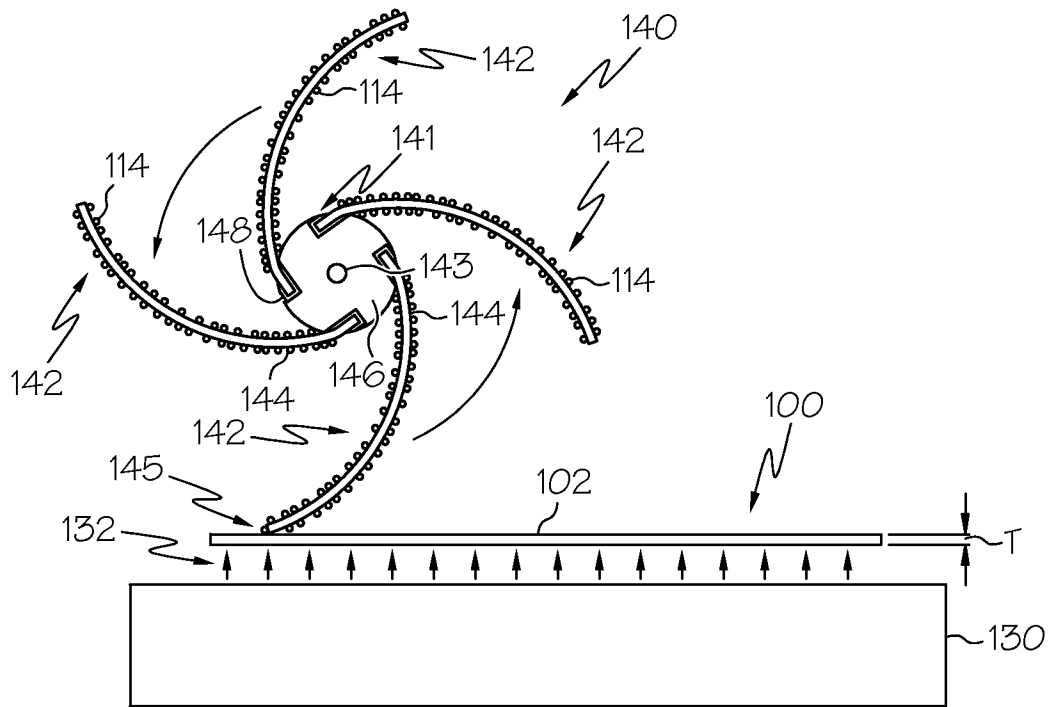


FIG. 4

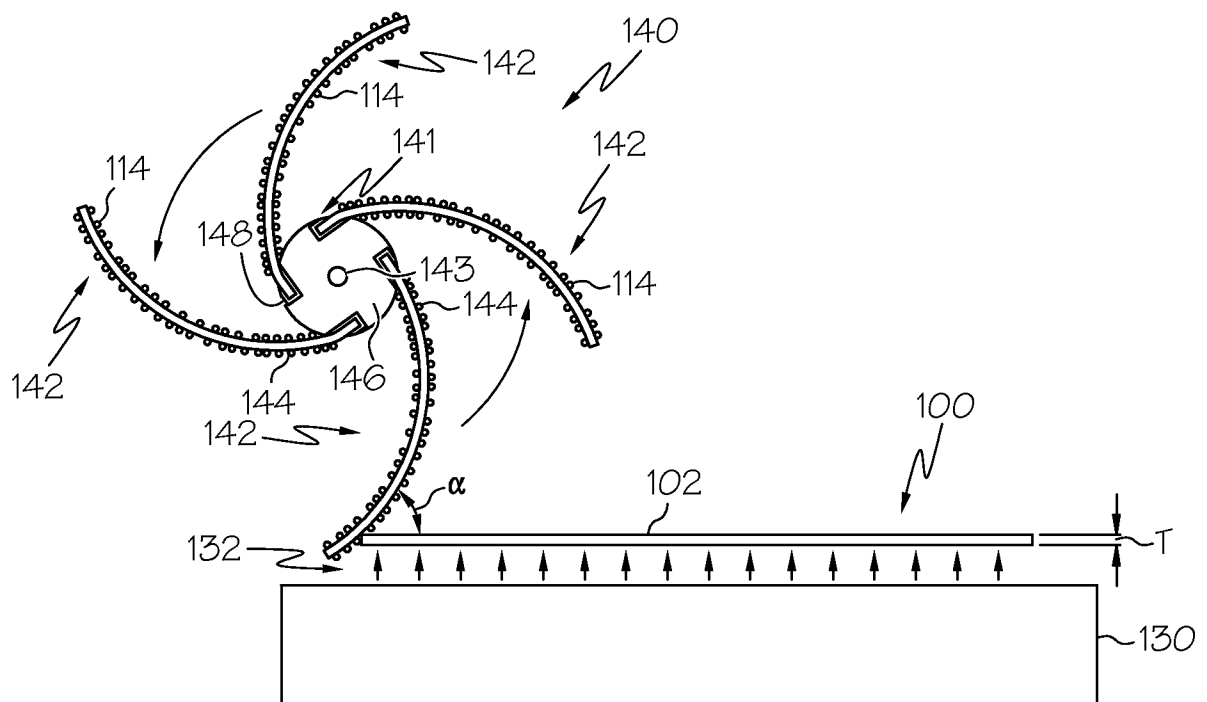


FIG. 5

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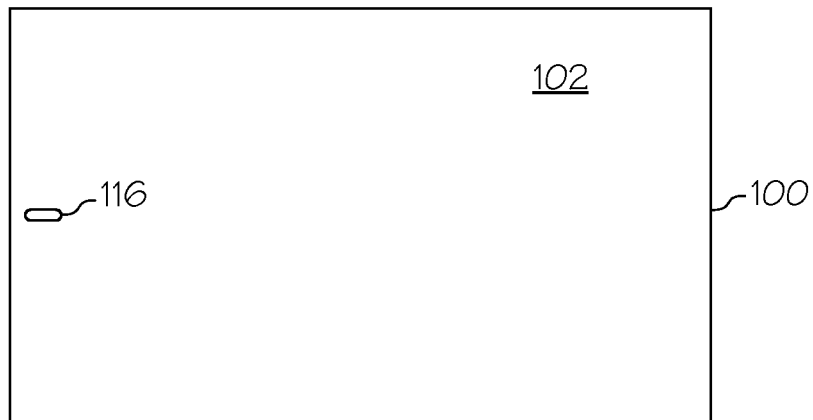


FIG. 6A

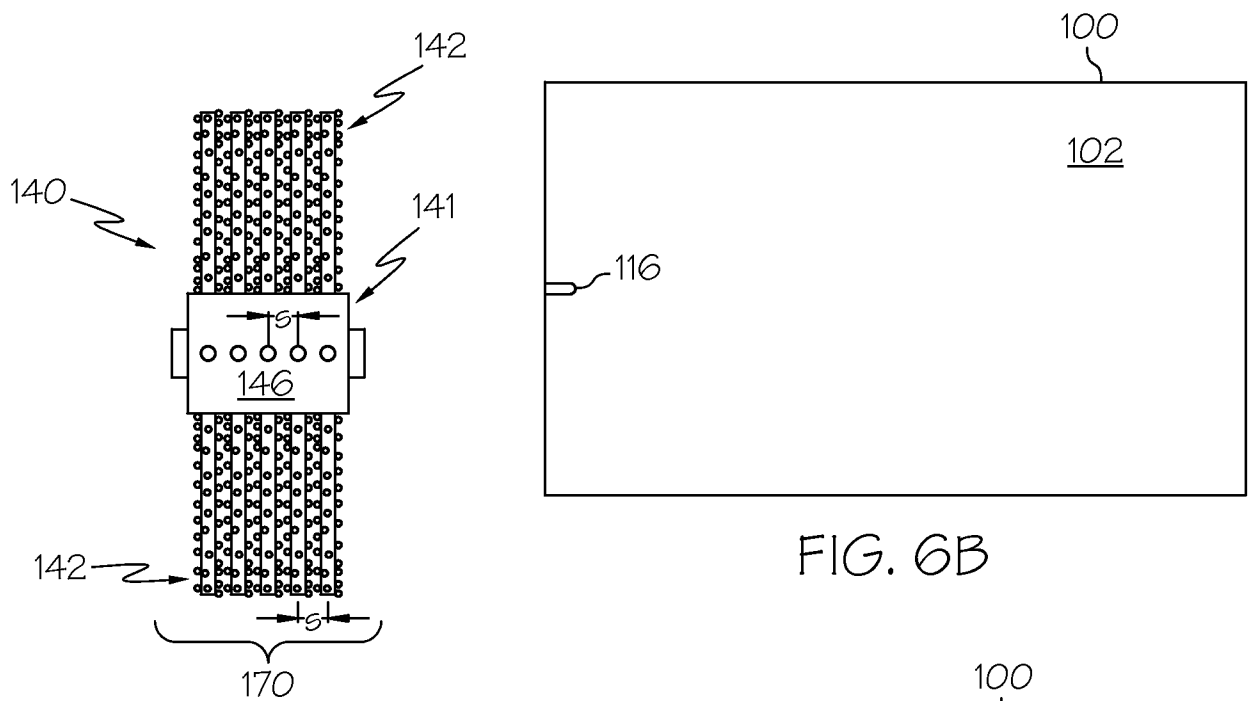


FIG. 6B

FIG. 7

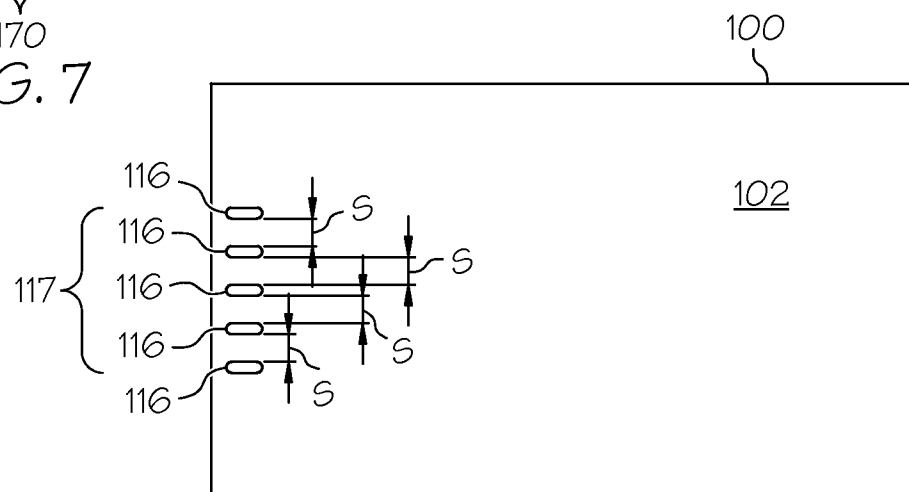


FIG. 8

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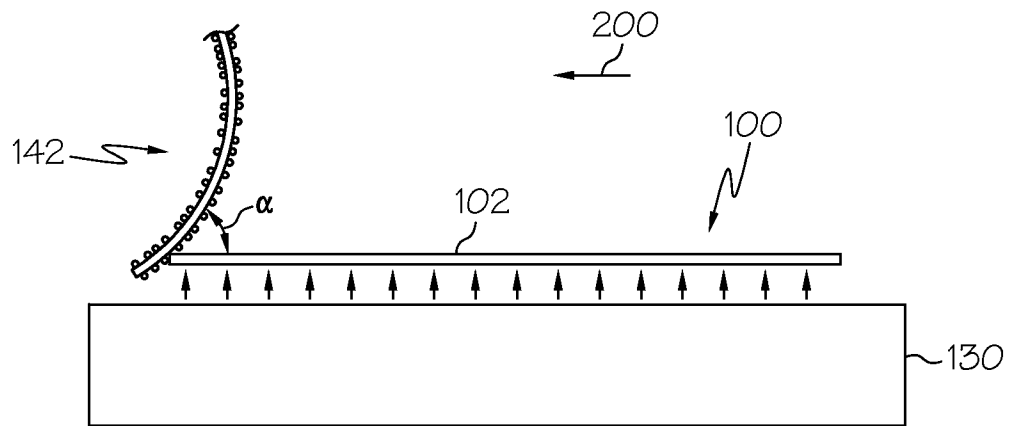


FIG. 9

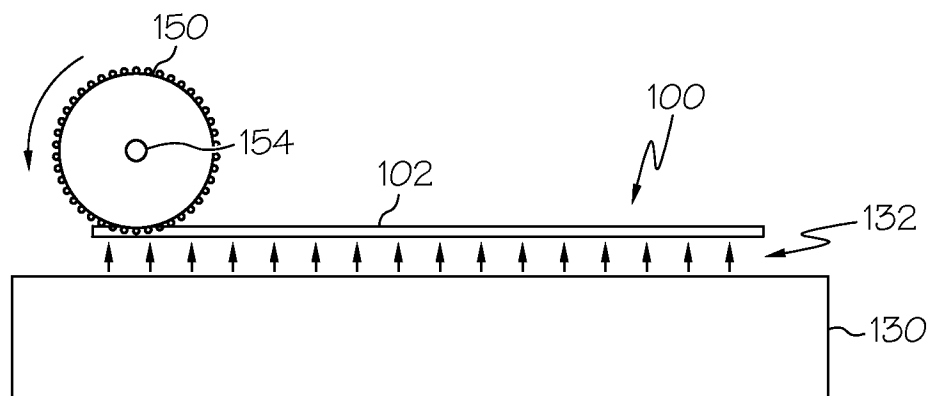


FIG. 10

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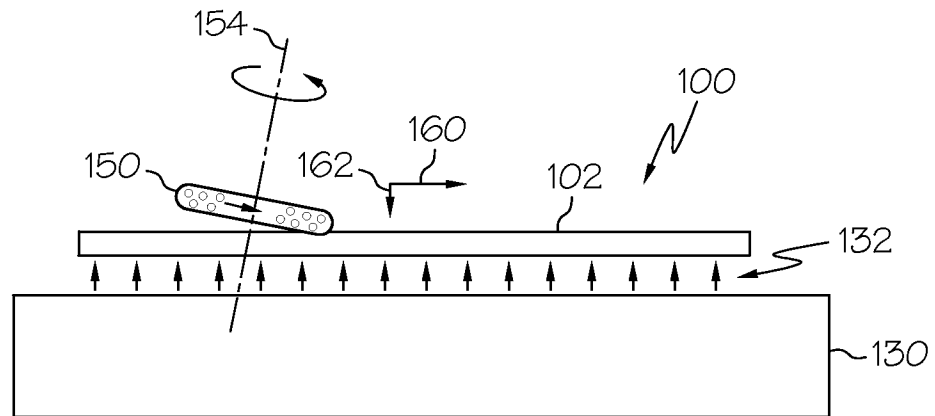


FIG. 11

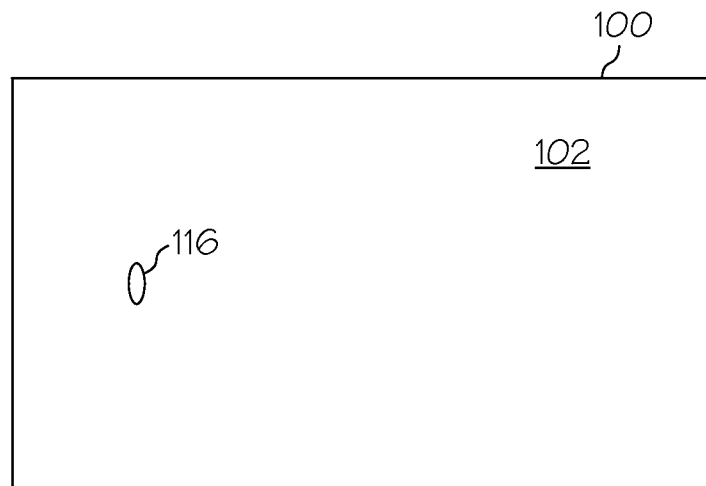


FIG. 12

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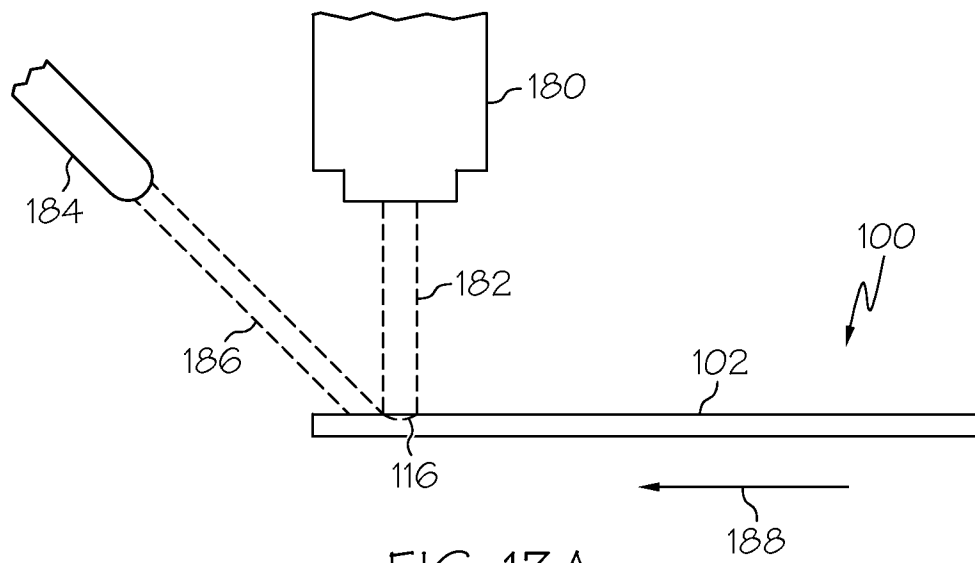


FIG. 13A

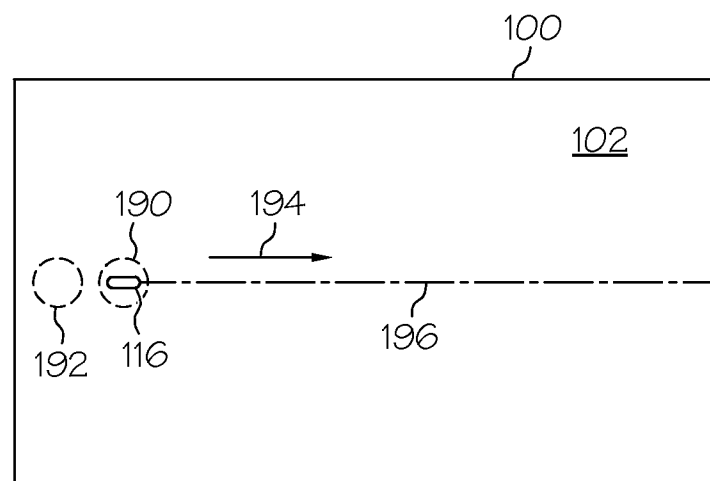


FIG. 13B

A. CLASSIFICATION OF SUBJECT MATTER*C03B 33/02(2006.01)i, C03B 33/033(2006.01)i, B23K 26/38(2006.01)i, B24B 1/00(2006.01)i*

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C03B 33/02; B26D 3/08; C03B 33/023; B23K 26/00; B26F 3/00; B24C 5/02; B28D 1/24; C03B 33/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: initiation defect, glass, fluid, abrasive material, laser source, abrading fiber, rotating abrasive wheel

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2006-103311 A (MJ Tech. Inc.) 20 April 2006. See paragraphs [0024]-[0025] and figure 6.	13, 20 1-12, 14-19
A	US 2006-0137505 A1 (Haruo Wakayama) 29 June 2006. See the entire document.	1-20
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A	JP 07-017733 A (Bando Kiko KK) 20 January 1995. See the entire document.	1-20
A	US 2010-0294746 A1 (Robert Bann et al.) 25 November 2010. See the entire document.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

10 SEPTEMBER 2012 (10.09.2012)

Date of mailing of the international search report

12 SEPTEMBER 2012 (12.09.2012)

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan
City, 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

CHANG, BONG HO

Telephone No. 82-42-481-3353



INTERNATIONAL SEARCH REPORTInternational application No.
PCT/US2012/030498**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

This ISA found multiple inventions as follows:

Group 1: Claims 1-4 relate to a method for forming an initiation defect in a glass substrate by using a flow of carrier fluid having abrasive material and a laser source.

Group 2: Claims 5-12 relate to a method for forming an initiation defect in a glass substrate by using an abrading fiber.

Group 3: Claims 13-20 relate to a method for forming an initiation defect in a glass substrate by using a rotating abrasive wheel.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2012/030498

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