

PROCESS FOR STRUCTURALLY THINNING MATERIALS DRILLED WITH VIA PATTERNS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. §119(e) of U.S. provisional application nos. 60/810,380, filed June 2, 2006, and 60/852,592, filed October 18, 2006, each of which is incorporated herein in its entirety by reference. This application is related to a concurrently-filed and commonly-assigned U.S. patent application entitled "PROCESS FOR OPTICALLY TRANSPARENT VIA FILLING," Atty. Doc. No. ESI-160-B.

FIELD OF THE DISCLOSURE

[0002] The field of the technical subject matter relates to a process for thinning a substrate prior to drilling and/or structurally reinforcing a thinned substrate having a via pattern after drilling.

BACKGROUND

[0003] Projecting a light through a housing to provide information is commonplace. Examples include but are not limited to computer keyboards that include indication lights for functions such as "Caps Lock" or "Num Lock"; computer monitors that include an "on/off" light, automobiles that include lights to indicate whether heated seats are on or off, or whether an air bag is on or off; televisions with indicator lights, and a whole host of other consumer electronics.

[0004] A common way to provide for such lighting is to provide a projecting light that is visible when the light is off, and brightly lit to indicate when it is on. A collection of lights, or holes for lights, may be disruptive to the objectives of an industrial designer.

SUMMARY

[0005] Disclosed are methods for improving light transmission and laser drill throughput by thinning a substrate or panel without substantially reducing the strength and durability of the substrate having through-hole vias.

[0006] One method of filling a via in a substrate with an optically transmissive material taught herein comprises forming a pocket in the substrate where the pocket has a second thickness. The second thickness is less than the first thickness of the substrate. The method in this example further includes drilling at least one via in the pocket and filling the via with an optically transmissive material.

[0007] Products formed by the method are also described herein. One example of such a product, a panel by example, has a first thickness and includes a section having a second thickness wherein the second thickness is less than the first thickness. The panel further includes a light transmissive section formed in that section of the panel having the second thickness wherein the light transmissive section is formed by at least one via filled with an optically transmissive material.

[0008] Details of the these aspects, and other inventive features of the disclosure are discussed below with reference to the drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The description herein makes reference to the accompanying drawings wherein like reference numerals refer to like parts throughout the several views, and wherein:

[0010] FIG. 1 is a schematic representation of a via geometry and the micrographs of the array of vias taken from the back or drill surface in FIG. 1A and from the front or exit surface in FIG. 1B;

[0011] FIG. 2 is a schematic representation of an application where the vias are drilled through a substrate having a standard thickness of about 400 μ m;

[0012] FIG. 3 is a schematic representation of an application where the vias are drilled through a substrate having a thinner thickness of about 100 μ m;

[0013] FIG. 4 is a schematic representation of an application where the vias are drilled inside a thinned pocket area of a substrate;

[0014] FIG. 5 is a schematic representation of the sequence of method steps of a substrate having a thinned pocket area reinforced by a solid reinforcing material; and

[0015] FIG. 6 is a schematic representation of the sequence of method steps of a substrate having a thinned pocket area reinforced by a liquid reinforcing material.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0016] A thinned substrate or panel having through-hole vias (also called micro-vias herein due to their relatively small size) made according to methods taught herein is shown in FIG. 1. The substrate can be thinned using standard machining or the substrate can be provided having a section including a reduced thickness. The substrate may incorporate a micro-via pattern array 10 in a substrate surface as shown in FIG. 2. After a micro-via pattern array 10 is drilled in the substrate 12, a transparent or translucent material filler 32 may be applied to the drilled micro-vias. Then, a material having transparent or translucent and strengthening properties can be applied to the drilled micro-via substrate surface to reinforce the strength of the thinned substrate as shown in FIGS. 3 and 4. The reinforcing material 36 could either be a solid that is bonded to the drilled surface or a liquid or viscous substance that cures to form a solid. The reinforcing material may also be used to color, diffuse, or apply lens effects or other artistic lighting effects in applications where lighted patterns are intended to be created with the micro-vias.

[0017] Referring to FIGS. 3-6 a method for reinforcing a thin substrate 12 having via 10 with a light transmissive material and a product made from using the method is shown and described below. The method and steps for structurally reinforcing a thin substrate having via with light transmissive material is illustrated in FIGS. 5 and 6. A panel or substrate 12 is provided. Substrate 12 is a relatively thin continuous sheet of material such as anodized aluminum. Substrate 12 includes a first or drill surface 14 and an opposing second or exit surface 18 defining a substrate thickness 20. Typically, when the substrate is aluminum, the substrate 12 should be about 400 micrometers (μm) thick in order for the substrate 12 to retain its structural integrity after the via array 10 has been drilled in the substrate drill surface 14. In an example of the present invention, the aluminum substrate 12 provided has a thin thickness 20a, that is a thickness of less than 400 micrometers (μm), as shown in FIG. 3. Alternatively, where an aluminum substrate 12 having a thickness 20 of about 400 micrometers (μm) is provided, a portion of the substrate 12 can be thinned on the drill surface 14 to a thinner thickness 20a as shown in FIG. 4.

[0018] In an application where an aluminum substrate 12 having a thickness of 400 micrometers (μm) is provided, the method includes thinning a pocket area 22 on the drill surface 14 to a thinner thickness 20a of about 100 micrometers (μm). As shown in FIG. 4, the thinned pocket area 22 can be machined using a bore or other machined device. The size of the thinned pocket area 22 should be large enough to accommodate the desired via array

pattern 10. The thinned pocket area 22 is shown in FIG. 4 as a having a circular shape, but it is understood that the thinned pocket area 22 can be of other shapes and configurations. The thinned area 22 of the substrate 12 improves light transmission and reduces the laser drill time of the vias.

[0019] In one application of the method shown in FIG. 5, act (referred hereafter as S) 1 includes drilling one or a plurality of micro-vias or holes 24 through the thinned substrate 12. As shown in FIG. 1, in one aspect, the vias 24 are conical-shaped having sidewalls 26 and a first opening 28 in substrate drill surface 14 and an opposing second opening 30 on substrate exit surface 18. First via opening 28 is larger in diameter than second via opening 30. For example where the substrate 12 is aluminum, first via opening 28 is approximately 90 - 100 micrometers (μm) in diameter and second via opening 30 is approximately 30 - 40 micrometers (μm) in diameter, as shown in FIGS. 1A and 1B. It is understood that larger or smaller openings and other via shapes and configurations may be used. The vias 24 in FIGS. 1A and 1B are drilled or machined out of the substrate using a laser, such as a diode-pumped solid-state pulsed laser 40 in a circular or spiral pattern.

[0020] Optionally, cleaning the drilled vias 24 to remove any debris or deposits formed during the machining process can be performed. It has been shown that a CO₂ snow jet cleaning and isopropyl are effective in cleaning the vias. Other via cleaning techniques known by those skilled in the art may also be used. Ultrasonic cleaning using, for example, ultrasonic baths may be used. Also, the application of high-pressure air, like the snow jet, may be made from a source movably located in a similar manner to the drill 40 to clean the vias.

[0021] In S2 shown in FIG. 5, the disclosed method can include applying a filler material coating 32 into the vias 24. The filler material 32 may be a visible light transmissive material. The exemplary UV curable filler material 32 is substantially clear when cured. As best seen in FIG. 1, the filler material 32 is applied to the substrate second surface 18 over the top of the second or smaller openings 30 of vias 24, filling the vias 24 as shown in FIG. 5. The filler material 32 as shown is applied with a syringe-type device 34. Although the step of filling the micro-vias is shown in FIG. 5, the method can proceed to S3 without filling the micro-vias with filler material 32.

[0022] Referring to FIG. 5 in S3, a reinforcing material 36 is applied to the thin substrate 12. The reinforcing material 36 having transparent or translucent properties is

applied to the drilled micro-via substrate surface 14 to reinforce the strength of the thinned substrate 12. As shown in FIG. 5, the reinforcing material 36 can be a solid preformed and/or pre-cured material having transparent or translucent properties, such as plastic or glass. A solid transparent reinforcing material 36 of the appropriate size is applied to the thin substrate as shown in FIG. 3 or to the thinned pocket area 22 of a substrate as shown in FIGS. 4 and 5. The reinforcing material 36 provides the substrate 12 with the structural support integrity of a substrate having a normal thickness, for aluminum that of 400 micrometers (μm).

[0023] If the vias have been filled in S2 and/or if the reinforcing material 36 is not pre-cured, the method may proceed to S4 where preferably a UV clear filler 32 and/or the reinforcing material 36 is then cured by exposing the filler material 32 to UV light through the transparent reinforcing material 36. When cured, the filler material 32 is optically transparent permitting passage of visible light through the filler material 32, the reinforcing material 36, and substrate 12 through vias 24. The curing of the UV clear filler material 32 bonds the reinforcing material 36 to the substrate 12.

[0024] In another example, the method shown in FIG. 6 includes drilling one or a plurality of micro-vias 24 through the thinned substrate 12 in S11. As shown in FIG. 1, the vias 24 are conical-shaped having sidewalls 26 and a first opening 28 in substrate first surface 14 and an opposing second opening 30 on substrate second surface 18 as described above. It is understood that larger or smaller openings and other via shapes and configurations may be used. The drilled vias 24 can be cleaned to remove any debris or deposits formed during the machining process.

[0025] The filler material 32 may be a visible light transmissive material. The exemplary UV curable filler material 32 is substantially clear when cured. Filler material 32 also may have better transmission of audible sound through the filler material 32 than transmission of audible sound through substrate 12 thickness 20. As best seen in FIG. 1, the filler material 32 is applied to the substrate second surface 18 over the top of the second or smaller openings 30 of vias 24, filling the vias 24 as shown in FIG. 5. The filler material 32 as shown is applied with a syringe-type device 34. Although, the step of filling the micro-vias is shown in FIG. 5, the method can proceed to S3 without filling the micro-vias with filler material 32.

[0026] In S12 shown in FIG. 6, the disclosed method can include applying a liquid filler material coating 32, such as a clear UV curable epoxy, into the vias 24. As shown in

FIG. 6, the filler material 32 is applied to the substrate second surface 18 over the top of the second or smaller openings 30 of vias 24 with a syringe-type device 34. Other filler material 32 application devices and techniques known by those skilled in the art may be used. For example, a thin material film, rather than a curable liquid filler material, can be applied to the drill surface 12 of the aluminum substrate 12, resulting in essentially unfilled vias.

[0027] If a liquid curable filler material 32 is applied to the micro-vias 24, the method proceeds to S13, where the filler material 32 is then cured by exposing the filler material 32 to UV light. Any excess or uncured filler material is removed from the substrate 12. If necessary, the method may also include additional curing after the excess filler material is removed by, for example, a simple isopropanol wipe.

[0028] In S14, a reinforcing material 36 is applied to the thinned pocket area 22 of the substrate as shown in FIG. 4 and 6. The reinforcing material 36 can be a liquid or viscous material that cures to form a solid material. A liquid transparent reinforcing material, such a clear epoxy or other reinforcing material provides structural support to the thinned substrate area. The reinforcing material 36 as shown is applied with a syringe-type device 38. Other application devices and techniques known by those skilled in the art may be used. The reinforcing material 36, when cured provides the substrate with a uniform structural integrity like that of a substrate having a conventional thickness.

[0029] The use of vias 24 and an optically transparent reinforcing material 36 and/or filler material 32 produces a smooth and continuous substrate surface to the naked eye that is capable of displaying controlled images through the vias from interior illumination. The resultant substrate 12 can be used in all manner of application. The disclosed method and resultant substrate is applicable in virtually all applications where a visually continuous and uninterrupted substrate surface is desired having the capability to produce illuminated messages, images or other perceptible characteristics for the user.

[0030] For example, the substrate 12 of FIGS. 3 and 4 is in the form of a panel. The panel 12 can be incorporated in a conventional housing as previously discussed or can be integral with a housing. When the panel 12, as part of a housing, is back lit with an LED, fluorescent or incandescent light, or other lighting device, the light emitted from the vias forms a pattern visible to the viewer.

[0031] In another example, the substrate can be thinned in a small area without application of a reinforcing material to the thinned area. In this example, thinning the small

area of the substrate should not reduce the structural strength of the substrate, obviating the need for a reinforcing material. The size of the thinned area possible in the substrate in order maintain the structural integrity of the substrate as a whole is dependent on the density of the drilled micro-via array, the strength of the substrate material, and/or the shape of the drilled vias, etc.

[0032] While the method has been described in connection with what is presently considered to be the most practical and preferred embodiments, it is to be understood that the method is not to be limited to the disclosed embodiments but, on the contrary, is intended to cover various modifications and equivalent steps and arrangements included within the spirit and scope of the invention and any appended claims.

What is claimed is:

1. A method of filling a via in a substrate with an optically transmissive material, the substrate including a first thickness; the method comprising:
forming a pocket in the substrate, the pocket having a second thickness, the second thickness being less than the first thickness;
drilling at least one via in the pocket; and
filling the via with an optically transmissive material.
2. The method as in claim 1 wherein the optically transmissive material is curable; and the method further comprising:
curing the optically transmissive material after filling the via.
3. The method as in claim 2, further comprising:
filling the pocket with an optically transmissive material.
4. The method as in claim 3 wherein the optically transmissive material is solid.
5. The method as in claim 3 wherein the first thickness is equal or greater than 400 micrometers and the second thickness is equal to or less than 100 micrometers.
6. The method as in claim 1 wherein the via is conically shaped.
7. The method as in claim 6 wherein the via includes a first end having a first diameter between 90 to 100 micrometers and a second end having a second diameter between 30 to 40 micrometers.
8. The method as in claim 1 wherein the via is drilled by a laser.
9. A panel having a first thickness, the panel including a section having a second thickness wherein the second thickness is less than the first thickness, the panel

including light transmissive section formed in that section of the panel having the second thickness, the light transmissive section being formed by at least one via filled with an optically transmissive material.

10. The panel as in claim 9 wherein the section having the second thickness forms a pocket, the pocket being filled by an optically transmissive material.

11. The panel as in claim 10 wherein the optically transmissive material filling the pocket is a UV curable polymer.

12. The panel as in claim 10 wherein the pocket has a thickness of equal to or less than 100 micrometers.

13. The panel as in claim 11 wherein the via is conical.

14. The panel as in claim 13 wherein the via includes a first diameter between 90 and 100 micrometers and a second diameter between 30 and 40 micrometers.

15. The panel as in claim 14 wherein the light transmissive section includes multiple vias organized into a pattern.