Method of sealing and contacting substrates using laser light and electronics module

Field of the Invention

The invention relates to processing substrates using laser. In particular, the invention relates to welding of glass and/or semiconductor substrates containing electrical contact areas together using pulsed laser light. The substrates may comprise e.g. sapphire, quartz or silicon.

Background of the Invention

EP 1369912 discloses a method of bonding a flip chip to a chip carrier using laser beam. The method comprises aligning a contact area of the chip and a contact area of the chip carrier and projecting a laser beam through the chip or carrier to the aligned contact areas to electrically bond them to each other. However, the surroundings of the contact area remain exposed to ambient air (oxygen) and humidity, which may have a detrimental effect on the device being manufactured.

US 2004/207314, US 2005/174042, US 2003/197827 and JP 2005/028891 disclose further methods utilizing laser welding for contacting or joining parts of semiconductor or glass substrates. Also none of these methods, however, is capable of producing a simultaneously well-contacted and well-sealed structure.

Summary of the Invention

~~It is an aim of the invention to achieve an improved~~Disclosed herein is a method of electrical contacting of substrates using laser light, the method also providing protection against particles, oxygen and humidity.

~~It is a further aim of the invention to provide~~Disclosed herein is a well-sealed electronics module having electrical contacts.

~~The aims are achieved by the method and electronics module according to the independent claims.~~

The invention is based on the finding that laser light may induce both fusing of substrate materials, which are generally insulating, and conductive layers applied thereon, together by sweeping of pulsed laser light over their interface zones. A practically complete fusion (welding) of both these areas is achieved.

In one embodiment, the invention provides a method of fusing and electrically contacting a first insulating substrate, preferably a glass substrate, having at least one first conductive layer, i.e., contact terminal, thereon with at least one second insulating substrate, preferably a glass or silicon substrate, having at least one second conductive layer thereon. The method comprises

- stacking the first and second substrates such that an interface zone is formed between them, the interface zone comprising
  - an electrical contacting zone where at least one first conductive layers faces and is at least partially aligned with at least one second conductive layer, and
  - a substrate fusing zone where the insulating substrates face (e.g. directly) each other,
- focusing to the interface zone of the substrates through one of the substrates a plurality of sequential focused laser pulses from a laser source, the pulse duration, pulse frequency and pulse power of the laser light being chosen to provide local melting the substrate materials and the conductive layers,
- moving the laser source and the substrate with respect to each other at a predetermined velocity and path so that a structurally modified zone is formed to the interface zone, the structurally modified zone overlapping with said electrical contacting zone and said substrate fusing zone.

The term "insulating substrate" refers to all non-conductive substrates, including intrinsic semiconducting substrates, which are frequently used as wafers in microelectronics. The conductive layer is typically a metal layer.

In another embodiment, the invention provides anelectronics module comprising a first substrate comprising a pattern of first conductive zones applied as a layer thereon, and a second substrate comprising a pattern of second conductive zones applied as a layer thereon, and wherein the first and second substrates are in stacked configuration such that an interface zone is formed between them, the interface zone comprising

- an electrical contacting zone where at least one first conductive zone faces and is at least partially aligned with at least one second conductive zone,
- a substrate fusing zone where the insulating substrates directly face each other,
- a continuous weld line going through said fusing zone and said electrical contacting zone, the weld line comprising substrate materials being locally fused with each other at the substrate fusing zone and conductive zones being locally fused with each other at the electrical contacting zone.

Embodiments of ~~T~~the invention may provides significant advantages. First, as the mechanical and electrical connecting of the substrates is carried out in the same processing stage, the method is simple and provides both time and cost savings. Second, the weld seam can be made completely hermetic because of direct fusion of materials. Third, the same laser exposure scheme can be used for purely mechanical or electrical connecting of other substrates or components in the same electrical device. Fourth, a very high-quality and pinhole-free weld seam can be produced.

According to one embodiment, at least one of the substrate bodies is transparent for the laser wavelength used. This allows for the laser to be guided through the substrate and focused to the interface, where the intensity per volume is high enough to achieve heating and welding of the substrates or their contact areas.

~~One aim of the invention is to~~According to the present teachings it may be possible to produce laser-induced welding and electrical contacting of substrates, in which the weld seam produced is higher quality, that is, essentially free of microcracks. This is achieved, in particular, by using picosecond-scale laser pulses which induce at the substrate, in addition to nonlinear absorption, also considerable linear absorption effect, provided that they are directed to the substrate temporally and spatially frequently enough. Therefore, a

subsequent pulse is directed to the substrate such that it significantly overlaps with the spot of the previous pulse, the spot still being hot enough, additional absorption of laser energy to the substrate is gained due to linear absorption. In addition to increased absorption, a high pulse repetition rate will reduce microcracking susceptibility of the substrate material(s). This is because a preceding pulse can make the material less rigid and when the succeeding pulse comes the shock wave will be dampened.

An apparatus can be used which comprises

- a pulsed laser source for emitting laser pulses having a predefined duration, pulsing frequency and focal spot diameter,
- means for holding the substrates such that laser light can be guided from the pulsed laser source to the interface zone of the substrates through one of the substrates,

Claims:

1. A method of fusing and electrically contacting a first insulating substrate ~~(28A)~~ having at least one first conductive layer ~~(29A)~~ thereon with at least one second insulating substrate ~~(28B)~~ having at least one second conductive layer ~~(29B)~~ thereon, the method comprising

- stacking the first and second substrates such that an interface zone is formed between them, the interface zone comprising
  - an electrical contacting zone where at least one first conductive layers ~~(29A)~~ faces and is at least partially aligned with at least one second conductive layer ~~(29B)~~, and
  - a substrate fusing zone where the insulating substrates ~~(28A, 28B)~~ directly face each other,
- focusing to the interface zone of the substrates ~~(28A, 28B)~~ through one of the substrates a plurality of sequential focused laser pulses from a laser source ~~(20)~~, the pulse duration, pulse frequency and pulse power of the laser light being chosen to provide local melting the substrate ~~(28A, 28B)~~ materials and the conductive layers ~~(29A, 29B)~~,
- moving the laser source ~~(20)~~ and the substrate with respect to each other at a predetermined velocity and path so that a structurally modified zone is formed to the interface zone, the structurally modified zone overlapping with said electrical contacting zone and said substrate fusing zone.

2. The method according to claim 1, wherein the structurally modified zone comprises a continuous hermetically sealed weld seam.

3. The method according to any ~~of the~~ preceding claims, wherein the path of the pulsed laser light forms a closed loop, preferably around a moisture- or oxygen-sensitive element contained in one of said substrates ~~(28A, 28B)~~.

4. The method according to any ~~of the~~ preceding claims, wherein at least one of the substrates ~~(28A, 28B)~~ comprises a microchip or a display panel having a plurality of contact terminals as said conductive layers.

5. The method according to any ~~of the~~ preceding claims, wherein at least one of the insulating substrates ~~(28A, 28B)~~ comprises a glass panel.

6. The method according to claim 5, comprising focusing said laser light to the interface zone through said glass panel.

7. The method according to any ~~of the~~ preceding claims, wherein at least one of the substrates ~~(28A, 28B)~~ comprises a silicon microchip, the second contacting layers forming the contact terminals of the silicon microchip.

8. The method according to any ~~of the~~ preceding claims, wherein a complete local fusion of the first and second substrates ~~(28A, 28B)~~ together is produced as said structurally modified zone at the substrate fusing zone and a complete local fusion of the first and second conductive layers ~~(29A, 29B)~~ together at the electrical contacting zone.

9. The method according to any ~~of the~~ preceding claims, wherein

- the pulse duration is 20 – 100 ps,
- the pulse frequency is at least 1 MHz, in particular at least 4 MHz,
- the moving velocity of the pulsed laser is adjusted such that successive pulses overlap with each other.

10. The method according to claim 9, wherein the distance between successive pulses is less than 1/5, in particular less than 1/10, preferably less than 1/20 of the diameter of the focal spot of the pulses.

11. The method according to any ~~of the~~ preceding claims, wherein the thickness of the conductive layers is less than 1 μm.

12. An electronics module comprising a first substrate ~~(28A)~~ comprising a pattern of first conductive zones ~~(29A)~~ applied as a layer thereon, and a second substrate ~~(28B)~~ comprising a pattern of second conductive zones ~~(29B)~~ applied as a layer thereon, and

wherein the first and second substrates ~~(28A, 28B)~~ are in stacked configuration such that an interface zone is formed between them, the interface zone comprising

- an electrical contacting zone where at least one first conductive zone ~~(29A)~~ faces and is at least partially aligned with at least one second conductive zone ~~(29B)~~,
- a substrate fusing zone where the insulating substrates ~~(28A, 28B)~~ directly face each other,
- a continuous weld line going through said fusing zone and said electrical contacting zone, the weld line comprising substrate ~~(28A, 28B)~~ materials being locally fused with each other at the substrate fusing zone and conductive zones ~~(29A, 29B)~~ being locally fused with each other at the electrical contacting zone.

13. The electronics module according to claim 12, wherein

- the first substrate ~~(28A)~~ is a glass substrate, and
- the second substrate ~~(28B)~~ is a microchip.

14. The electronics module according to claim 12 or 13, wherein the continuous weld line forms both a hermetic seal between the substrates and an electrical connection between the substrates.