

SPECIFICATION

Title of the Invention

Method of Working an Organic Film

Background of the Invention

The present invention relates to a method of working an organic film and more particularly, to an organic film working method for forming minute via-holes in a film substrate which is formed of an organic insulating film of polyimide and an conductive layer of copper foil and is useful as a substrate for film package of an LSI or an organic film substrate used for a printer head and the like.

Multilayer wiring board techniques have been developed for LSI packaging in personal computers and large-scale computers and at present, for the purpose of meeting reduction of device costs and speed-up of packaged devices, a high-density packaging technique using an insulating film having good high-frequency characteristics has been desired to be practiced. Especially, a method of forming minute via-holes in a film substrate formed of an organic film and a metal layer stuck thereto at high throughput and low costs has been sought.

Further, in an application to an ink jet printer and the like, a method of forming a great number of minute via-holes in an organic film substrate having a thickness of about 100 μ m at low costs and high rates



has been sought.

As this type of organic film working method, the present inventors have proposed a method for formation of highly reliable via-holes. According to the proposal, a via-hole formed in a film substrate constructed of an organic insulating film and a conductive layer has a high aspect ratio, and no insulating layer remains at an interface between the organic insulating film and the conductive layer. More particularly, the substrate formed of the insulating film containing an organic substance is irradiated with a pulse laser beam of a wavelength absorbable by the substrate at a portion where a via-hole is to be formed, a residual film on the bottom of the via-hole at the irradiated portion is then vaporized and removed by irradiation of a second pulse laser beam of a pulse width of 200ns or less and thereafter, the substrate is washed by ultrasonic washing to wash and remove a deposit on the via-hole side wall, thus forming minute via-holes at high throughput.

The conventional via-hole forming method, however, requires ultrasonic washing in the final step, thus increasing the number of steps and making it difficult to reduce the production cost.

Further, in an application to the formation of minute via-holes in a printer head, work must be done under a condition that mechanism holding parts are



assembled on the insulating film and therefore, a solution treatment process needed for the ultrasonic washing cannot sometimes be applied.

Summary of the Invention

Therefore, it is an object of the present invention to provide an organic film working method which can permit an organic film to be worked at low costs through only a laser irradiation process, without resort to a wet process.

According to an aspect of the present invention, to accomplish the above object, there is provided an organic film working and forming method comprising the steps of irradiating a first pulse laser beam having a pulse width of a first predetermined time width on a film substrate formed of an insulating layer containing an organic substance and a metal layer laminated thereon at a via-hole forming portion of the film substrate to cause at least any one of reactions of thermally decomposing a laser beam irradiated portion of the insulating layer and of generating a gas due to thermal decomposition, and irradiating a second pulse laser beam of a second predetermined time width on the portion of the insulating layer on which the first pulse laser beam is irradiated to vaporize and remove a residual film on the bottom of a via-hole, the second pulse laser beam has an irradiation beam spot size larger than that of the first pulse laser beam so



as to expand to a range which covers a thermally denatured area of the insulating layer.

According to another aspect of the present invention, there is provided a method of working a film containing an organic substance (referred to as an organic film) comprises the steps of irradiating a first pulse laser beam having a pulse width of a first predetermined time width on the organic film at a via-hole forming portion of the organic film to cause at least any one of reactions of thermally decomposing a first laser beam irradiated portion of the organic film and of generating a gas due to thermal decomposition, and irradiating a second pulse laser beam having a beam spot size larger than that of the first pulse laser beam so as to expand to a range which covers a thermally denatured area of the organic film and having a pulse width of a second predetermined time width, on the first pulse laser beam irradiated portion of the organic film.

In the conventional method of forming via-holes in a substrate formed of an insulating film and a conductive film laminated thereon, it has been known that a residual film on the via-hole bottom can be vaporized and removed by irradiation of a short pulse laser beam. But, the irradiation beam for vaporization and removal has the same beam spot size as the first pulse laser beam and consequently, even after the



irradiation of the second pulse laser beam, the deposit on the via-hole side wall still remains unremoved, so that even after the irradiation of the second pulse laser beam, the ultrasonic washing process is needed to remove the deposit on the via-hole side wall.

Contrary to this, according to the present invention, the ultrasonic washing process for removal of the deposit on the via-hole side wall can be dispensed with to ensure that minute via-holes can be formed through a reduced number of steps with high controllability and at high throughput. The present invention can dispense with any wet process during working process as described above and therefore it can expand objects to be worked to which the invention is applied and can reduce the production cost greatly to advantage.

Brief Description of the Drawings

Figs. 1A-1D diagrammatically illustrate steps of a work process according to an embodiment of the invention.

Detailed Description of the Preferred Embodiment

The present invention will now be described by way of example with reference to the accompanying drawing.

A work process according to an embodiment of the present invention is diagrammatically depicted in order of work steps in Figs. 1A to 1E.

This Sheet Has Been Replaced



Referring to Figs. 1A to 1E, a substrate to be worked is a film substrate for packaging formed of a polyimide film 2 having a thickness of $30\mu\text{m}$ and a copper layer 3 having a thickness of $10\mu\text{m}$. During irradiation of a laser beam, the substrate is worked while spraying a nitrogen gas at a flow rate of 10 liters/minute to an irradiated portion on the substrate.

In a first step, as shown in Fig. 1A, a first pulse laser beam 1 having a pulse width of 0.3ms obtained by modulating an argon laser beam of a wavelength of 515nm by means of an ultrasonic modulator is formed into an irradiation beam spot size of $40\mu\text{m}$ and irradiated by two shots at irradiation intervals of 10ms. The irradiation intensity is $500\text{kW}/\text{cm}^2$.

A worked shape after the irradiation of the first pulse laser is illustrated in sectional form in Fig. 1B. In Fig. 1B, a via-hole VH has a bottom diameter of $40\mu\text{m}$ and an upper diameter of $70\mu\text{m}$. A decomposed substance 4 of about $30\mu\text{m}$ thickness is deposited on the side wall of a via-hole 6 to form a deposit thereon and a thin residual film 7 denatured from polyimide remains on the bottom of the via-hole.

In a subsequent second step, as shown in Fig. 1C, a second pulse laser beam 5 formed of second higher harmonics of a QswYAG laser (having an irradiation beam spot size of $70\mu\text{m}$, a pulse width of 10ns and an



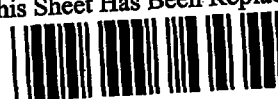
irradiation peak power density of $100\text{MW}/\text{cm}^2$) is irradiated by one or more shots.

A worked shape after the irradiation of the second pulse laser beam 5 is illustrated in sectional form in Fig. 1D. As shown thereat, not only the residual film 7 on the via-hole bottom but also the deposit 4 on the via-hole side wall is vaporized and removed to form a via-hole 6 having a smooth side wall. Through observation with an electron microscope, no deposit is found on the via-hole side wall 8.

In embedding copper in the thus formed via-hole by electrolytic plating, the via-hole 6 can be embedded neatly with copper at about 100% yield and with high reproducibility as shown in Fig. 1E. This additionally proves that the via-hole according to the present invention can be shaped with high reproducibility and the deposit can be removed completely.

In the case of a comparative example in which the second pulse laser beam 5 is irradiated at the same irradiation spot size as that of the first pulse laser beam 1 which amounts to $40\mu\text{m}$, the residual film on the bottom can be removed completely but the deposit on the via-hole side wall cannot be removed.

In the foregoing embodiment, the present invention has been described as being applied to the formation of via-holes in the substrate for packaging electronic parts but a second embodiment will be



described as an example directed to opening of minute holes in a polyimide film of about 100 μ m thickness practically used in an application to printer head and the like.

In the present embodiment, a laser beam source similarly constructed to that in the foregoing first embodiment is used to open through-holes in a polyimide film.

Conditions for irradiation of a first pulse laser beam 1 in a first step (see Fig. 1A) are a beam spot size of 40 μ m, a pulse width of 0.3ms, the number of pulses being 6 shots, an irradiation interval of 10ms and an irradiation intensity of 500kW/cm².

Conditions for irradiation of a second pulse laser beam 5 in a second step (see Fig. 1C) are an irradiation beam spot size of 120 μ m, a pulse width of 10ns, an irradiation peak power density of 100MW/cm² and the number of pulses being one shot.

The obtained via-hole has a bottom diameter of 80 μ m and an upper diameter of 110 μ m. Since the polyimide film used in the present embodiment differs from the packaging substrate in that it is devoid of a copper foil of high heat conduction, the via-hole diameter increases laterally owing to thermal diffusion in the polyimide film but any deposit does not remain on the via-hole side wall after the irradiation of the second laser beam 5 and a tendency toward higher



smoothness of the side wall than that in the first embodiment is observed.

In formation of via-holes in the printer head and the like, higher smoothness of the side wall and controllability of the inclined angle of the via-hole are important for the sake of controlling the flow of ink. The via-hole formation method according to the present embodiment can ensure higher smoothness of the side wall and permit the inclined angle to change in accordance with the number of shots of the first pulse laser beam 1 and is proven to be a practically effective method.

The first pulse laser beam has the pulse width ranging 10 μ s to 20 ms. The reason of which is because, since a thermal via-hole forming is performed, if the pulse width is less than 10 μ s, the heat will be diffused at the surface of the insulation layer when irradiated by the laser beam and the quantity of heat sufficient for the via-hole forming cannot be obtained, and further if said pulse width is larger than 20 ms, the heat will damage the underlying metal layer because the quantity of heat is too large, and therefore, it is not usable as a product.

The second pulse laser beam has the irradiation intensity less than about 200 ns of the pulse width and more than about 10 MW/cm² of the peak power density. The reason of which is because the underlying layer and



via-hole side wall are adversely affected if the pulse width of the pulse laser beam becomes larger. Further, the use of a peak power density of about 10 MW/cm^2 or more is applied as the minimum intensity for removing the thermally decomposed deposit on the insulation layer of the via-hole bottom opened by the first laser beam irradiation, and if the lower intensity is applied in the irradiation, it is not possible to remove the thermally decomposed portion.

The pulse width of the first pulse laser beam is used for thermally decomposing the organic film. The pulse width in the range of 10 μs to 20 ms is appropriate. The reason is described as follows. In the abrasion process method, which is well known as the method of processing the organic film, an ultraviolet light is used having the pulse width of about 20 ns and about 0.5 μm of the smaller absorption length of the laser beam. On the other hand, in the irradiation of the first pulse laser beam of the present invention, since the laser beam is permeated to a certain depth of more than several μm to form a deep hole with one shot of the pulse, if a sudden heat is applied by a short pulse beam, an explosive decomposition reaction is caused by the laser energy as absorbed in the depth direction of the film and by the shock a problem of a crack is caused to the organic film near the periphery of the irradiated portion. Further, in the abrasion



process method, a conductive substance is formed on the processed side wall. On the other hand, in the process of the present invention, when compared to the pulse width as used in the abrasion process method, a relatively longer pulse width is used, and as a result, an advantage is obtained to be able to remove easily and without difficulty the decomposed layer of the side wall by the slow thermal decomposition reaction causing no occurrence of cracks by the shock. Experimentally, it was found out that, in order to avoid the occurrence of the cracks or the side wall conductive layer, the pulse width of more than 10 μ s was appropriate. On the other hand, in the upper limit of the pulse width of the first pulse beam irradiation, the problems will be caused that, by the effect of heat diffusion within the film, the boundary of the heat decomposition region is expanded too wide toward the outside causing the lowering of the controllability of the processing diameter, and the worsening of the aspect ratio of the via-hole to be formed, and that the quantity of heat to be transported to the copper foil at the bottom of the substrate causing the copper foil near the periphery of the irradiated portion to be peeled off easily. As a result of the experimental review on the pulse width in order to avoid said problems, it was found out that the pulse width of less than 20 ms eliminates the problem of controllability of the above processing diameter and



the problem of the peeling off of the conductive substance at the bottom of the substrate.

On the other hand, since the role of the second pulse laser beam irradiation exists in the blow off by the thermal shock of the decomposition of the irradiated portion side wall of the organic film as formed by the first pulse laser irradiation and in transpiring and removing the residual film at the bottom portion of the via-hole, it is appropriate to apply the same pulse width as the normal abrasion process method, and the pulse width of about 20 ns typically, or of about 200 ns at the longest, is appropriate.

As described above, according to the present invention, minute via-holes can advantageously be formed through a small number of steps with high controllability and at high throughput and in addition, any wet step is not required during work process to thereby expand the kind of workpieces and greatly reduce the production cost to advantage.

This Sheet Has Been Replaced





What is Claimed is:

1. An organic film working method comprising the steps of:

irradiating a first pulse laser beam having a pulse width of a first predetermined time width on a film substrate formed of an insulating layer containing an organic substance and a metal layer laminated thereon at a via-hole forming portion of said film substrate to cause at least any one of reactions of thermally decomposing a laser beam irradiated portion of said insulating layer and of generating a gas due to thermal decomposition; and

irradiating a second pulse laser beam of a second predetermined time width on the portion of said insulating layer on which the first pulse laser beam is irradiated to vaporize and remove a residual film on the bottom of a via-hole,

said second pulse laser beam having an irradiation beam spot size larger than that of said first pulse laser beam so as to expand to a range which covers a thermally denatured area of said insulating layer.

2. A method according to Claim 1, wherein the predetermined time width of said first pulse laser beam is the pulse width ranging 10 μ s to 20 ms, and the second pulse laser beam has the irradiation intensity less than about 200 ns of the pulse width and more than





about 10 MW/cm² of the peak power density.

3. A method according to Claim 1, further comprising the steps of:

spraying a gas to said laser beam irradiated portion.

4. A method according to Claim 1, wherein the irradiation beam spot size of said second pulse laser beam is so set as to reach an outer diameter, close to said insulating layer containing an organic substance or the surface of said film, of a thermally decomposed deposit created on a side wall portion near an opening edge by the irradiation of said first pulse laser beam.

5. A method of working a film containing an organic substance, comprising the steps of:

irradiating a first pulse laser beam having a pulse width of a first predetermined time width on said organic film at a via-hole forming portion of said organic film to cause at least any one of reactions of thermally decomposing a first laser beam irradiated portion of said organic film and of generating a gas due to thermal decomposition; and

irradiating a second pulse laser beam having a beam spot size larger than that of said first pulse laser beam so as to expand to a range which covers a thermally denatured area of said organic film and having a pulse width of a second predetermined time width on said first pulse laser beam irradiated portion





of said organic film.

6. A method according to Claim 5, wherein the predetermined time width of said first pulse laser beam is the pulse width ranging 10 μ s to 20 ms, and the second pulse laser beam has the irradiation intensity less than about 200 ns of the pulse width and more than about 10 MW/cm² of the peak power density.

7. An organic film working method according to Claim 5, further comprising the step of spraying a gas to said laser beam irradiated portion.

8. An organic film working method according to Claim 5, wherein the irradiation beam spot size of said second pulse laser beam is so set as to reach an outer diameter, close to said insulating layer containing an organic substance or the surface of said film, of a thermally decomposed deposit created on a side wall portion near an opening edge by the irradiation of said first pulse laser beam.

