HIGH ACCURACY BLAST PROCESSING METHOD AND HIGH ACCURACY BLAST PROCESSING APPARATUS

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ABSTRACT

In a high accuracy blast processing method of the present invention which is a blast processing method for processing a substrate by injecting an injection material from a nozzle by compressed air, injection of the injection material is either intermittent injection for repeating the injection and injection stop at short intervals or a combination of the intermittent injection and continuous injection. By doing so, even if a processing progresses, processing efficiency is not deteriorated and a non-processing target region is not damaged even without using a mask. A high accuracy blast processing apparatus of the present invention consists of a nozzle unit forcibly feeding the injection material to the nozzle by the compressed air and a work table moving the substrate horizontally and vertically. A solenoid valve for injecting and stopping the injection material and a control unit outputting an intermittent operating signal to the solenoid valve are connected to the nozzle unit.
FIG. 3

- Example (test No. 1)
- Example (test No. 2)
- Comparison example (test No. 3)

Injection time (min)

Hole diameter (mm)
HIGH ACCURACY BLAST PROCESSING
METHOD AND HIGH ACCURACY BLAST
PROCESSING APPARATUS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a high accuracy blast processing method for conducting perforation, cutting, patterning to a substrate mainly consisting of hard, fragile material such as silicon, glass or ceramic and a high accuracy blast processing apparatus used therefor.

[0003] 2. Description of the Prior Art

[0004] As means for performing various processings including perforating and cutting to a substrate consisting of a hard, fragile material such as silicon, glass or ceramic and forming a fine pattern thereon, a sand blasting method capable of conducting a dry fine processing has been widely used. This processing method is to continuously inject a microscopic projection material, such as alumina or SiC, onto a processing target surface from a nozzle by compressed air for a predetermined time to thereby blast the processing target surface.

[0005] Assume that many transparent holes are formed in a substrate at predetermined intervals by the above-stated blast processing method. To prevent non-processing target regions from being damaged, when one hole is perforated by the continuous injection of an injection material which is moving in a nozzle, the injection is temporarily stopped and the nozzle is moved to the next perforating target position. Then, an injection material is injected again and the perforating processing is conducted. In this case, however, the injection material remains in a hose forcibly feeding the injection material to the nozzle due to the stop of the injection, and the residual injection material is injected together with the following injection material at the time of the next perforating processing. As a result, the injection material larger in quantity than that in a stationary injection state is injected, disadvantageously deteriorating processing accuracy.

[0006] Further, if perforating is conducted to form holes each having a predetermined depth by continuously injecting an injection material, it is difficult to discharge the injection material from the holes which are not perforated yet in the middle of the processing. As a result, the injection material remains in the holes and prevent the holes from being further processed, disadvantageously, greatly decreasing processing speed and requiring a long time to complete the processing. Besides, a part of the injection material is splashed over and collided on the peripherities of the holes to be processed. Due to this, if it takes a long time to form one hole, a non-processing target region around the hole is disadvantageously roughened and damaged.

[0007] As means for preventing the collision of the injection material on such a non-processing target regions, there are proposed methods for masking the non-processing target region and selectively blasting unmasked portions. For example, a method using a photoresist as a mask enables carrying out the highest accuracy processing. However, it is necessary to use a mask in the steps of pattern transfer, development and drying using a photographic plate as well as the step of peeling off and wash the mask after the processing. The steps become disadvantageously complicated to thereby push up cost. Besides, it is necessary to conduct a waste liquid treatment. For these reasons, this method cannot be easily adopted.

[0008] It is, therefore, an object of the present invention to provide a high accuracy blast processing method and a high accuracy blast processing apparatus capable of solving the above-stated conventional disadvantages and accurately processing a substrate without deteriorating processing efficiency even if the processing progresses. It is another object of the present invention to provide a high accuracy blast processing method and a high accuracy blast processing apparatus capable of accurately processing a substrate without damaging a non-processing target region even if a mask is completely not used.

SUMMARY OF THE INVENTION

[0009] In a high accuracy blast processing method according to the present invention which is a high accuracy blast processing method for processing a substrate by injecting an injection material from a nozzle by compressed air, injection of the injection material is intermittent injection for repeating injection and injection stop at short intervals. Thus, in a perforating processing, when the processing progresses to a certain degree, the injection material is discharged without remaining in a bottomed hole, making it possible to prevent processing efficiency from being deteriorated and to complete the processing in far shorter time than that in the conventional method. In addition, it is possible to prevent the splashed injection material from being collided on the injection material which has been injected and to thereby prevent the peripheral portion of the hole from being damaged by the spattering and collision of the injection material. According to the high accuracy blast processing method of the present invention, therefore, it is possible to carry out a fine processing without deteriorating processing efficiency even if the processing progresses and without damaging a non-processing target region even if a complete mask is not used.

[0010] According to the preferred embodiment of the present invention, the high accuracy blast processing method in which the injection of the injection material is intermittent injection for repeating injection and injection stop at short intervals, is conducted by combining the intermittent injection with continuous injection. By doing so, it is possible to obtain a greater advantage than that in case of conducting only the intermittent injection. In addition, it is preferable that the injection and the injection stop of the intermittent injection are repeated at intervals of not more than 1 second. It is noted that it is the most preferable for processing a substrate consisting of a hard, fragile material such as silicon, glass or ceramic that the substrate is processed by injecting the injection material having a mean particle diameter of not more than 50 μm and an injection quantity of not more than 50 g/min from the nozzle having an inside diameter of 0.2 to 2 mm by compressed air of 0.2 to 2.5 MPa.

[0011] A high accuracy blast processing apparatus according to the present invention is used for the above-stated high accuracy blast processing method comprising: a nozzle unit forcibly feeding an injection material to a nozzle by compressed air; and a work table moving a substrate horizontally and vertically. A control unit outputting an intermittent operating signal for injecting and stopping the injection material is connected to the nozzle unit. Alternatively, a solenoid valve may be attached to the nozzle unit so as to inject and stop the injection material in response to a signal applied from the control unit. This control unit turns on and
off the nozzle unit at predetermined intervals to thereby allow the injection material to be intermittently injected. Besides, the quantity of the injection material remaining in the hose is greatly reduced even if the injection is completely stopped, thereby maintaining processing accuracy.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a perspective view showing the constitution of a high accuracy blast processing apparatus according to the present invention;

[0013] FIG. 2 is a graph showing changes in the depths of holes relative to injection time for injecting an injection material according to the present invention; and

[0014] FIG. 3 is a graph showing changes in the diameters of holes relative to injection time for injecting the injection material by the method of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0015] The preferred embodiment of the present invention will be described hereinafter with reference to the drawings.

[0016] FIG. 1 shows one example of a high accuracy blast processing apparatus according to the present invention. In FIG. 1, reference numeral 1 denotes a substrate subjected to be blasted, 2 denotes a nozzle unit for forcibly feeding an injection material to the nozzle to inject the injection material, 3 denotes the nozzle, and 4 denotes a work table. The nozzle unit 2 is connected to a hose to which the injection material as well as compressed air is supplied from a hopper which is not shown in FIG. 1. Also, the nozzle unit has a mechanism in which the injection material in a predetermined quantity is forcibly fed to the nozzle 3 and injected therefrom. Reference numerals 5 and 6 denote two solenoid valves, 6 denotes a control unit setting a predetermined cycle time, outputs signals to these solenoid valves 5 and thereby intermittently turns on and off the solenoid valves 5. The control unit 6 is connected to the nozzle unit 2 stated above. Then, out of the two solenoid valve 5, one is used to shut off the injection material and the other is used to shut off the compressed air. It is noted that a personal computer, an NC unit, a sequencer or the like can be used as the control unit 6. In addition, instead of employing the solenoid valves in the apparatus shown in FIG. 1, a control unit intermittently turning on and off an electric signal may be directly connected to the nozzle unit so as to intermittently inject the injection material. The work table 4 is moved horizontally and vertically by an X axis slider 7, a Y axis slider 8 and a Z axis slider 9. The movement of the work table 4 is made by transmitting movement signals to the respective sliders from the control unit 6 through a motor driver 10.

[0017] A blast processing is carried out by disposing the nozzle 3 at the predetermined position of the substrate 1 and injecting an injection material having predetermined mean particle diameters and a predetermined quantity from the nozzle 3 at predetermined pressure. Here, the inside diameter of the nozzle 3 is preferably 0.2 to 2 mm for the following reasons. If the inside diameter of the nozzle 3 exceeds 2 mm, the processing accuracy of the apparatus is deteriorated to make it difficult to conduct a desired microscopic processing. If the inside diameter of the nozzle 3 is less than 0.2 mm, the injection material becomes small in quantity and the polishing and cleaning performance of the nozzle 3 is deteriorated. In addition, if the diameter of the injection material is large enough to exceed 50 μm, the target substrate cannot be processed sufficiently and microscopically. If the mean particle diameter of the injection material is less than 5 μm, sufficient polishing and cleaning performances cannot be ensured. It is, therefore, preferable that the mean particle diameter of the injection material is 5 to 50 μm. It is noted that the material of the injection material is not limited to specific one and that powder such as alumina, SiC or silica sand can be appropriately used.

[0018] Moreover, according to the present invention, it is preferable that the injection material is injected by compressed air at a pressure of 0.2 to 2.5 MPa for the following reasons. If the pressure of the compressed air exceeds 2.5 MPa, the injection material is splashed and scattered to a large degree and the non-processing target regions of the substrate are badly damaged. On the other hand, if the pressure of the compressed air is less than 0.2 MPa, sufficient polishing and cleaning performance cannot be ensured. Besides, if the injection quantity of the injection material exceeds 50 g/min, the quantity of the injection material remaining in the holes disadvantageously increases during the perforating processing, which in turn deteriorates processing efficiency. It, therefore, suffices that the injection quantity of the injection material is not more than 50 g/min.

[0019] Further, to process the substrate, intermittent injection is conducted, at least partially, so that the injection of the injection material and the stop of the injection are alternately repeated at short intervals. That is, in the perforating processing, only intermittent injection is normally conducted. In a cutting processing and a stop processing, it is effective to combine intermittent injection for repeating the injection and the stop of injection at short intervals and continuous injection so as to inject the injection material. The injection in the combination of the intermittent injection and the continuous injection will now be described. In a cutting processing, it occurs less frequently that it becomes difficult to discharge the injection material in the middle of the processing as seen in the perforating processing. Due to this, in the cutting processing, it basically suffices to conduct only the continuous injection. If there are regions requiring a highly accurate processing, the intermittent injection may be partially conducted to such regions. Further, in the injection stop processing for temporarily stopping the injection of the injection material after the continuous injection, the intermittent injection is utilized right after the start of the processing and/or right before the end of the processing. The reasons are as follows. The hose is interposed between the injection material supply unit and the nozzle in the blasting processing apparatus. Due to this, if injection is temporarily stopped after the continuous injection, the injection material remaining in the hose is injected together with the next injection material when the next injection is started, with the result that processing accuracy is disadvantageously deteriorated. By utilizing the intermittent injection right after the start of the processing, the injection material remaining in the hose is not injected at a further stage. By utilizing the intermittent injection right before the end of the processing, a large quantity of the injection material does not remain in the hose.

[0020] Furthermore, the interval between injection and injection stop in this intermittent injection is preferably not more than 1 second. This is because if injection time and stop time exceed 1 second, respectively, processing efficiency and processing accuracy are deteriorated. Needless to say, the intermittent injection in this embodiment means that an injection material is intermittently injected to process the substrate. The continuous injection means that the injection material is continuously injected to process the substrate. If
the processing target portions of the substrate are located at required intervals and the processing target is moved from one processing target portion to the next processing target portion, then it is defined that the injection is continuous injection even if the injection is stopped during the movement of the processing target portions. In the intermittent injection of the injection material, the supply of either the compressed air or the injection material may be stopped. More preferably, the compressed air and the injection material are simultaneously stopped since the injection material remaining in the hose is not spread by a long distance.

[0021] Now, the present invention will be described in detail while referring to examples (in which an injection material was intermittently injected) and comparison examples (in which an injection material was continuously injected) conducted for a perforating processing.

[0022] In both the examples and the comparison examples, the above-stated high accuracy blast processing apparatus was employed. Using alumina powder having a mean particle diameter of 10 μm as an injection material, the injection material was injected to a soda lime glass plate having a thickness of 3 mm. After 5 minutes of the injection, the diameters of holes and the presence/absence of damages around the holes were examined. The injection conditions and processing results are shown in Table 1 below.

[0023] Table 1 → ANOTHER PAPER

[0024] In Table 1, test Nos. 1 to 4 show test results conducted under conditions that the inside diameter of the nozzle was 0.6 mm, air pressure was 1.0 MPa and the injection quantity of the injection material was 10 g/min.

[0025] In the test No. 3 as a comparison example shown in Table 1, after 5 minutes of continuous injection, the depth of a hole was 0.60 mm, the diameter of the hole was 1.40 mm and a cloud-shaped damage was generated around the hole due to the splashing of the injection material. In the test No. 1 as an example of the present invention, by contrast, the conditions were the same as those of the test No. 3 except that the processing was conducted by injecting the injection material intermittently for injection time of 0.04 sec and stop time of 0.04 sec. The depth of a hole after 5 minutes of the injection was 1.81 mm which was about three times as large as that in the comparison example, indicating that processing efficiency was largely improved. Also, the diameter of the hole after 5 minutes of the injection was 1.02 mm which was smaller than that in the test No. 3. That is, it was possible to form a highly accurate hole and no damage was seen around the hole.

[0026] Likewise, in the test No. 2 as the example of the present invention, the processing was conducted by injecting the injection material intermittently for injection time of 0.5 sec and stop time of 0.5 sec with the other conditions set the same as those of the test No. 3. The depth of a hole after 5 minutes of the injection was 1.21 mm which was smaller than that in the example of the test No. 1 but about twice as large as that in the comparison example of the test No. 3, thereby exhibiting high processing accuracy. Further, the diameter of the hole after 3 minutes of the injection was 1.15 mm which was smaller than that in the example of the test No. 1 but about twice as large as that in the comparison example of the test No. 3, making it possible to conduct the perforating processing without generating a damage with higher accuracy than that of the comparison example of the test No. 3. In the test No. 4 in which the injection of the injection material for 1.05 sec and the injection stop thereof for 1.05 sec were alternately repeated, the depth of the hole after 5 minutes was as small as 0.75 mm, the diameter of the hole was 1.31 mm and damage, though quite slightly, was generated around the hole. It was, however, confirmed that the test No. 4 was superior to the comparison example of the test No. 3.

[0027] Next, FIG. 2 shows the manners of changes in the depths of holes in the examples of the test Nos. 1 and 2 and the comparison example of the test No. 3 and FIG. 3 shows the manners of changes in the diameters thereof. As can be seen from FIGS. 2 and 3, the examples of the present invention ensured high processing efficiency and high processing accuracy from the initial period of the injection compared with the comparison example.

[0028] In addition, test Nos. 5 to 6 in Table 1 show test results conducted under the conditions that the inside diameter of the nozzle was 1.8 mm, the mean particle diameter of the injection material was 45 μm, air pressure was 2.5 MPa and the injection quantity of the injection material was 50 g/min. The example of the test No. 5 in which the injection material was injected intermittently, could attain higher processing efficiency and higher processing accuracy than those of the comparison example of the test No. 6 in which the injection material was continuously injected under the same conditions as those of the test No. 5. Further, in Table 1, test Nos. 7 to 8 show test results conducted under the conditions that the inside diameter of the nozzle was 0.2 mm, the mean particle diameter of the injection material was 5 μm, air pressure was 0.2 MPa and the injection quantity of the injection material was 2 g/min. In the example of the test No. 7 in which the injection material was intermittently injected, it was possible to conduct a perforating processing to the substrate with higher processing efficiency and higher processing accuracy than those of the comparison example of the test No. 8 in which the injection material was continuously injected under the same conditions as those of the test No. 7. In the examples of test Nos. 6 and 8, damages were seen around the holes. In the examples of the test Nos. 5 and 7, no damages were seen around the holes. It was, therefore, confirmed that it was possible to conduct a highly accurate blast processing by processing the substrate by intermittently injecting the injection material without using a mask such as a photo resist.

[0029] The high accuracy blast processing method according to the present invention is particularly optimum for locating a nozzle at a predetermined position and conducting a perforating processing. However, this method is also advantageous for scanning a nozzle and forming a large square recess. That is, by conducting intermittent injection only right after the start of the processing and right before the end of the processing to reduce the residual injection material in the hose and conducting intermittent injection only for processing the peripheral portion of the recess to prevent the occurrence of a damage on the outer peripheral portion of the recess, the outer peripheral portion is not damaged even if the injection material is continuously injected to the central portion of the recess and the injection material is removed without remaining in the recess. It is, therefore, possible to ensure a high speed processing. As can be seen, by appropriately combining the intermittent injection and the continuous injection of the injection material, it is possible to conduct a processing with high efficiency and high accuracy without the need to use a mask. Besides, in case of a cutting processing for the substrate, by intermittently injecting the injection material or combining the intermittent injection and the continuous injection, it is possible to cut the substrate at high speed with high dimensional accuracy without generating damage in the vicinity of the cut end face of the substrate.
What is claimed is:

1. A high accuracy blast processing method for processing a substrate by injecting an injection material from a nozzle by compressed air, wherein

   injection of the injection material is intermittent injection for repeating injection and injection stop at short intervals.

2. A high accuracy blast processing method for processing a substrate by injecting an injection material from a nozzle by compressed air, wherein

   injection of the injection material is a combination of intermittent injection for repeating injection and injection stop at short intervals and continuous injection.

3. A high accuracy blast processing method according to claim 1 or 2, wherein

   the injection and the injection stop of the intermittent injection are repeated at intervals of not more than 1 second.

4. A high accuracy blast processing method according to claim 1, 2 or 3, wherein

   the substrate is processed by injecting the injection material having a mean particle diameter of not more than 50 µm and an injection quantity of not more than 50 g/min from the nozzle having an inside diameter of 0.2 to 2 mm by the compressed air of 0.2 to 2.5 MPa.

5. A high accuracy blast processing apparatus comprising:

   a nozzle unit forcibly feeding an injection material to a nozzle by compressed air; and

   a work table moving a substrate horizontally and vertically, wherein

   a control unit outputting an intermittent operating signal for injecting and stopping the injection material is connected to said nozzle unit.

6. A high accuracy blast processing apparatus comprising:

   a nozzle unit forcibly feeding an injection material to a nozzle by compressed air; and

   a work table moving a substrate horizontally and vertically, wherein

   a solenoid valve for injecting and stopping the injection material and a control unit outputting an intermittent operating signal to the solenoid valve are connected to said nozzle unit.

7. A high accuracy blast processing apparatus according to claim 5 or 6, wherein

   the nozzle unit is constituted of the nozzle having an inside diameter of 0.2 to 2 mm and a mechanism for forcibly feeding the injection material having a mean particle diameter of not more than 50 µm in a quantity of not more than 50 g/min to the nozzle by the compressed air of 0.2 to 2.5 MPa.

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<th>injection material quantity (g/min)</th>
<th>injection time (sec)</th>
<th>stop time (sec)</th>
<th>after 5 minutes depth (mm)</th>
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TABLE 1