Blasting Method and Apparatus

A blasting apparatus and a blasting method enable a processing pattern to be enlarged or modified in a section type blasting apparatus by using a relatively simple composition, and also permit stable, continuous ejection of an abrasive in the enlarged or modified processing pattern. A nozzle (42) of a blast gun (40) of a section type blasting apparatus is surrounded by a nozzle cover (49) with a predetermined gap provided therebetween, and a passage (43) which is opened in an abrasive ejection direction between the outer periphery of the nozzle (42) and the inner periphery of the nozzle cover (49) is communicated with a supply source of compressed air. An abrasive dispersion chamber (52) serving as a dispersing nozzle is connected to an ejection port (47) of the blast gun (40).

13 Claims, 7 Drawing Sheets
**Fig. 3(A)**

Grinding Material

1st Compressed Air

2nd Compressed Air

10' 12' 13

14' 48 13'

**Fig. 3(B)**

2nd Compressed Air

Grinding Material

1st Compressed Air

10' 11 12' 12

14' 48 43 14 13'

13'
Fig. 8
1

BLASTING METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a blasting apparatus used for ejecting at high speed an abrasive or grinding material composed of natural silica sand, alumina or silicon carbide powder, glass beads, fine steel balls, etc., with a fluid such as air in order to form a sain finish pattern or other pattern on a workpiece, or to perform precision engraving of glass, silicon wafers, etc., engraving of the ribs of display plaques, coating engraving, the surface treatment such as coating pretreatment, or blasting for surface processing and more particularly, to a blasting method and a blasting apparatus which make it possible to enlarge or modify a processing shape (herein referred to as "processing pattern") which is to be formed on the surface of a workpiece, by ejecting an abrasive and also to ensure uniform blast density of the abrasive in the processing pattern.

2. Description of Prior Art

Hitherto, as a suction type blast gun for this type of blasting apparatus, a blast gun 10 shown in FIG. 9, for example, has been used. The blast gun 10 is equipped with a gun main body 11 which has an abrasive intake chamber 12 into which an abrasive is introduced through an abrasive introducing inlet 24 via an abrasive hose 31 from a recovery tank of a blasting apparatus. The abrasive intake chamber 12 has a conical inner surface 16 at the front end thereof, a nozzle 14 being provided at the conical inner surface 16.

The distal end of a jet 13 having the rear end thereof in communication with a supply source of compressed air, not shown, is inserted in the conical inner surface 16 from the rear of the abrasive intake chamber 12 so that compressed air having a relatively high pressure supplied from the supply source of compressed air, may be injected through the injection outlet at the distal end of the jet 13.

A cylindrical holder 15 has a tapered inner peripheral surface. The tapered portion of the outer peripheral nozzle 14 is fitted to the tapered portion of the inner periphery of the holder 15 and the threaded portion formed on the outer periphery of the holder 15 is screwed, for example, to the gun main body 11 so as to secure the nozzle 14 to the gun main body 11.

In the blast gun 10 constructed as described above, when high pressure air is injected through the distal end of the jet 13, which is in communication with the supply source of compressed air, via the hose 32, negative pressure is produced in the abrasive intake chamber 12. The negative pressure causes the abrasive in the recovery tank, not shown, to be sucked into the abrasive intake chamber 12 via the abrasive hose 31.

The abrasive in the abrasive intake chamber 12 is drawn into an annular gap between the conical inner surface 16 and the outer periphery of the jet 13, then it rides on an air stream injected from the jet 13 so that it is sprayed while conically dispersing outside the nozzle 14 to form an approximately circular processing pattern on the surface of a workpiece.

In such a conventional suction type blast gun 10, the inside diameter of the ejection hole of the jet 13 is made small in order to permit high speed air stream released from the jet 13; therefore, the effective injection range wherein uniform processing by an abrasive ejected with an air stream, which is emitted from the jet 13 and which has a small sectional area, can be achieved is determined by the inside diameter of the ejection hole of the nozzle 14, and the processing pattern is accordingly limited.

Hence, in order to carry out blasting on a workpiece to a desired pattern, it is required to move the blast gun 10 and or the workpiece or to take other similar measures to continue the intended pattern formed by the blast gun.

In the processing method described above, however, if a blast gun for a relatively small processing pattern is used, then the blast gun and or the workpiece must be moved over a large area. This requires relative long time to finish one processing cycle and also requires that the blast gun or the workpiece be moved accurately at a constant speed and at constant intervals in order to perform uniform processing on the workpiece, thus making the blasting difficult. For this reason, there has been a demand for developing a blast gun which permits a larger processing pattern and also a uniform blast density of an abrasive in the processing pattern.

The suction type blast gun, however, cannot meet the demand for a larger processing pattern by using such a simply method in which the inside diameter of the ejection hole, i.e. the nozzle diameter, of the blast gun 10 is increased.

If the inside diameter of the jet 13 is made larger to provide a larger processing pattern, then the injection speed and the injection pressure of the air stream emitted from the jet will decrease; therefore, in order to maintain the injection speed and the injection pressure at constant levels, it would be necessary to employ a larger compressor or the like, with a larger capacity as the supply source of compressed air, inevitably making the apparatus larger and more expensive.

If the inside diameter of the nozzle or the jet is increased to provide larger processing patterns, then the abrasive blast density in a processing pattern would be uneven, resulting in uneven blasting effects.

In view of the shortcomings of the prior art described above, the applicant has already applied the invention on a method and apparatus for increasing the width of a processing pattern by ejecting two air streams toward nearly the same positions with respect to the center of an injection stream of a mixed fluid composed of an abrasive and compressed air emitted from a blast gun in such a manner that they hold the jet stream of the mixed fluid therebetween (Japanese Patent Application No. 7-79163 applied on Apr. 4, 1995 not laid open before the convention date on which the present application is based).

According to the method and apparatus disclosed under Japanese Patent Application No. 7-79163, the processing pattern can be made significantly wider than that of a conventional blast gun and a uniform blast density of an abrasive in the processing pattern can be achieved.

The processing patterns produced by the aforementioned method is limited to circular or elliptic patterns, and it is difficult to change the processing patterns according to the material of the workpiece, the processing conditions, processing shape, etc., thus limiting the enlargement of the processing patterns.

In addition to the suction type blasting apparatus, there is a straight-hydraulic type blasting apparatus. In this straight-hydraulic type blasting apparatus, fine particles are sealed in an abrasive tank, compressed air is supplied into the tank, and the fine particles ejected through an outlet connected to the bottom of the tank are ejected with the compressed air through the nozzle; therefore, this type of blasting apparatus does not have the member corresponding to the jet of the suction type blasting apparatus, making it possible to easily enlarge the processing patterns by increasing the inside diameter of the nozzle. The straight-hydraulic blasting apparatus, however, has shortcomings such as the need for
stopping the blasting apparatus to supply the abrasive when the tank has run out of the abrasive, making it unsuitable for continuous processing based on continuous blast of an abrasive. In addition, the amount of injected abrasive varies, depending on the amount of the abrasive present in the abrasive tank, leading to such problems as variations in the processing accuracy as time elapses when an abrasive is ejected continuously for a predetermined time. Thus, the straight-hydraulic blasting apparatus is unsuitable especially for forming ribs or barriers of plasma displays or precision machining and micro-machining of sapphire, glass, silicon wafer, ceramics, or other materials used for semiconductors and other electronic equipment parts.

SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide a blasting method and a blasting apparatus which permit a processing pattern to be made wider and also permit the processing pattern shape to be changed as necessary in a suction type blasting apparatus which is able to continuously eject a stable amount of an abrasive, and also to provide a blasting method and an apparatus which allow highly accurate blasting with a uniform blasting density of an abrasive in an enlarged processing pattern.

To this end, according to one aspect of the present invention, there is provided a blasting method in which a nozzle 42 is disposed in the front of a jet 13 in communication with a supply source of compressed air in an air ejecting direction, an abrasive in an abrasive intake chamber 12 in communication with an abrasive supply source disposed between the jet 13 and the nozzle 42 is sucked in by an air stream emitted from the jet 13, and a mixed fluid of the abrasive and the compressed air is ejected through the nozzle 42 to the surface of a workpiece W;

wherein secondary compressed air, which has been supplied from the supply source of compressed air, is introduced at the front of the nozzle 42 in a mixed fluid ejecting direction and merged with the ejected stream of the mixed fluid, and an ejected stream of a secondary mixed fluid which has been merged with the secondary compressed air is injected in an abrasive dispersion space formed to have an arbitrary cross-sectional shape at the front in the secondary mixed fluid ejecting direction, and

ejected stream of the secondary mixed fluid, which has been introduced in the abrasive dispersion space, is rectified to the cross-sectional shape of the abrasive dispersion space and ejected to the surface of the workpiece.

Further according to another aspect of the present invention, there is provided a blasting apparatus equipped with a blast gun which draws in and ejects an abrasive supplied from an abrasive supply source by an air stream supplied from a supply source of compressed air, wherein the blast gun 40 is provided with a nozzle 42 in the air ejecting direction of a jet 13 in communication with the supply source of compressed air, an abrasive intake chamber 12 in communication with the abrasive supply source, between the jet 13 and the nozzle 42, and a nozzle cover 49 surrounding the nozzle 42 with a predetermined gap therebetween, and a passage 43 of compressed air in communication with the supply source of compressed air between the outer surface of the nozzle 42 and the inner surface of the nozzle cover 49, the passage 43 being opened in the ejecting direction of the nozzle 42 so as to merge the passage 43 at the front in the direction in which the mixed fluid is injected by the nozzle 42.

According to yet another aspect of the present invention, there is provided a blasting apparatus having a nozzle 42 at the front of the air ejecting direction of a jet 13 in communication with a supply source of compressed air, and a suction type blast gun 40 equipped with an abrasive intake chamber 12 in communication with an abrasive supply source, between the jet 13 and the nozzle 42 wherein the nozzle 42 of the blast gun 40 is projected in a merging chamber 48 in communication with the supply source of compressed air at the front in the ejecting direction of the nozzle, and the merging chamber 48 is communicated with an abrasive dispersion chamber 52 which is provided with an abrasive dispersion space having a section formed to an arbitrary shape, which introduces a blast stream of a secondary mixed fluid emitted from the merging chamber 48, and which rectifies the blast stream to the cross-sectional shape of the abrasive dispersion space and ejects it.

BRIEF DESCRIPTION OF THE DRAWINGS

The object and advantages of the invention will become understood from the following detailed description of preferred embodiments thereof in connection with the accompanying drawings in which like numerals designate like elements, and in which:

FIG. 1 is a longitudinal sectional view of a blast gun used in the present invention;

FIG. 2 is a sectional view at the line II—II of FIG. 1;

FIG. 3(A), (B) are longitudinally sectional views that provide a schematic representation of the embodiments of the present invention;

FIG. 4 is a perspective view illustrative of an embodiment of an abrasive dispersion chamber or a dispersion nozzle, according to the present invention;

FIG. 5 is a sectional view at the line IV—IV of FIG. 4;

FIG. 6 is a general schematic view of a blasting apparatus according to the present invention;

FIG. 7 is a general schematic view of the blasting apparatus according to the present invention;

FIG. 8 is a perspective view illustrative of the interior of an abrasive supply device according to the present invention, and

FIG. 9 is a sectional view illustrative of a known blast gun.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the entire configuration of a blasting apparatus in accordance with the present invention will now be described.

The blasting apparatus used in the embodiment is a pneumatic section type blasting apparatus as shown in FIG. 6 and FIG. 7. In FIG. 6 and FIG. 7, a cabinet 61 is equipped with a supplying port through which a workpiece W is loaded or unloaded; provided in the cabinet 61 is a blast gun 40 which is connected to an abrasive dispersion chamber 52 and which ejects an abrasive to the workpiece W fed through the supplying port.

A hopper 68 is provided at the bottom of the cabinet 61; the bottom end of the hopper 68 is communicated to the top of a recovery tank 70 for collecting an abrasive which is installed on the top of the cabinet 61 via a conduit 65.

The recovery tank 70 is a so-called cyclone collector for separating dust from an abrasive; it is constituted, as shown in FIG. 6, by a cylindrical section at the top and a conical section at the bottom which is gradually tapered toward the
An inlet pipe 83 is connected to the trailing end of the abrasive hose 31 in communication with the abrasive dispersion chamber 52 in the abrasive supply direction; the trailing end of the inlet pipe 83 has an inlet 84 which has approximately the same width as the circumferential surface of the gathering rotary board 81, and it is tapered from the inlet 84 toward the front in the abrasive supply direction. As shown in FIG. 8, the inlet 84 is shaped like a funnel and the full lengthwise dimension of the inlet 84 is set so that it can fully cover the width of the gathering rotary board 81, the inlet 84 being located nearly at the top of the circumferential surface of the gathering rotary board 81.

As the gathering rotary board 81 is turned clockwise in FIG. 8 at an equal velocity by the rotary driving means, the abrasive from the abrasive layer which has entered in the groove section 82 on the circumferential surface of the gathering rotary board 81 is transferred to the air layer 88. When compressed air is supplied from the supply source of compressed air to the nozzle, negative pressure is produced in the abrasive hose 31 and the inlet pipe 83, and the abrasive in the groove section 82 of the turning gathering rotary board 81 is sucked in through the inlet 84 at the circumferential top of the gathering rotary board 81, thus being supplied to the nozzle via the abrasive hose 31. The gathering rotary board 81 is turned at the equal velocity and the amount of the abrasive picked up by the circumferential surface of the gathering rotary board 81 is constant, so that the amount of the abrasive drawn in through the inlet 84 and supplied to the nozzle is accordingly constant. The edge of the inlet 84 functions as a scraper for removing excess abrasive from the circumferential surface of the gathering rotary board 81, contributing to ensure the constant amount of abrasive supplied.

The rotational speed of the gathering rotary board 81 may be adjusted to increase or decrease the amount of the abrasive supplied to the nozzle. For example, the rotational speed of the gathering rotary board 81 is increased to increase the amount of an abrasive to be supplied, while the rotational speed of the gathering rotary board 81 is decreased to decrease the amount of the abrasive to be supplied. Regardless of the set rotational speed, the gathering rotary board 81 is always maintained at a constant speed so as to stably supply a fixed amount of an abrasive to the nozzle which ejects the fixed amount of the abrasive to the workpiece at all times. Thus, the rotational speed of the gathering rotary board 81 and the amount of an abrasive supplied are correlated with each other; therefore, the amount of an abrasive supplied can be easily adjusted to a desired value by determining the above relational expression and by digitizing the amount of an abrasive supplied according to the rotational speed of the gathering rotary board 81.

A communicating pipe 74 is provided near at the center of the top end wall surface of the recovery tank 70; it is communicated with a dust collector 66 via a discharge pipe 67. The dust collector 66 actuates an exhaustor 69 to release the air in the dust collector 66 to open air. The exhaustor 69 draws out air from the cabinet 61, the conduit 65, and the recovery tank 70 to produce negative pressure in these components. The air supplied from the supply source of compressed air, not shown, is emitted with the abrasive from the abrasive dispersion chamber 52 via the blast gun 40, and the air stream runs from the cabinet 61 to the conduit 65, the recovery tank 70, and the dust collector 66.

According to the blasting method of the present invention, the blast stream of secondary compressed air is merged with
the blast stream of a primary mixed fluid generated from an abrasive and primary compressed air in order to generate a blast stream of a pressurized secondary mixed fluid.

As an example, a blast gun 10 shown in FIG. 9 and a blast gun which has a different shape of a jet 13 shown in FIG. 3B from an already-known one as it will be discussed later are prepared. Using these blast guns 10, 10', the primary mixed fluid generated from the primary compressed air is introduced from the blast gun 10 disposed at the rear of the blast gun 10 into an abrasive intake chamber 12 or the outer 13 of the blast gun 10 positioned at the front in the direction in which the abrasive as the primary mixed fluid is emitted as shown in FIG. 3A and FIG. 3B. The secondary compressed air is introduced into the jet 13 shown in FIG. 3A or the abrasive (referred as grinding material in FIG. 3) intake chamber 12 shown in FIG. 3B so as to form a merging chamber 48 between the front of the jet 13 and the nozzle 14 (FIG. 3A) and at the rear of the nozzle 14 (FIG. 3B) via a gap 43 at the inner wall of the nozzle main body 11 in front of the jet 13. This relatively easy method makes it possible to merge the secondary compressed air with the blast of the primary mixed fluid emitted by the primary compressed air from the already-known blast gun 10, or the blast stream of the primary mixed fluid generated from the primary compressed air emitted from the already-known blast gun 10 is merged with the blast stream of the secondary compressed air also referred as 1st and 2nd Compressed air in FIG. 3, respectively so as to generate the blast stream of the pressurized secondary mixed fluid. The entire apparatus can be made smaller by employing a blast gun 40. In FIG. 3B which omits details, there is a gap between the outer peripheral of the distal end of the jet-like member 13 and the inner wall of the gun main body 11, thus forming a passage 43 for the secondary compressed air.

In FIG. 1, the blast gun 40 is equipped with the gun main body 11. Formed in the gun main body 11 is the approximately cylindrical abrasive intake chamber 12 in communication with the abrasive introducing inlet 24 and through which an abrasive is drawn in from the recovery tank of the blasting apparatus via the abrasive hose 31. The front end of the abrasive intake chamber 12 has a conical inner surface 46.

Further, the distal end of the jet 13 inserted from thereof the abrasive intake chamber 12 is disposed in the abrasive intake chamber 12. The ejecting orifice of the jet 13 is disposed on the extension of the center line of the nozzle 14 inserted from the distal end of the gun main body 11 of the blast gun 40.

The jet 13 is communicated with a supply source of compressed air, not shown, via the hose 32. The blast gun of this embodiment is almost identical to the conventional blast gun 10 in that compressed air of a relatively high pressure is fed to the jet 13 via the hose 32.

In the blast gun 40 according to the present invention, as shown in FIG. 1, a nozzle 42 of the blast gun 40 is surrounded by a cylindrical nozzle cover 49 corresponding to the holder 15 of the gun main body 11 via a predetermined gap, and a passage 43 for passing the compressed air as the secondary compressed air for forcibly feeding an abrasive is formed between the of the nozzle 42 and the inner peripheral surface of the nozzle cover 49.

To be more specific, the nozzle 42 of the blast gun 40 according to the embodiment is equipped with a conical tapered surface on the outer periphery thereof, a base 42a inserted in the gun main body 11, and a cylindrical section 42b which is formed to have a cylindrical shape narrower than the base 42a. The nozzle 42 is fitted in the nozzle cover 49 having an inside diameter which is slightly larger than the outside diameter of the cylindrical section 42b of the nozzle 42 and also having an orifice which fits to the configuration of the base 42a of the nozzle at the rear end thereof. The rear end of the nozzle cover 49 is screwed or the like onto the gun main body 11 to secure the nozzle 42 and the nozzle cover 49 to the gun main body 11.

Then, the passage 43 through which the secondary compressed air for forcibly feeding an abrasive passes is formed via a bore 44 which will be discussed later and which is formed on the outer periphery of the nozzle cover 49 by the gap formed between the outer periphery of the cylindrical section 42b of the nozzle 14 and the inner peripheral surface of the nozzle cover 49.

A hose 34 through which the secondary compressed air for forcibly feeding an abrasive mentioned above is introduced is connected via a connecting fixture 46 to the bore 44 formed around the outer peripheral surface of the nozzle cover 49, the outer end of the hose 34 is in communication with the supply source of compressed air which is not shown.

The outer periphery of one end of an approximately cylindrical merging nozzle 45 is secured by screwing or the like to the inner periphery of the tip of the nozzle cover 49. The cylindrical merging nozzle 45 jets out in the ejecting direction beyond the distal end of the nozzle 42, a merging chamber 48 wherein the blast of the primary mixed fluid merges with the secondary compressed air for forcibly feeding an abrasive is formed in the merging nozzle 45.

When compressed air of a relatively high pressure is supplied via the hose 32 connected to the rear end of the jet 13 of the blast gun 40 constructed as described above, the primary compressed air is ejected from the distal end of the jet 13 into the abrasive intake chamber 12 formed in the gun main body 11. Then, the negative pressure generated by the compressed air emitted from the distal end of the jet 13 causes an abrasive to be drawn from an abrasive tank, not shown, into the abrasive intake chamber 12, and the abrasive which has been thus drawn in is ejected together with an air stream, which has been emitted from the jet 13, from the nozzle 42 of the blast gun 10. At the moment the abrasive is ejected from the nozzle 42, the blast range of the abrasive is proportional to the diameter of an injection orifice 18 at the distal end of the nozzle 42. The moment the compressed air is supplied to the jet 13, the secondary compressed air for forcibly feeding the abrasive is supplied to the passage 43, which is formed between the inner periphery of the nozzle cover 49 and the outer periphery of the nozzle 42, via the bore 44 provided in the nozzle cover 49; and the secondary compressed air released toward the injection orifice 18 of the nozzle 42 surrounds and merges with the blast stream of the primary mixed fluid ejected from the nozzle 42.

The secondary compressed air for forcibly feeding the abrasive, which has been introduced through the bore 44 of the nozzle cover 49, is ejected to the blast stream of the primary mixed fluid emitted from the nozzle 42 to merge them so as to produce the secondary mixed fluid. This causes the blast stream of the secondary mixed fluid to have a high pressure and disperse. Hence, the processing pattern formed by the blast stream of the secondary mixed fluid ejected by the blast gun 40 is enlarged to the configuration of an ejection port 47 at the distal end of the merging chamber 48, while maintaining the abrasive blast pressure and the blast density uniform in the processing pattern at fixed levels.
The abrasive dispersion chamber 52 into which the secondary mixed fluid composed of the abrasive and the secondary compressed air emitted from the blast gun 40 is introduced and which emits it in the form of a blast stream having a desired shape of cross section is connected to the ejection port 47 of the blast gun 40. This enables the processing pattern to be formed to the shape of the cross section of the abrasive dispersion chamber 52.

As shown in FIG. 4 and FIG. 5, this abrasive dispersion chamber 52 can be directly connected to the distal end of the blast gun 40, in this embodiment, however, the abrasive dispersion chamber 52 is communicated to the blast gun 40 via a hose 33 which is secured to the inner periphery of the nozzle cover 49 of the blast gun 40 and which is connected to a cylindrical merging nozzle 45 jetting out in the abrasive ejection direction.

The abrasive dispersion chamber 52 functions to introduce the blast stream of the secondary mixed fluid composed of the abrasive and the secondary compressed air emitted from the blast gun 40 and rectify the blast stream to the shape of the cross section of the abrasive dispersion chamber 52 before ejecting it so as to increase the width of a processing pattern. For this purpose, the abrasive dispersion chamber 52 has an abrasive dispersion space for dispersing and rectifying the secondary mixed fluid composed of the abrasive and the secondary compressed air introduced from the blast gun 40.

The abrasive dispersion space is formed such that it is wider toward a communicating orifice 55 and narrower toward an abrasive ejection orifice 54. More specifically, the abrasive dispersion chamber 52 according to this embodiment is formed to have a rectangular cross section measuring 30 mm by 100 mm for a length of 100 mm from the communicating orifice 55 toward the abrasive ejection orifice 54, and the rectangular space continues to an abrasive dispersion section 52a which is gradually tapered from the 30-mm width and which continues to an abrasive rectifying section 52b measuring 0.7 mm by 100 mm. The abrasive rectifying section 52b is formed to have the same rectangular cross section as the abrasive ejection orifice 54; it is 50 mm long.

In this embodiment, the abrasive ejection orifice 54 and the abrasive rectifying section 52b are formed to have the 0.7-mm short sides as mentioned above; however, the short sides may be changed within the range of 0.05 mm to 5 mm according to the type of material of a workpiece, processing conditions, required processing accuracy, etc. When using a pulsed abrasive of #240 to #3000 (average particle diameter: 5 μ to 80 μ according to JIS6001), it is preferable that the short sides are 0.1 mm to 3 mm because if they are smaller than 0.1 mm, then the air drag on the inner wall surface of the abrasive rectifying section 52b increases, whereas if they are larger than 3 mm, then the problem set forth below would arise when the pulsed abrasive which has been ejected from the abrasive rectifying section 52b bumps against a workpiece and reflects.

A part of the abrasive jetted from the center in the depth direction of abrasive rectifying section 52b bounces nearly perpendicularly when it hits the workpiece and reflects, and the bounced abrasive bumps against the following ejected abrasive, causing various problems in which the abrasive accumulates on the bottoms of line grooves to be processed, or the energy of the subsequent abrasive is exhausted, or the abrasive reflects in random directions and the abrasive hits the side walls surfaces of the fine grooves to be processed, scraping the side wall surfaces.

Preferably, the long side of the cross section of the abrasive rectifying section 52b is at least ten times as long as the short side. Specifically, when the short side is 0.1 mm to 3 mm, the long side should be 25 mm to 500 mm. Further, the abrasive rectifying section 52b is preferably at least ten times as long as the short side of the cross section to impart straightness to ejected abrasive.

The shape of the abrasive dispersion section 52a is not limited to the aforesaid trapezoid in cross section; it may alternatively be an inverse triangular shape, etc. in cross section. Likewise, the shape of the abrasive ejection orifice 54 is not limited to the long, narrow rectangle; the ejection orifice 54 may alternately have a long, narrow cross section composed of a combination of an arc part of an ellipse or other curve such as an ellipse and a straight line or the like.

Forming the abrasive ejection orifice 54 of the abrasive dispersion chamber 52 to a long, narrow shape makes it possible to increase the width of the processing pattern. For instance, when performing such machining as grinding for forming a plurality of parallel line grooves to produce the ribs of a plasma display panel (PDP), positioning the long sides of the abrasive jetting orifice 54 orthogonally in relation to the moving direction of the blast gun or a workpiece and setting the moving direction in parallel to the lengths of the recessions or grooves to be formed on the workpiece make it possible to form many grooves or recessed portions at the same time while making the grinding depths of the grooves approximately the same, thus permitting higher machining accuracy.

When the blast gun 40 or 10 is communicated with the communicating orifice 55 of the abrasive dispersion chamber 52 configured as described above via the hose 33 connected to the distal end of the blast gun 40, the abrasive dispersion chamber 48 in communication with the supply source of compressed air to introduce the blast stream of the secondary mixed fluid into the abrasive dispersion chamber 52, the blast of the secondary mixed fluid, the pressure of which has been increased from the merging with the secondary compressed air, disperses in the abrasive dispersion section 52a. Then, the abrasive in the secondary mixed fluid bumps against both side walls 58, 59 of the long sides of the rectangular cross section of the abrasive dispersion section 52a of the abrasive dispersion chamber 52, and changes its direction before it disperses.

Subsequently, the secondary mixed fluid is pushed out to the abrasive rectifying section 52b continuing from the abrasive dispersion section 52a, and the cross section of the secondary mixed fluid is changed to the long, narrow shape in the abrasive rectifying section 52b. The internal pressure of the abrasive dispersion section 52a is further increased to promote the dispersion of the secondary mixed fluid, and the secondary mixed fluid introduced into the abrasive rectifying section 52b is rectified in the abrasive rectifying section 52b and imparted straightness before it is projected through the abrasive ejection orifice 54.

In this embodiment, the abrasive ejection orifice 54 corresponding to the long sides is linear in the horizontal direction. The abrasive ejection orifice 54, however, may be angled to a short side; in this case, the cutting effect or the depth may be changed according to different blasting distances.

Preferably, especially when a pulsed abrasive is used, the distance from the abrasive ejection orifice 54 of the abrasive on the bottom of abrasive rectifying section 52b to a workpiece is approximately 200 mm or less which hardly affects the cutting depth. This is because an abrasive would lose its straight advancing property if the injecting distance is excessively long.
Thus, the blast of the secondary mixed fluid ejected from the blast gun 40 can be easily enlarged to the shape of the cross section of the abrasive rectifying section 52. In addition, the abrasive density of the abrasive in the cross section of the abrasive blast is maintained at a constant level, permitting uniform machining of a workpiece in the processing pattern.

The following shows the results of machining workpieces by using a blasting apparatus which incorporates the blast gun 40 and the abrasive dispersion chamber 52 constructed as described above.

**Processing Example 1**

**[Table 1]**

<table>
<thead>
<tr>
<th>Processing Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast Gun</td>
</tr>
<tr>
<td>Jet injection orifice inside diameter: 1.0 mm</td>
</tr>
<tr>
<td>Jet: compressed air pressure: 5 kg/cm²</td>
</tr>
<tr>
<td>Nozzle injection orifice: 1.0 mm</td>
</tr>
<tr>
<td>Secondary compressed air pressure: 1.3 kg/cm²</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abrasive Dispersion Chamber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasive dispersion section</td>
</tr>
<tr>
<td>----------------------------</td>
</tr>
<tr>
<td>Straight portion</td>
</tr>
<tr>
<td>Tapered portion</td>
</tr>
<tr>
<td>Abrasive rectifying section</td>
</tr>
<tr>
<td>Abrasive injection port</td>
</tr>
</tbody>
</table>

Amount of abrasive injected: 250 g
Distance between workpiece and abrasive injection port: 10 mm
Type of abrasive: Carbon dioxide
Primary mixed air pressure: 10 kg/cm²
Type of workpiece: Glass plate (Soda glass)

Under the processing conditions shown above, the nozzle was fixed and the abrasive was injected for one minute. As a result, an orifice almost as large as the abrasive injection port 54 of the dispersion nozzle 51 was cut on the workpiece.

The cut orifice was 380 μm deep and it had a flat bottom with an approximately uniform rectangular cross section. From this result, it is understood that the blasting apparatus in accordance with the present invention is able to increase the width of the processing pattern to 25 mm, 33 mm, and 50 mm by changing the length of the jet nozzle. It is also possible to change the abrasive density of the abrasive in the processing pattern.

Hence, the blasting apparatus according to the present invention is suitably applied to the blasting wherein high accuracy is required as in the applications of precision machining and micro-machining.

**Processing Example 2**

A silicon wafer as a workpiece was machined under the same processing conditions as in Processing Example 1 except that the secondary compressed air pressure was set to 1.0 kg/cm².

As a result of one-minute injection of the abrasive to the workpiece under the processing conditions mentioned above, an orifice approximately as large as the jet nozzle of the dispersion nozzle 51 was formed on the workpiece.

The orifice was 350 μm deep and it had an even depth and a flat bottom, proving that the abrasive injection density in the enlarged processing pattern is uniform.
a secondary mixed fluid produced by merging said primary mixed fluid and said secondary compressed air is introduced into an abrasive dispersion space;

said abrasive dispersion space being composed of an abrasive dispersion section, the cross section of which in the width direction is gradually narrowed toward the direction in which said secondary mixed fluid is ejected, an abrasive rectifying section formed in front of said abrasive dispersion section and having a rectangular cross section, the cross-sectional shape of said secondary mixed fluid being rectified to the cross-sectional shape of said abrasive dispersion space; and

said secondary mixed fluid being injected to the surface of a workpiece.

2. A blasting method according to claim 1, wherein:

the blast stream of said primary mixed fluid is introduced into a merging chamber disposed in front of said nozzle in the direction in which said mixed fluid is ejected; said secondary compressed air supplied from said supply source of compressed air is introduced into said merging chamber;

the blast stream of said primary mixed fluid is merged with said secondary compressed air; and said secondary mixed fluid produced by merging said primary mixed fluid with said secondary compressed air is introduced into abrasive dispersion space at the front in the direction in which said secondary mixed fluid is ejected.

3. A blasting method according to claim 2, wherein the abrasive dispersion section has a long side extending in the direction of the major axis of the cross section the major axis of the cross section of said abrasive dispersion space which is oriented such that it is orthogonal in relation to the moving direction of a blast gun or a workpiece, and said moving direction being parallel to the longitudinal direction of a recessed portion or groove to be formed on said workpiece.

4. A blasting method according to claim 2, wherein said abrasive rectifying space has a cross section composed of a long side or a major axis which is at least ten times longer than a short side or a minor axis and has a height which is at least ten times higher than said short side or said minor axis.

5. A blasting method according to claim 1, wherein said abrasive rectifying section is narrow and long, the short side or the minor axis of the cross section thereof being 0.1 mm to 5 mm, and the long side or the major axis being 25 mm to 500 mm.

6. A blasting method according to claim 1, wherein the cross section of the abrasive dispersion space has a long side or major axis oriented such that the long side or major axis is orthogonal in relation to the moving direction of blast gun or a workpiece, and wherein said moving direction is parallel to the longitudinal direction of a recessed portion or a groove to be formed on said workpiece.

7. A blasting apparatus comprising a section type blast gun equipped with a nozzle at the front of the air ejecting direction of a jet in communication with a supply source at the front of the air ejecting direction of a jet in communication with a supply source of compressed air and an abrasive intake chamber in communication with an abrasive supply source between said jet and said nozzle; wherein

the nozzle of said blast gun is projected into a merging chamber in communication with said supply source of compressed air in front of said nozzle in the ejecting direction and said merging chamber being in communication with an abrasive dispersion chamber;

said abrasive dispersion chamber defining a space composed of an abrasive dispersion section, the cross section of which in the width direction is gradually narrowed toward the direction in which said secondary mixed fluid is ejected, and an abrasive rectifying section formed in front of said abrasive dispersion section and having a rectangular cross section, the blast stream of a secondary mixed fluid emitted from said merging chamber being rectified to the cross-sectional shape of said abrasive dispersion chamber and ejected.

8. A blasting apparatus according to claim 6, wherein said abrasive dispersion chamber has a long, narrow rectangular cross section having a long side or major axis which is at least ten times longer than a short side or minor axis, said cross section being maintain for a length which is at least ten times longer than said short side or said minor axis, and the chamber being provided with an abrasive ejection aperture for ejecting an abrasive at a front end thereof.

9. A blasting apparatus according to claim 7, wherein said abrasive dispersion chamber has a narrow, long cross section, the short side or the minor axis thereof being 0.1 mm to 3 mm and the long side or the major axis thereof being 25 mm to 500 mm.

10. A blasting apparatus according to claim 6, wherein said abrasive dispersion chamber comprises an abrasive dispersion section, the cross section of which becomes gradually smaller widthwise in the direction in which said secondary mixed fluid is ejected, and an abrasive rectifying section which is formed in front of said abrasive dispersion section and which has a rectangular cross section.

11. A blasting apparatus according to claim 7, wherein said abrasive dispersion chamber has a long, narrow rectangular cross section having a long side or a major axis of which is at least ten times longer than a short side or minor axis, said cross section being maintain for a length which is at least ten times said short side or said minor axis, and the chamber being provided with an abrasive ejection aperture for ejecting an abrasive at a front end thereof.

12. A blasting apparatus according to claim 7, wherein said abrasive dispersion chamber has a narrow, long cross section, the short side or the minor axis thereof being 0.1 mm to 3 mm and the long side or the major axis thereof being 25 mm to 500 mm.

13. Blasting apparatus according to claim 7, wherein said blast gun has a compressed air passage in communication with said supply source of compressed air between the outer surface of said nozzle and the inner surface of a component such as a nozzle cover or a gun body which surrounds said nozzle with a predetermined gap therebetween so as to permit purging with the blast stream of said mixed fluid in front of said nozzle in the direction in which said mixed fluid is ejected.