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Kanda

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[54] **BLASTING METHOD AND APPARATUS**

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[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**^{6} **B24C 5/04**

[52] **U.S. Cl.** **451/38**; 451/102

[58] **Field of Search** 451/102, 90, 78, 451/38, 39, 75

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Primary Examiner—Robert A. Rose
Attorney, Agent, or Firm—Millen, White, Zelano, & Branigan, P.C.

[57] **ABSTRACT**

A blasting apparatus and a blasting method enable a processing pattern to be enlarged or modified in a suction 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 suction 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 ejecting 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

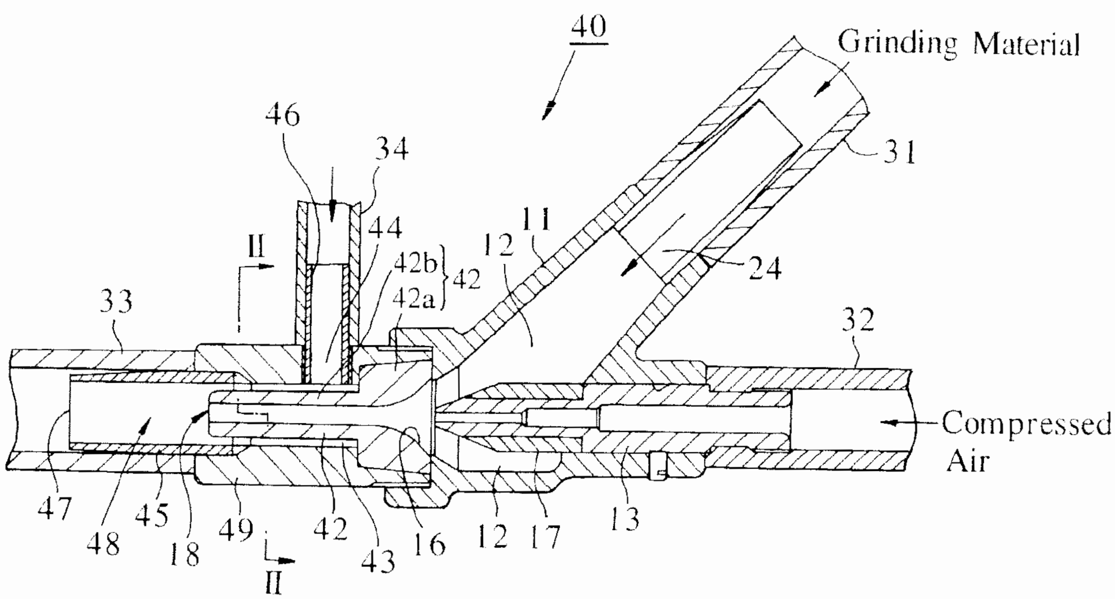
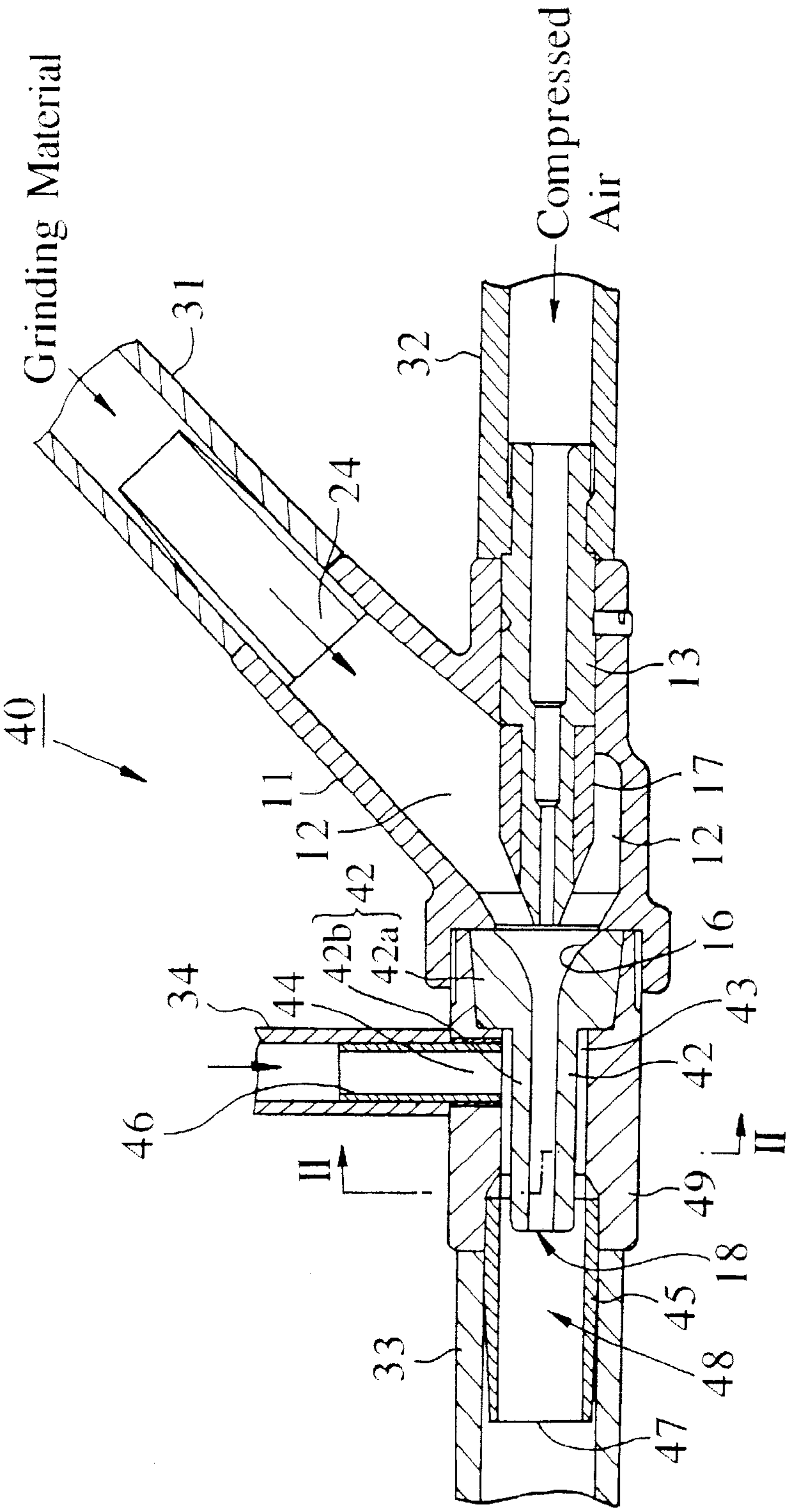


Fig. 1



Grinding Material
Compressed Air
40
31
32
24
13
11
12
17
12
42
42b
42a
16
34
44
43
42
46
II
II
49
18
45
33
48
47

Fig.2

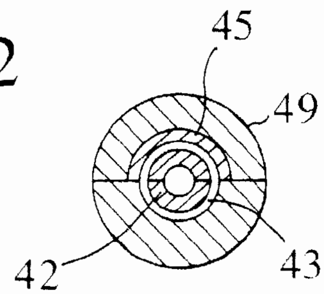


Fig.4

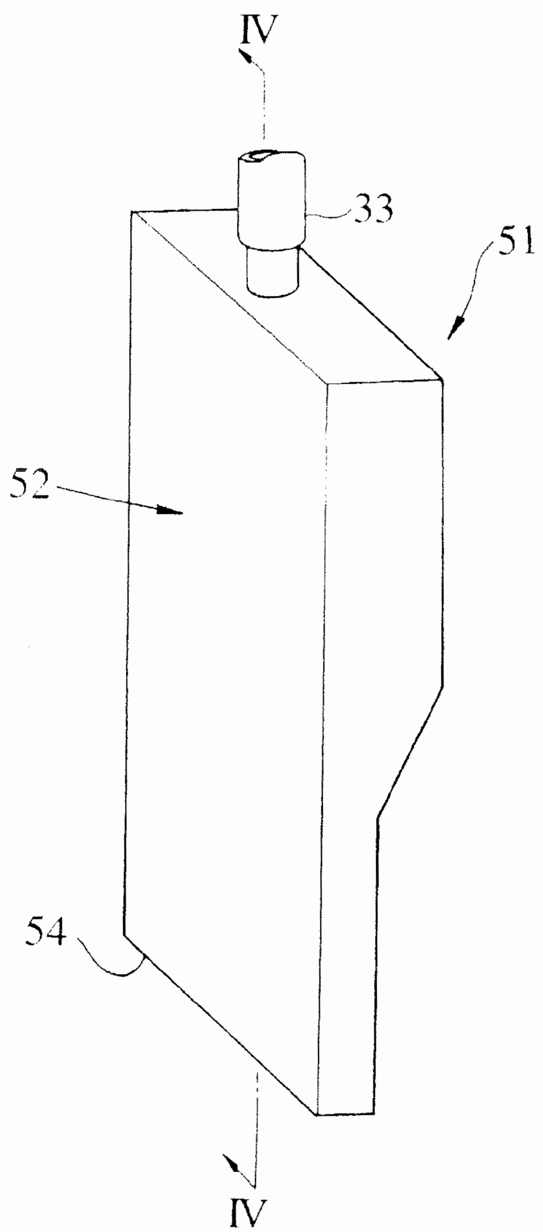


Fig.5

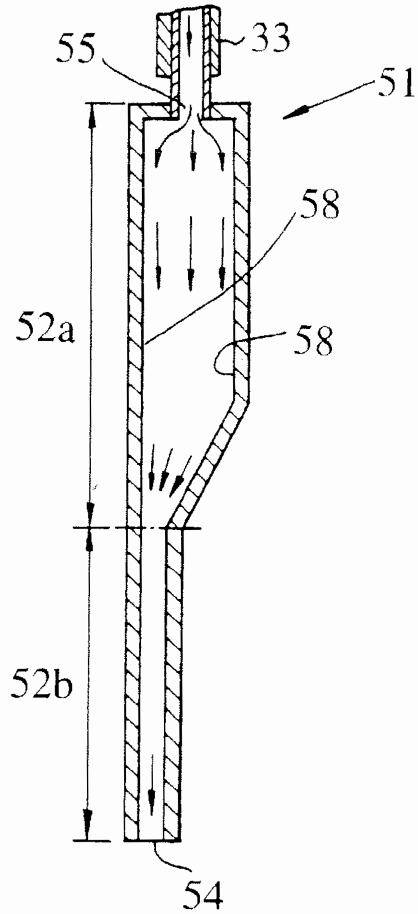


Fig.3(A)

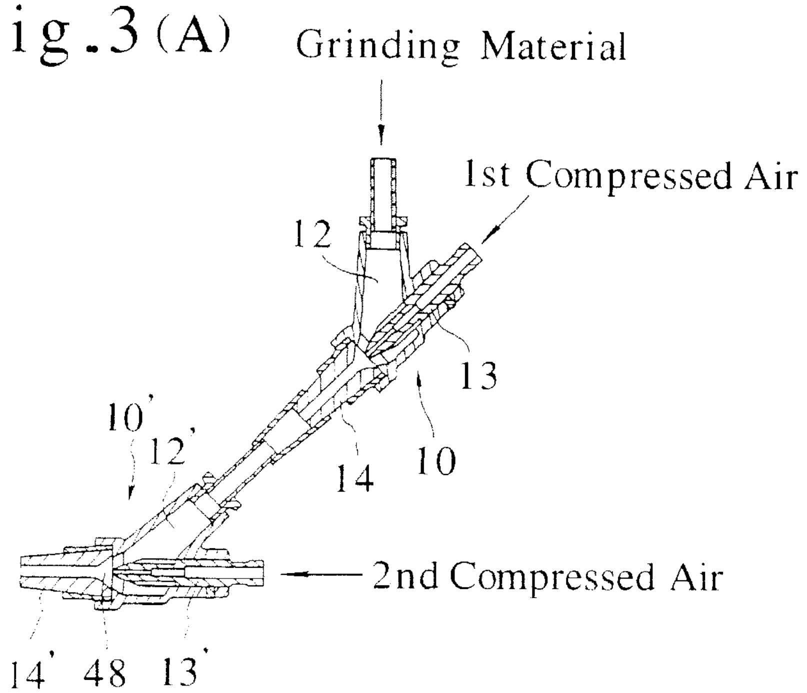

Grinding Material
1st Compressed Air
12
13
10'
12'
14
10
2nd Compressed Air
14'
48
13'

Fig.3(B)

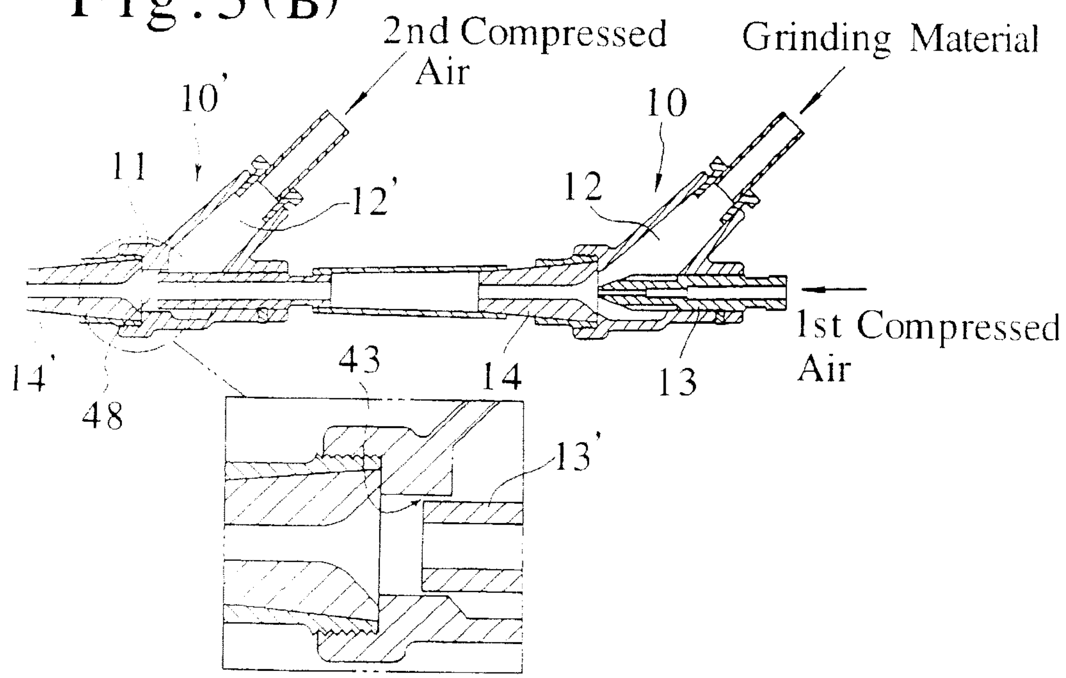

2nd Compressed Air
Grinding Material
10'
10
11
12'
12
1st Compressed Air
14'
48
43
14
13
13'

Fig.6

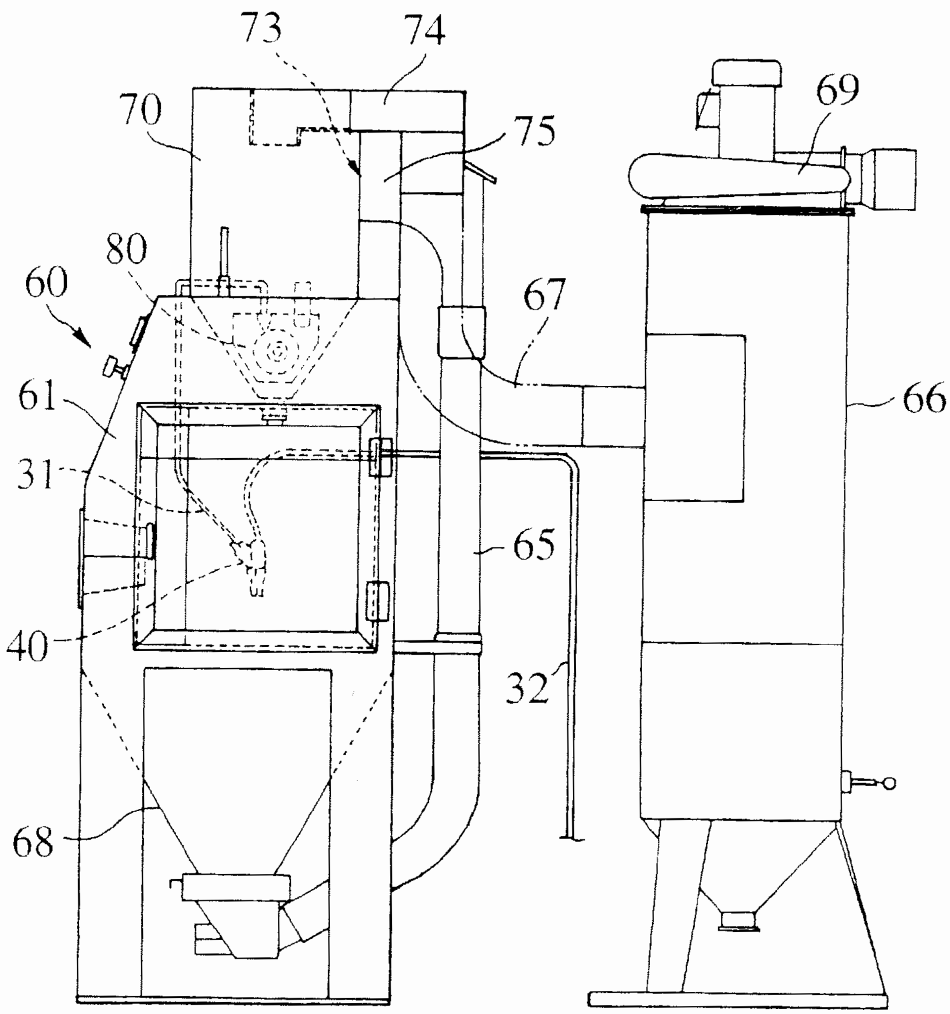


Fig. 7

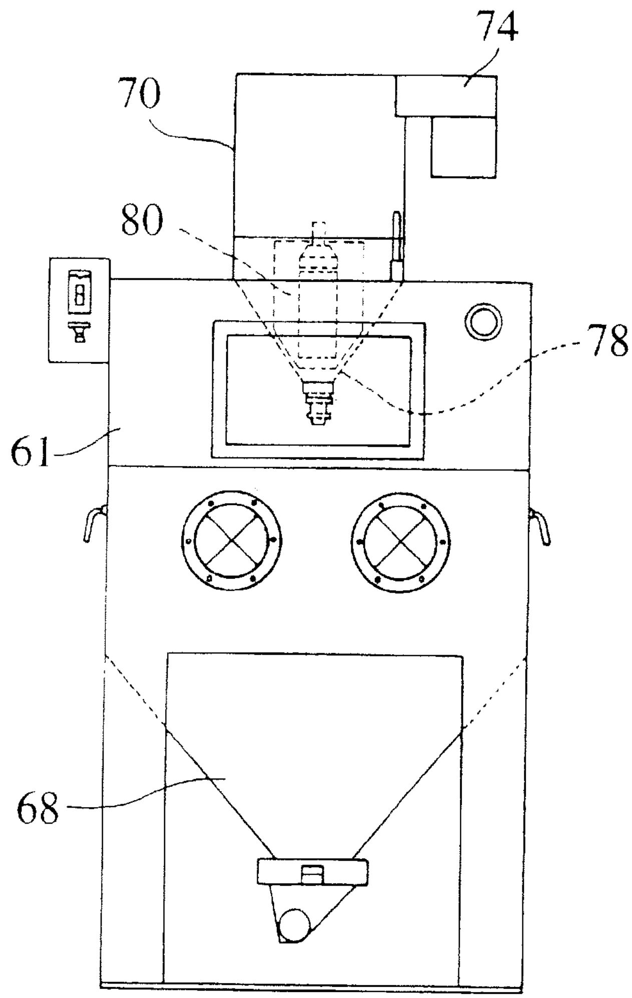


Fig.8

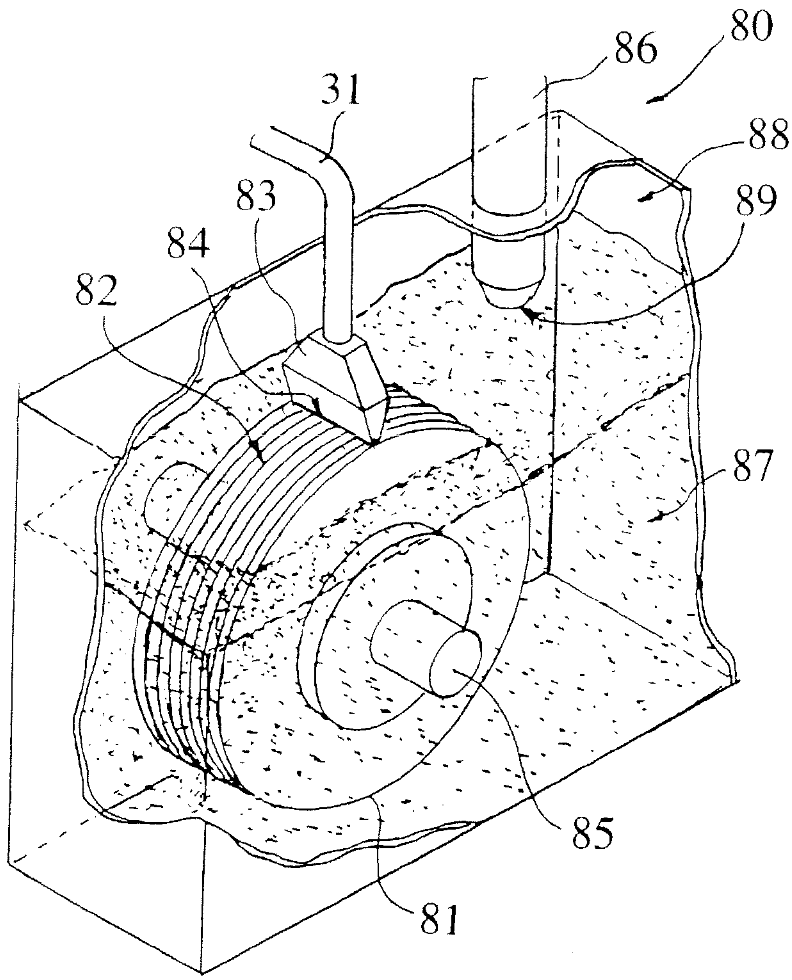
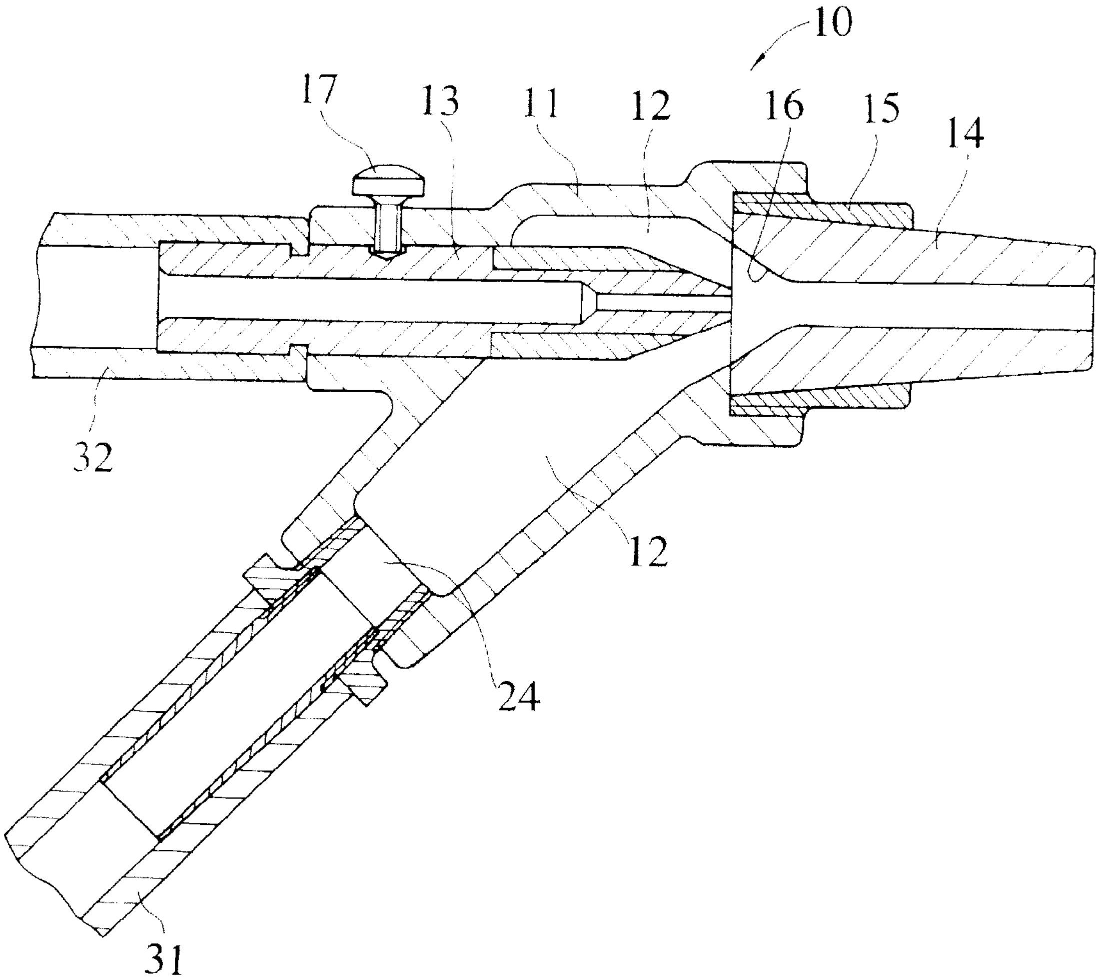


Fig. 9



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 satin finish pattern or other pattern on a workpiece, or to perform precision engraving of glass, silicon wafers, etc., engraving of the ribs of plasma displays, 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 after 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 of 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 nozzle **14** 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 aforesaid 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

an 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 fragmentary 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 suction 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 cyclon 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 bottom. An inlet **73** is formed on the top side wall of the cylindrical section of the recovery tank **70**; an end of the conduit **65** is connected to the inlet **73** via a communicating tube **75**.

The axis of the communicating tube **75** is positioned in the tangent direction of the inner wall surface of the cylindrical section having a circular cross section; therefore, an air stream introduced into the recovery tank **70** through the communicating tube **75** moves down while turning along the inner wall of the cylindrical section.

At the bottom end of the conical section of the recovery tank **70**, there is an abrasive supply device **80** for regulating the amount of the abrasive ejected from the abrasive dispersion chamber **52**; the blast gun **40**, to which the abrasive dispersion chamber **52** is connected, is communicated with the abrasive supply device **80**.

In FIG. **8**, an introducing pipe **86** communicating with the bottom of the recovery tank **70** is inserted into the abrasive supply device **80** from the top wall surface thereof; the surface of an inlet **89** at the distal end of the introducing pipe **86** is positioned at a height about two thirds of the height from the bottom surface of the abrasive supply device **80**. Thus, an abrasive in the recovery tank **70** drops into the abrasive supply device **80** located below via the introducing pipe **86** to form an abrasive layer below the inlet **89**, the abrasive layer being composed of the abrasive building up on the bottom inside the abrasive supply device **80**. An air layer **88** is formed on the abrasive layer. As the abrasive flows from the recovery tank **70** into the abrasive supply device **80**, the top surface of the abrasive layer goes up until it reaches the height of the inlet **89** of the introducing pipe **86**. This means that when the top surface of the abrasive layer rises to the inlet **89**, the abrasive in the recovery tank **70** no longer moves into the abrasive supply device **80**. Hence, approximately one third of the upper portion of the abrasive supply device **80** is always filled with the air layer **88**, whereas approximately two thirds of the lower portion thereof are always filled with the abrasive layer.

A gathering rotary board **81** has a groove section **82** composed of a plurality of endless, continuous V-shaped grooves arranged in parallel widthwise on the circumferential surface of the gathering rotary board **81** in the circumferential direction. The gathering rotary board **81** is longitudinally rotatably supported by a rotary shaft **85** via a bearing in the abrasive layer in the abrasive supply device **80**. The rotary shaft **85** is positioned below the top surface of the abrasive layer, whereas a part of the upper or lower portion of the gathering rotary board **81** is positioned such that it is exposed to the air layer **88**; the upper portion of the gathering rotary board **81** refers to the area located above the horizontal line passing through the center of the rotary shaft of the gathering rotary board **81**. Thus, in this embodiment, the full circumferential lower half of the gathering rotary board **81** is securely sunk in the abrasive layer, while a part of the circumferential upper half of the gathering rotary board **81** is exposed to the air layer **88**. Hence, when the gathering rotary board **81** rotates, the abrasive easily moves into the groove section **82** and the abrasive of the abrasive layer is securely transferred to the air layer **88** since the circumferential upper half of the gathering rotary board **81** is partly buried in the abrasive layer.

The rotary shaft **85** is supported by the bearing, not shown, outside the abrasive supply device **80**; it is connected to a rotary driving means such as a motor via a V belt attached to a pulley provided on an end of the rotary shaft **85** to transmit torque. The rotational speed of the rotary driving means can be easily adjusted by a known means.

An intake 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 intake 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 intake 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 nearly 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 exhauster **69** to release the air in the dust collector **66** to open air. The exhauster **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 jet **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 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 periphery 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** or 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 **42***a* inserted in the gun main body **11**, and a cylindrical section **42***b* which is formed to have a cylindrical shape narrower than the base **42***a*. 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 **42***b* of the nozzle **42** and also having an orifice which fits to the configuration of the base **42***a* 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 **42***b* 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 other 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 streams 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 ejecting 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 ejecting 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 ejecting orifice **54**, and the rectangular space continues to an abrasive dispersion section **52***a* which is gradually tapered from the 30-mm width and which continues to an abrasive rectifying section **54***b* measuring 0.7 mm by 100 mm. The abrasive rectifying section **52***b* is formed to have the same rectangular cross section as the abrasive ejecting orifice **54**; it is 50 mm long.

In this embodiment, the abrasive ejecting orifice **54** and the abrasive rectifying section **52***b* are formed to have the 0.7-mm short sides as mentioned above; however, the short sides maybe 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 pulverized abrasive of #240 to #3000 (average particle diameter: 5μ to 80μ 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 mmn, then the drag on the inner wall surface of the abrasive rectifying section **52***b* increases, whereas if they are larger than 3 mm, then the problem set forth below would arise when the pulverized abrasive which has been ejected from the abrasive rectifying section **52***b* bumps against a workpiece and reflects.

A part of the abrasive jetted from the center in the depth direction of abrasive rectifying section **52***b* 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 fine 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 wall 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 **52***b* 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 **52***b* 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 **52***a* 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 ejecting orifice **54** is not limited to the long, narrow rectangle; the ejecting 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 undulation and a straight line or the like.

Forming the abrasive ejecting 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 fine 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** or the merging chamber **48** in communication with the supply source of compressed air to introduce the blast stream of the second 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 **52***a*. Then, the abrasive in the secondary mixed fluid bumps against both side walls **58**, **58** of the long sides of the rectangular cross section of the abrasive dispersion section **52***a* 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 **52***b* continuing from the abrasive dispersion section **52***a*, and the cross section of the secondary mixed fluid is changed to the long, narrow shape in the abrasive rectifying section **52***b*. The internal pressure of the abrasive dispersion section **52***a* is further increased to promote the dispersion of the secondary mixed fluid, and the secondary mixed fluid introduced into the abrasive rectifying section **52***b* is rectified in the abrasive rectifying section **52***b* and imparted straightness before it is projected through the abrasive ejecting orifice **54**.

In this embodiment, the abrasive ejecting orifice **54** corresponding to the long sides is linear in the horizontal direction. The abrasive ejecting 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 pulverized abrasive is used, the distance from the abrasive ejecting orifice **54** of the abrasive rectifying section **52***b* 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***b*. In addition, the blast 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]

Processing Condition			
Blast Gun			
Jet injection orifice inside diameter (I.D.): 3.2 mm			
Jet compressed air pressure: 5 kg/cm^2			
Nozzle injection orifice I.D.: 7.0 mm			
Secondary compressed air pressure: 1.5 kg/cm^2			
Abrasive Dispersion Chamber			
Abrasive dispersion section:	Long side	Short side	Height
Straight portion	100 mm	30 mm	100 mm
Tapered portion	100 mm		30 mm
Abrasive rectifying section:	100 mm	0.7 mm	50 mm
Abrasive injection port:	100 mm	0.7 mm	
Amount of abrasive injected: 250 g/s			
Distance between workpiece and abrasive injection port: 10 mm			
Type of abrasive: Carborundum #600			
Secondary compressed air pressure: 1.5 kg/cm^2			
Type of workpiece: Glass pane (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 μ 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 about 31 times the inside diameter of the injection orifice of the jet of the blast gun or about 14 times the inside diameter of the nozzle injection orifice and it is also able to ensure a uniform injection 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/cm^2.

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 injection port of the dispersion nozzle **51** was cut on the workpiece.

The orifice was 350 μ deep and it had an even depth and a flat bottom, proving that the abrasive injection density in the enlarged processing pattern is uniform.

Thus, according to the blasting method and the blasting apparatus in accordance with the present invention, a processing pattern can be easily enlarged or changed in a suction type blasting apparatus, and the injection density of an abrasive in the enlarged or changed processing pattern can be made uniform.

Moreover, according to the blasting method and the blasting apparatus in accordance with the present invention which employ the abrasive dispersion chamber **52** enable a processing pattern to be further enlarged or changed, and the injection density of an abrasive in the enlarged or changed processing pattern can be made even. The processing pattern can be changed to a desired shape.

Furthermore, according to the blasting apparatus of the present invention, a processing pattern can be easily enlarged by replacing the blast gun of a conventional blasting apparatus or by installing the blast gun and the abrasive dispersion chamber in accordance with this invention. This makes it possible to effectively use an existing blasting apparatus, thereby saving cost.

As discussed above, the blast gun employed in this invention is characterized by the structure of the distal end thereof; other components including the body and the jet share the same structures of a conventional known blast gun, thus permitting inexpensive, easy manufacture thereof.

Thus, the broadest claims that follow are not directed to a machine that is configure in a specific way. Instead, said broadest claims are intended to protect the heart or essence of this breakthrough invention. This invention is clearly new and useful. Moreover, it was not obvious to those of ordinary skill in the art at the time it was made, in view of the prior art when considered as a whole.

Moreover, in view of the revolutionary nature of this invention, it is clearly a pioneering invention. As such, the claims that follow are entitled to very broad interpretation as to protect the heart of this invention, as a matter of law.

It will thus be seen that the objects set forth above, and those made apparent from the foregoing description, are efficiently attained. Also, since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matters contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Now that the invention has been described;

What is claimed is:

1. A blasting method wherein:

an air stream is ejected from a jet in communication with a supply source of compressed air;

an abrasive is drawn in via an abrasive intake chamber, which is formed between said jet and a nozzle disposed at the front in the air injecting direction of said jet, from an abrasive supply source in communication with said abrasive intake chamber;

secondary compressed air supplied from said supply source of compressed air is merged with a primary mixed fluid which is ejected from said nozzle and which is composed of said abrasive and primary compressed air in front of said nozzle in the direction in which said primary mixed fluid is ejected;

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 1, 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 3 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 suction 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.

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