

DESCRIPTION

WATER-SOLUBLE WORKING FLUID FOR FIXED ABRASIVE GRAIN WIRE SAW

Technical Field

[0001] The present invention relates to a water-soluble working fluid for a fixed abrasive grain wire saw.

Background Art

[0002] In recent years, silicon wafers have rapidly had larger diameters in an attempt to reduce manufacturing costs of semiconductor devices, and thus it has become important to improve a technique for performing a cutting process on a silicon wafer. As the technique for performing a cutting process on a silicon wafer, there is a cutting method using a wire tool (i.e. wire saw) with less cutting loss and a good working efficiency. There are two types of cutting method: a loose abrasive grain type, and a fixed abrasive grain type. As for the loose abrasive grain type, the following problems have been pointed out: (1) since a slurry in which abrasive grains are dispersed in fluid is used as a working fluid, a cut workpiece and its surrounding environment are severely contaminated; (2) it is necessary to dispose of the slurry containing a large amount of cut debris which is produced during cutting; (3) it is difficult to separate the loose abrasive grains from the cut debris; and (4) there is a limitation in improving the working efficiency due to a limitation to a running speed of a wire. In order to solve these problems, there has been studied a fixed abrasive grain type wire

saw in which abrasive grains are fixed onto a surface of a piano wire or the like by electrodeposition, resin bond, or some other means. For example, Patent Document 1 discloses a fixed abrasive grain wire saw in which abrasive grains having 30 to 60 μm or less are fixed by resin bond. This wire saw is moved at a speed of 1000 to 2500 m/min to cut a brittle material, thereby enabling highly efficient cutting.

[0003] On the other hand, when performing a cutting process on a brittle material with a fixed abrasive grain wire saw, a working fluid is used concurrently for the purposes of lubrication, cooling, dispersion of cut debris, and the like. As to the working fluid, it is preferable to use a water-soluble one, in consideration of: a problem of flammability, improvement of working environment, simplification of cleaning steps after the cutting process, waste disposal, and the like. Further, when a material to be cut is silicon, the following problem arises. That is, silicon is highly reactive, in some cases reacting with an acid or an alkali during a cutting process to produce hydrogen gas. And, when a water-soluble fluid is used, ignition is likely to occur at a time of processing. Therefore, a working fluid which is prevented from reacting with silicon is preferred. From these viewpoints, Patent Document 2 suggests a water-soluble working fluid composition for a fixed abrasive grain wire saw which contains (A) glycols.

Patent Document 1: Japanese Patent Application Laid-Open (JP-A) No. 2001-054850

Patent Document 2: JP-A No. 2003-082334

Disclosure of Invention

Problems to be Solved by the Invention

[0004] In Patent Document 2, a water-soluble working fluid composition for a fixed abrasive grain wire saw contains glycols, and optionally contains other components, thereby being suited for cutting workpiece materials other than rare-earth magnets and for cutting silicon. Also, it can be prevented from reacting with silicon. However, in view of the recent demands, a working fluid which is capable of processing a silicon wafer with higher precision is preferred. Further, it is found that the water-soluble working fluid composition for a fixed abrasive grain wire saw disclosed in Patent Document 2, does not have sufficient fluid stability when the cut debris of silicon is mixed thereinto, in some cases affecting the processability of silicon.

[0005] The present invention has been made in view of the above; and an object of the present invention is to provide a water-soluble working fluid for a fixed abrasive grain wire saw which is excellent in processing silicon.

Means for Solving the Problems

[0006] The inventors conducted an intensive study to solve the above problems, and obtained the following findings.

(1) It is seen that the processability of silicon can be improved by appropriately regulating a load and the like imposed on a wire during a cutting process to prevent breaking and slipping of the wire. In the light of preventing breaking and slipping of a wire, various parameters of a working fluid were examined. As a result, it was found that there existed an appropriate

viscosity in the working fluid. That is, when the viscosity is too low, breaking of a wire is caused; and when the viscosity is too high, slipping of a wire is caused, resulting in insufficient processing of silicon.

(2) It was found that when the cut debris of silicon was mixed in, the state of a working fluid sometimes became unstable, causing rise in the fluid viscosity. When the fluid viscosity rises, slipping of a wire is caused as described above. And, there is fear that the processability (of silicon) is degraded and also that the life of the fluid is reduced.

(3) In order to stabilize the state of a working fluid in a case when the cut debris of silicon is mixed therein, it is seen to be effective to prevent the reaction of the silicon and the working fluid. In light of preventing the reaction of a working fluid with silicon, various parameters of a working fluid were examined. As a result, it was found that there existed an appropriate pH level in the working fluid. That is, by setting the pH of a working fluid within a predetermined range, it is possible to further prevent the reaction (of the working fluid) with silicon. This enables stabilization of the state of the working fluid and maintenance of an appropriate viscosity of the working fluid. Accordingly, the processability of silicon can be improved and the reduction of the fluid life can be suppressed.

(4) As a result of the studies on adjustment of the viscosity and the pH of a working fluid, it was found to be preferable to add an acid and a base to the working fluid. Especially, by adding as an acid component, a carboxylic acid, or preferably a carboxylic acid having 7 or less carbon atoms, the processability

of silicon can be further improved.

[0007] The present invention has been made based on the above findings, and takes the following composition.

Specifically, the present invention is a water-soluble working fluid for a fixed abrasive grain wire saw, comprising (A) glycols and water, wherein a viscosity of the working fluid at a temperature of 25°C is 3 mPa·s or more and 50 mPa·s or less. In the present invention, it is preferable that the above mentioned viscosity at a temperature of 25°C be 5 mPa·s or more and 25 mPa·s or less.

[0008] In the present invention, the "viscosity" refers to a viscosity measured by a B type viscometer.

The phrase "comprising glycols and water" encompasses the idea that the water-soluble working fluid for a fixed abrasive grain wire saw may consist only of glycols and water, and the idea that it may also contain other components.

[0009] In the present invention, a pH of the working fluid is preferably adjusted to be 5.0 or more and 7.5 or less, and more preferably 5.5 or more and 6.5 or less.

[0010] Additionally, in the present invention, it is preferable to further comprise a (B) carboxylic acid, and a (C) compound showing basicity on dissolution in water.

[0011] In the present invention comprising a (B) carboxylic acid, the (B) carboxylic acid preferably has 7 or less carbon atoms.

[0012] Further, in the present invention, on a basis that the total amount of the (A) glycols, the (B) carboxylic acid, and the (C) compound showing basicity on dissolution in water, is 100%

by mass, it is preferable to contain: 5% by mass or more and 95% by mass or less of the (A) glycols; 0.01% by mass or more and 60% by mass or less of the (B) carboxylic acid; and 0.01% by mass or more and 60% by mass or less of the (C) compound showing basicity on dissolution in water. And it is preferable to contain 0.02% by mass or more and 60% by mass or less in total, of the (B) carboxylic acid and the (C) compound showing basicity on dissolution in water.

[0013] Furthermore, the water-soluble working fluid for a fixed abrasive grain wire saw of the present invention is suitable for use in performing a cutting process on silicon materials.

Effects of the Invention

[0014] According to the present invention, the processing time in a cutting process can be reduced, and cutting precision of a silicon wafer can be improved. Thus, it is possible to provide a water-soluble working fluid for a fixed abrasive grain wire saw which is especially excellent in processing silicon, in performing a cutting process with a fixed abrasive grain wire saw.

Brief Description of the Drawings

[0015]

Fig. 1 is an illustration of one of the evaluation methods of Examples.

Modes for Carrying Out the Invention

[0016] A water-soluble working fluid for a fixed abrasive

grain wire saw of the present invention (simply referred to as a "water-soluble working fluid", hereinafter) can comprise (A)glycols and water; and can optionally further comprise (B)a carboxylic acid and (C)a compound showing basicity on dissolution in water, or other components. Hereinafter, each of the components will be described in detail.

[0017] (A)Glycols

The water-soluble working fluid of the present invention comprises (A)glycols. Examples of the glycols are water-soluble glycols such as: ethylene glycol; propylene glycol; 1,4-Butanediol; hexamethylene glycol; neopentyl glycol; diethylene glycol; triethylene glycol; dipropylene glycol; tripropylene glycol; polyethylene glycol; polypropylene glycol; a polyethylene glycol-polypropylene glycol copolymer; a polyoxyethylene-polyoxypropylene copolymer; glycol monoalkyl ethers such as triethylene glycol monobutyl ether, triethylene glycol monomethyl ether, diethylene glycol monobutyl ether, and tripropylene glycol monomethyl ether; and a monoalkyl ether of polyoxyethylene polyoxypropylene copolymer. Among the above examples of the glycols, it is preferable to use: propylene glycol; dipropylene glycol; diethylene glycol; triethylene glycol; polyethylene glycol; or polypropylene glycol. And it is especially preferable to use propylene glycol or polyethylene glycol. These glycols may be used singularly or in combination. Further, it may be a copolymer consisting of two or more of the above described components. A molecular weight of the above glycols is preferably 70 to 100,000, and more preferably 76 to 10,000. If the molecular weight is within this range, it is

possible to further improve the processability of silicon.

[0018] In the water-soluble working fluid of the present invention, on a basis of the working fluid as a whole, the lower limit of the (A)glycols is preferably 1% by mass or more; more preferably 5% by mass or more; still more preferably 15% by mass or more; even more preferably 20% by mass or more; and in especial preferably 30% by mass or more. The upper limit is preferably 95% by mass or less; more preferably 89% by mass or less; and still more preferably 85% by mass or less. By setting the content of the (A)glycols as above, it is possible to prevent rise in the viscosity during processing.

[0019] The water-soluble working fluid of the present invention comprises the above (A)glycols and water. It may consist only of the (A)glycols, with the rest being water; however, it may further contain other components such as additives. Additionally, it is preferable to still further contain a (B)carboxylic acid and a (C)compound showing basicity on dissolution in water.

[0020] (B)Carboxylic acid

The water-soluble working fluid of the present invention preferably further comprises a (B)carboxylic acid, in addition to the (A)glycols and water. As to the (B)carboxylic acid, it is preferable to use a carboxylic acid having 7 or less carbon atoms; more preferable to use a carboxylic acid having 2 or more and 6 or less carbon atoms; and especially preferable to use a carboxylic acid having 6 carbon atoms. Specific examples of the carboxylic acid to be preferably used include: citric acid; succinic acid; lactic acid; malic acid; adipic acid; oxalic acid;

and acetic acid. Citric acid and succinic acid are more preferable; and citric acid is especially preferable. These carboxylic acids may be used singularly or in combination. By using a carboxylic acid having 7 or less carbon atoms, it is possible to suitably maintain the fluid stability even when the cut debris of silicon is mixed in during a cutting process; and also to make the water-soluble working fluid excellent in processing silicon.

[0021] In the water-soluble working fluid of the present invention, on a basis of the working fluid as a whole, the (B) carboxylic acid is preferably contained in an amount of 0.01% by mass or more and 60% by mass or less; more preferably in an amount of 0.05% by mass or more and 10% by mass or less; and in especial preferably in an amount of 0.1% by mass or more and 5% by mass or less. By setting the content of the (B) carboxylic acid as above, it is possible to suitably maintain the fluid stability even when the cut debris of silicon is mixed in; and also to make the water-soluble working fluid excellent in processing silicon.

[0022] (C) Compound showing basicity on dissolution in water

In a composition that the water-soluble working fluid of the present invention comprises the (B) carboxylic acid as well as the (A) glycols, the water-soluble working fluid preferably still further comprises a (C) compound showing basicity on dissolution in water (hereinafter referred to as a "(C) basic compound"). Examples of the (C) basic compound include: a compound containing alkali metal elements; alkanolamine; alkylamine; and ammonia. These basic compounds may be used singularly or in combination. Among these, it is preferable to

use the compound containing alkali metal elements. Examples of the compound containing alkali metal elements include: sodium hydroxide; potassium hydroxide; sodium carbonate; potassium carbonate; sodium hydrogen carbonate; and potassium hydrogen carbonate. And potassium hydroxide is in especial preferably used.

[0023] In the water-soluble working fluid of the present invention, on a basis of the working fluid as a whole, the (C) basic compound is preferably contained in an amount of 0.01% by mass or more and 60% by mass or less; more preferably in an amount of 0.05% by mass or more and 10% by mass or less; and in especial preferably in an amount of 0.1% by mass or more and 5% by mass or less. Especially, the pH level (of the working fluid) is preferably adjusted to be within an appropriate range by adding the (B) carboxylic acid and the (C) basic compound, with the content of the (B) carboxylic acid set as an index. By setting the content of the basic compound as above, it is possible to suitably maintain the fluid stability even when the cut debris of silicon is mixed in; and also to make the water-soluble working fluid excellent in processing silicon.

[0024] Further, instead of the above (B) carboxylic acid and (C) basic compound, a salt formed of the (B) carboxylic acid and the (C) basic compound (, hereinafter sometimes referred to as a "(D)salt") may be contained. The content of the (D)salt is preferably set to be equivalent to the above described content when converted into the content of the (B) carboxylic acid and (C) basic compound. Examples of the (D)salt include an alkali metal salt of a carboxylic acid; and an amine salt of a carboxylic

acid.

[0025] In the water-soluble working fluid of the present invention, on a basis of the working fluid as a whole, the total content of the (B)carboxylic acid and (C)basic compound is preferably 0.02% by mass or more and 60% by mass or less; more preferably 0.1% by mass or more and 20% by mass or less; and in especial preferably 0.2% by mass or more and 10% by mass or less. By setting the content in this way, it is possible to prevent the reaction of the working fluid with silicon, and thereby to make the working fluid which is excellent in both fluid stability and processability of silicon.

[0026] Further, when the total amount of the (A)glycols, the (B)carboxylic acid and the (C)basic compound is set at 100% by mass, the mixed proportion thereof is preferably 30% by mass or more and 95% by mass or less of the (A)glycols; 0.1% by mass or more and 5% by mass or less of the (B)carboxylic acid; 0.1% by mass or more and 5% by mass or less of the (C)basic compound; the rest being water. In addition, it is preferable to adjust the pH of the working fluid to be 5.0 or more and 7.5 or less, by adjusting the amounts of the (A)glycols, (B)carboxylic acid; and (C)basic compound. And by doing so, it is possible to suitably maintain the fluid stability even when the cut debris of silicon is mixed in during a cutting process; and is especially effective in making the water-soluble working fluid excellent in processing silicon.

[0027] (E)Other components

In the water-soluble working fluid of the present invention, in addition to the above (A)glycols and water; and the optionally

contained (B) carboxylic acid and (C) basic compound, or (D) salt, (E) other components may be contained. For example, various kinds of additives may be added to an extent that does not affect working performance, the additives not causing bad effects such as corrosion and discoloration on a workpiece material, and not affecting the stability of the mixed systems. For example, a viscosity modifier, pH adjuster, antifoaming agent, antioxidant and the like may be added. As to the viscosity modifier, a known viscosity modifier may be used without special restrictions; however, the viscosity modifier is preferably soluble in water. Further, as to the pH adjuster, the following may be used: an inorganic base (e.g. the above mentioned sodium hydroxide, potassium hydroxide, and ammonia); an organic base (e.g. the above mentioned alkanolamine and alkylamine); an inorganic acid (e.g. hydrochloric acid and sulfuric acid); and an organic acid (e.g. the above mentioned carboxylic acid). As to the antifoaming agent, antioxidant and the like, known ones may be used without special restrictions; however, they are preferably soluble in water.

[0028] The water-soluble working fluid of the present invention comprises the above described components. Further, the water-soluble working fluid of the present invention may be adequately diluted with water depending on the working environment in the cutting process. Specifically, the following may be carried out: a concentrated composition composed of the above described (A) components and the like, excluding water, is mixed to be produced; is adequately diluted with water at a time of performing cutting operations on site; thereby preparing an

appropriate water-soluble working fluid to be used, in accordance with the working environment and conditions. Further, the following may also be carried out: a concentrated composition composed of the above (A) components and the like, including a certain amount of water, is mixed to be produced; and is further diluted with water at a time of performing cutting operations on site.

[0029] In the water-soluble working fluid of the present invention, its viscosity at a time of performing cutting operations (i.e. referring to the viscosity of the working fluid before the dilution when the working fluid is used for cutting without being diluted; and referring to the viscosity of the working fluid after the dilution when the working fluid is used for cutting after being diluted) is adjusted to be 3 mPa·s or more and 50 mPa·s or less at a temperature of 25°C. The "viscosity" refers to a viscosity measured by a B type viscometer. The viscosity of the water-soluble working fluid at a temperature of 25°C is preferably 3 mPa·s or more and 50 mPa·s or less; more preferably 5 mPa·s or more and 30 mPa·s or less; and in especial preferably 5 mPa·s or more and 25 mPa·s or less. By setting the viscosity of the water-soluble working fluid within this range, it is possible to make the water-soluble working fluid especially excellent in processing silicon when used for cutting with a fixed abrasive grain wire saw. The viscosity can be adequately adjusted by the content of the (A) glycols; or the content of the (B) carboxylic acid and (C) basic compound, or other additives (i.e. a viscosity modifier).

[0030] Further, in addition to the above described viscosity,

the pH of the water-soluble working fluid of the present invention is preferably adjusted to be 5.0 or more and 7.5 or less. The pH level of 5.5 or more and 6.5 or less is especially preferable. By setting the pH level within this range, it is possible to prevent the reaction of the silicon and the working fluid even when the silicon as cut debris is mixed into the working fluid after the cutting process, and to stabilize the working fluid. Accordingly, rise in the viscosity of the working fluid and reduction of the fluid life can be suppressed, and it is possible to make the water-soluble working fluid more excellent in processing silicon. The pH level can be adequately adjusted by the content of the (A) glycols; or the content of the (B) carboxylic acid and (C) basic compound, or other additives (i.e. a pH adjuster).

[0031] By using the water-soluble working fluid of the present invention when cutting with a fixed abrasive grain wire saw, it becomes possible to carry out a cutting process which is especially excellent in cutting silicon.

[0032] Hereinafter, the water-soluble working fluid for a fixed abrasive grain wire saw of the present invention will be explained in more detail by Examples.

Examples

[0033] (Production of a water-soluble working fluid for a fixed abrasive grain wire saw)

The following were mixed so as to form a composition shown in Table 1, thereby producing a working fluid: propylene glycol (PG, propylene glycol produced by Wako Pure Chemical Industries,

Ltd.); polyethylene glycol 200 (PEG 200, polyethylene glycol 200 produced by Wako Pure Chemical Industries, Ltd., average molecular weight: 180 to 200); polyethylene glycol 300 (PEG 300, polyethylene glycol 300 produced by Wako Pure Chemical Industries, Ltd., average molecular weight: 300); water; citric acid (citric acid produced by Wako Pure Chemical Industries, Ltd.); succinic acid (succinic acid produced by Wako Pure Chemical Industries, Ltd.); and potassium hydroxide (potassium hydroxide produced by Wako Pure Chemical Industries, Ltd.). Additionally, the viscosity at a temperature of 25°C and the pH of each of the working fluids were measured. The viscosity shown in Table 1 was measured by using a B type viscometer made by Tokyo Keiki Inc. (at 60 rpm).

[0034]

	Example 1	Example 2	Example 3	Example 4	Example 5	Comparative Example 1	Comparative Example 2	Reference Example 1	Reference Example 2
PG	30	70	-	-	-	10	-	-	-
PEG200	-	-	70	-	70	-	-	70	50
PEG300	-	-	-	70	-	-	90	-	-
H ₂ O	70	30	30	30	30	90	10	30	50
Citric acid	0.3	0.3	-	-	-	0.3	-	-	0.3
Succinic Acid	-	-	0.3	0.3	0.3	-	0.3	0.3	-
Potassium hydroxide	0.25	0.25	0.2	0.2	0.25	0.3	0.2	0.45	0.05
pH	5.1	5.7	6.0	6.2	6.5	5.2	6.5	7.8	4.3
Viscosity(mPa·s)	4.0	10.0	18.0	30.0	18.0	2.6	55.0	17.0	7.0

[Table 1]

[0035] (Evaluation of performance: cutting process of polycrystalline silicon)

A polycrystalline silicon ingot having a square shape of 25 mm was used as a material to be cut. Further, a single wire saw cutting machine (made by TOKO MACHINERY Co., Ltd.) was used as a fixed abrasive grain wire saw. The operating conditions of the multi-cutting machine were set as shown in Table 2.

[0036]

[Table 2]

Items	Conditions
Running speed of wire	200 m/min
Tension of wire	1.5 kg
Cutting load	400 g
Number of sample grooves	10 grooves
Number of times at which wire is reciprocated	20 times
Length of wire to be used	26 m

[0037] The above multi-cutting machine was used to process the material to be cut. Specifically, the material was grooved at ten locations as shown in Fig.1, by using the working fluids of Examples 1 to 5, Comparative Examples 1 and 2, or Reference Examples 1 and 2, and the above single wire saw cutting machine. The total cutting depth of the grooves at the ten locations was used as an index for the evaluation. The working fluid was poured toward the wire to run along back and forth of the areas to be cut on the material. The results are shown in Table 3.

[0038] Further, just as 5% by mass of silicon as cut debris was mixed in the working fluids during processing of the material to be cut using a fixed abrasive grain, each of the working fluids

with 5% by mass of the silicon mixed therein was allowed to stand for 24 hours, after which the viscosity of the working fluids was measured and used as an index for the evaluation. The results are shown in Table 3.

[0039]

[Table 3]

	Example 1	Example 2	Example 3	Example 4	Example 5	Comparative Example 1	Comparative Example 2	Reference Example 1	Reference Example 2
Viscosity (mPa·s, 25°C)	4	10	18	30	18	2.6	55	17	7
Total cutting depth (mm)	82	80	77	65	77	Breaking of wire	33	77	21
Viscosity after cut debris of Si is mixed in (mPa·s, 25°C)	6	14	23	35	22	2.8	65	122	10

[0040] As shown in Table 3, in all of Examples 1 to 5 of the present invention, the cutting depth was large, showing a satisfactory cutting ability and excellent processability of

silicon. Further, even after silicon was mixed in, it was possible to maintain an appropriate viscosity, thereby enabling prevention of reduction of the fluid life and enabling improvement of the processability of silicon.

In comparative Examples 1 and 2, the wire was broken or the cutting depth was insufficient, therefore resulting in insufficient processability of silicon. In addition, in Comparative Examples 1 and 2, the viscosity of the working fluids remained outside an appropriate range after silicon (Si) was mixed therein.

On the other hand, in Reference Example 1, the cutting depth was sufficient; however, by raising the pH of the working fluid to 7.8, the reaction of the working fluid with the silicon was brought about after the silicon was mixed therein, degrading the fluid stability; and thereby the viscosity resulted in outside an appropriate range. Further in Reference Example 2, an appropriate viscosity was maintained even after the silicon was mixed in and the fluid stability was achieved; however, by lowering the pH of the working fluid to 4.3, a sufficient cutting depth was hindered and the wire was broken after processing. It was found from this, that the pH of the working fluid, as well as the viscosity thereof, becomes an important factor for maintaining the processability of silicon.

[0041] The invention has been described above as to the embodiment which is supposed to be practical as well as preferable at present. However, it should be understood that the invention is not limited to the embodiment disclosed in the specification and can be appropriately modified within the range that does not

depart from the gist or spirit of the invention, which can be read from the appended claims and the overall specification, and a water-soluble working fluid for a fixed abrasive grain wire saw with such modifications are also encompassed within the technical range of the invention.

Industrial Applicability

[0042] The present invention can be suitably used as a water-soluble working fluid for a fixed abrasive grain wire saw, which is capable of cutting a silicon material with precision by using a fixed abrasive grain wire saw in manufacturing a silicon wafer.

CLAIMS

1. A water-soluble working fluid for a fixed abrasive grain wire saw comprising: (A) glycols; a (B) carboxylic acid having 2 or more and 6 or less carbon atoms; a (C) compound showing basicity on dissolution in water; and water,

wherein a viscosity of the working fluid at a temperature of 25 °C is 3 mPa.s or more and 50 mPa.s or less.

2. The water-soluble working fluid for a fixed abrasive grain wire saw according to claim 1, wherein a pH of the working fluid is adjusted to be 5.0 or more and 7.5 or less.

3. The water-soluble working fluid for a fixed abrasive grain wire saw according to claim 1 or 2, wherein on a basis that the total amount of the (A) glycols, the (B) carboxylic acid, and the (C) compound showing basicity on dissolution in water, is 100% by mass, 5% by mass or more and 95% by mass or less of the (A) glycols; 0.01% by mass or more and 60% by mass or less of the (B) carboxylic acid; and 0.01% by mass or more and 60% by mass or less of the (C) compound showing basicity on dissolution in water, are contained;

0.02% by mass or more and 60% by mass or less in total, of the (B) carboxylic acid and the (C) compound showing basicity on dissolution in water is contained; and

the rest is water.

4. The water-soluble working fluid for a fixed abrasive grain wire saw according to any one of claims 1 to 3, which is used in performing a cutting process on a silicon material.