

DESCRIPTION

INORGANIC FIBER, INORGANIC FIBER PRODUCT, METHOD OF
MANUFACTURING INORGANIC FIBER PRODUCT, COMPOSITION FOR
MANUFACTURING INORGANIC FIBER, AND METHOD OF MANUFACTURING
INORGANIC FIBER

TECHNICAL FIELD

[0001]

The present invention relates to an inorganic fiber, an inorganic fiber product, a method of manufacturing an inorganic fiber product, a composition for manufacturing an inorganic fiber, and a method of manufacturing an inorganic fiber.

BACKGROUND ART

[0002]

Inorganic fibers represented by rock wool and glass wool have been used in various industries such as steel, petroleum, chemicals, electricity, automobiles, building materials, and aerospace for various usages such as refractory materials, heat insulating materials, and sealing materials, and are indispensable materials.

[0003]

In the related art, slag-based rock wool blended with steel slag is fiberized and manufactured as follows. Specifically, natural stones such as silica stone, silica sand, and basalt are added to steel slag as a component adjusting agent, the resultant mixture is melted in a cupola or an electric furnace, and the melt is allowed to flow out from the bottom of the furnace. The melt is fiberized by a spinning method in which the melt is brought into contact with a high-speed rotating body, or a blowing method in which the melt is fiberized by compressed air.

[0004]

Although the rock wool in the related art has higher heat resistance indicated by a heating shrinkage rate in comparison to typical glass wool, the rock wool is melted at approximately 800°C. Therefore, in the rock wool in the related art, a ratio of iron oxide in a fiber is increased by increasing a blending ratio of basalt containing iron oxide, converter slag, or the like, thereby improving heat resistance (refer to PATENT LITERATURE 1 and PATENT LITERATURE 2).

[0005]

However, since iron oxide in a rock wool raw material is partially reduced in melting, metallic iron is deposited on the bottom of a melting furnace. Therefore, when the amount of iron increases in the rock wool raw material, the frequency of a work of periodically extracting the metallic iron increases. Due to this, time productivity of the rock wool is lowered, and thus it is necessary to significantly lower the blending ratio of iron oxide in the rock wool raw material from the viewpoint of production.

[0006]

From the viewpoint, PATENT LITERATURE 3 discloses rock wool having high heat resistance even though the content of iron oxide is small. The rock wool contains 35% by mass to 45% by mass of SiO_2 , 10% by mass to 15% by mass of Al_2O_3 , 20% by mass to 35% by mass of CaO , 10% by mass to 25% by mass of MgO , and FeO and Fe_2O_3 in a total content of 2% by mass to 10% by mass. A molar ratio of divalent Fe atoms to the sum of divalent Fe atoms and trivalent Fe atoms is set to 0.8 or greater.

CITATION LIST

PATENT LITERATURE

[0007]

PATENT LITERATURE 1: JP H6-45472 B

PATENT LITERATURE 2: JP H6-65617 B

PATENT LITERATURE 3: WO 2012/176799 A

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0008]

In the rock wool described in PATENT LITERATURE 3, it is necessary to adjust the molar ratio of divalent Fe and trivalent Fe within a predetermined range, and thus a selectable raw material is limited. Accordingly, with regard to an inorganic fiber such as rock wool, it is desired to have high heat resistance even though the content of oxide iron is small, and it is desired to further raise productivity while expanding the option of a raw material.

[0009]

In addition, the present inventors also found that there is a new problem of deterioration of productivity or limitation of a selectable raw material even in the case of adding a compound of transition metals other than Fe from the viewpoint of improving heat resistance of an inorganic fiber such as rock wool.

[0010]

The invention has made in consideration of the problem, and an object thereof is to provide an inorganic fiber in which heat resistance is high, an option of a raw material is wide, and productivity is high, an inorganic fiber product, a method of manufacturing an inorganic fiber product, a composition for manufacturing an inorganic fiber, and a method of manufacturing an inorganic fiber.

SOLUTION TO PROBLEM

[0011]

The present inventors have made a thorough investigation. As a result, they found that when a molar basicity expressed by a molar ratio of the sum of CaO and MgO to the sum of SiO₂ and Al₂O₃, and a total amount of a transition metal compound and SO₃ contained in an inorganic fiber are set within predetermined ranges, an inorganic fiber having high heat resistance is obtained, and they accomplished the invention.

[0012]

Accordingly, according to the inorganic fiber according to the invention, when a total amount Q of a transition metal compound and SO₃ is 0.5% by mass or greater, a molar basicity P expressed by a molar ratio (mol% (CaO + MgO)/mol% (SiO₂ + Al₂O₃)) of the sum of CaO and MgO to the sum of SiO₂ and Al₂O₃ is 0.6 or greater, and Expression (1): $-3.3 \times P + 5.1 \leq Q$ (1) is satisfied, the above-described problem is solved.

[0013]

At this time, the transition metal compound may be at least one kind of compound selected from the group consisting of Fe, Mn, Cu, Ni, Co, Zr, V, Nb, Mo, W, and Y.

At this time, a heating shrinkage rate at 1110°C may be 14% or less.

[0014]

At this time, the inorganic fiber may have a composition containing:

25% by weight to 45% by weight of SiO₂;

5% by weight to 25% by weight of Al₂O₃;

15% by weight to 50% by weight of CaO;

3% by weight to 20% by weight of MgO;

0.1% by weight to 14% by weight of transition metal compound; and

0.1% by weight to 10% by weight of SO₃.

[0015]

At this time, the inorganic fiber may further contain:

0% by weight to 10% by weight of Na₂O; and

0% by weight to 10% by weight of K₂O.

[0016]

At this time, the inorganic fiber may contain at least one or more kinds selected from the group consisting of P₂O₅, Li₂O, Na₂O, and K₂O, and a total amount of P₂O₅, Li₂O, Na₂O, and K₂O is 3% by weight to 10% by weight.

[0017]

At this time, the inorganic fiber may be at least one or more kinds selected from the group consisting of rock wool, stone wool, slag wool, mineral wool, glass wool, and mineral glass wool.

[0018]

According to an inorganic fiber product according to the invention, the above-described inorganic fiber is included, and thus the above-described problem is solved.

At this time, the inorganic fiber product may be a heat insulating material or a refractory material.

[0019]

According to a method of manufacturing an inorganic fiber product according to the invention, the method includes molding the inorganic fiber, and thus the above-described problem is solved.

[0020]

According to a composition for manufacturing an inorganic fiber according to the invention, a total amount

Q of a transition metal compound and SO_3 is 0.5% by mass or greater, a molar basicity P expressed by a molar ratio ($\text{mol}\% (\text{CaO} + \text{MgO}) / \text{mol}\% (\text{SiO}_2 + \text{Al}_2\text{O}_3)$) of the sum of CaO and MgO to the sum of SiO_2 and Al_2O_3 is 0.6 or greater, and Expression (1): $-3.3 \times P + 5.1 \leq Q$ (1) is satisfied, and thus the above-described problem is solved.

[0021]

According to a method of manufacturing an inorganic fiber according to the invention, the method includes melting the composition for manufacturing an inorganic fiber, and making the resultant melt into a fiber to obtain an inorganic fiber, and thus the above-described problem is solved.

ADVANTAGEOUS EFFECTS OF INVENTION

[0022]

According to the invention, it is possible to provide an inorganic fiber in which heat resistance is high, an option of a raw material is wide, and productivity is high, an inorganic fiber product, a method of manufacturing an inorganic fiber, a composition for manufacturing an inorganic fiber, and a method of manufacturing an inorganic fiber.

BRIEF DESCRIPTION OF DRAWINGS

[0023]

FIG. 1 is a graph obtained by extracting samples in which a heating shrinkage rate at 1110°C is 14% or less (upper drawing) and samples melted at 1110°C (lower drawing) among respective samples in Test 1, and by plotting a molar basicity P in the horizontal axis and a total content Q of a transition metal compound and sulfur in the vertical axis.

FIG. 2 is a graph obtained by extracting samples in

which the heating shrinkage rate at 1110°C is 12% or less (upper drawing) and samples in which the shrinkage rate is more than 12% (lower drawing) among the respective samples in Test 1, and by plotting the molar basicity P in the horizontal axis and the total content Q of the transition metal compound and sulfur in the vertical axis.

FIG. 3 is a graph obtained by extracting samples in which the heating shrinkage rate at 1110°C is 10% or less (upper drawing) and samples in which the shrinkage rate is more than 10% (lower drawing) among the respective samples in Test 1, and by plotting the molar basicity P in the horizontal axis and the total content Q of the transition metal compound and sulfur in the vertical axis.

FIG. 4 is a graph obtained by extracting samples in which the molar basicity P is 1.4 among the respective samples in Test 1, and by plotting the total content Q of the transition metal compound and sulfur in the horizontal axis and a crystallization peak temperature in the vertical axis.

FIG. 5 is a graph obtained by extracting samples in which the total content Q of the transition metal compound and sulfur is 4.2% by mass among the respective samples in Test 1, and by plotting the molar basicity P in the horizontal axis and the crystallization peak temperature in the vertical axis.

FIG. 6 is a graph obtained by plotting the crystallization peak temperature of the respective samples in Test 1 in the horizontal axis and the heating shrinkage rate at 1110°C in the vertical axis.

FIG. 7 is a graph obtained by plotting the molar basicity P in the horizontal axis and the total content Q of the transition metal compound and sulfur in the vertical

axis with respect to respective inorganic fiber sample in Test 2.

DESCRIPTION OF EMBODIMENTS

[0024]

Hereinafter, an embodiment (hereinafter, referred to as this embodiment) of the invention will be described with reference to FIG. 1 to FIG. 7. This embodiment relates to an inorganic fiber, an inorganic fiber product, a method of manufacturing an inorganic fiber product, a composition for manufacturing an inorganic fiber, and a method of manufacturing an inorganic fiber.

[0025]

<Definition>

In this specification, $\bigcirc\%$ by weight to $\Delta\%$ by weight represents to equal to or greater than $\bigcirc\%$ by weight and equal to or less than $\Delta\%$ by weight.

In this specification, the content of each component is noted in terms of an oxide, and can be measured by fluorescent X-ray analysis (XRF). Here, even though the content of each component is noted in terms of an oxide, it is not necessary for the component to be contained as an oxide. For example, each component (S or Fe) may not be contained as an oxide (SO_3 or Fe_2O_3), and respective components may be contained in a type of a compound such as a sulfide (FeS).

[0026]

<Inorganic Fiber and Composition for Manufacturing Inorganic Fiber>

An inorganic fiber (ore fiber) of this embodiment is a fiber-shaped material that is mainly manufactured from various natural ores such as silica and andesite, raw

materials such as clay, slag, and glass, or materials obtained by crushing the raw materials. Examples of the inorganic fiber include at least one or more kinds selected from the group consisting of rock wool, stone wool, slag wool, mineral wool, glass wool, and mineral glass wool. As the inorganic fiber of this embodiment, the rock wool or the slag wool is preferable from the viewpoint of heat resistance. [0027]

Here, the composition for manufacturing an inorganic fiber is a composition that becomes a raw material when manufacturing the inorganic fiber, and a state thereof is not particularly limited, and examples thereof include a state in which respective components exist as a mixed solidified material, a state in which respective components are melted, a state in which respective components exist as a powder, and the like. [0028]

The inorganic fiber and the composition for manufacturing an inorganic fiber of this embodiment contain a transition metal compound such as SiO_2 , Al_2O_3 , CaO , MgO , and Fe_2O_3 , and SO_3 as an essential component, a total amount Q of a transition metal compound and SO_3 is 0.5% by mass or greater, a molar basicity P expressed by a molar ratio ($\text{mol}\% (\text{CaO} + \text{MgO}) / \text{mol}\% (\text{SiO}_2 + \text{Al}_2\text{O}_3)$) of the sum of CaO and MgO to the sum of SiO_2 and Al_2O_3 is 0.6 or greater, and Expression (1): $-3.3 \times P + 5.1 \leq Q$ (1) or Expression (1'): $-3.3 \times P + 5.1 < Q$ (1') is satisfied. [0029]

In addition, in the inorganic fiber and the composition for manufacturing an inorganic fiber, it is preferable that the total amount Q of the transition metal compound and SO_3 is 0.5% by mass or greater, the molar basicity P is 0.6 or

greater, and Expression (2): $-7.5 \times P + 11.0 \leq Q$ (2) or Expression (2'): $-7.5 \times P + 11.0 < Q$ (2') is satisfied.

[0030]

In addition, in the inorganic fiber and the composition for manufacturing an inorganic fiber, it is more preferable that the total amount Q of the transition metal compound and SO_3 is 2.5% by mass or greater, the molar basicity P is 0.6 or greater, and Expression (3): $-6.7 \times P + 11.9 \leq Q$ (3) or Expression (2'): $-6.7 \times P + 11.9 < Q$ (3') is satisfied.

[0031]

(Content (Q) of Transition Metal Compound and sulfur)

The total content Q of the transition metal compound and sulfur (SO_3) plays an important role in heat resistance of the inorganic fiber. In the inorganic fiber and the composition for manufacturing an inorganic fiber of this embodiment, a lower limit value of the total content Q (% by mass) of the transition metal compound and sulfur is 0.5% by mass or greater from the viewpoint of the heat resistance, preferably 1.0% by mass or greater, and more preferably 2.5% by mass or greater when the sum of components contained in the inorganic fiber is set as 100% by mass.

[0032]

Here, since the transition metal compound in a raw material partially reduced in melting and is deposited as a metal on the bottom of a melting furnace, it is preferable to suppress the amount of the transition metal compound to be low. In addition, when rock wool is fiberized, if a large amount of sulfur exists, iron used in a device is corroded, and thus it is preferable to suppress the amount of sulfur to be low.

[0033]

Specifically, an upper limit value of a total amount

Q (% by mass) of the transition metal compound and sulfur is 15% by mass or less from the viewpoint of productivity, preferably 12% by mass or less, and more preferably 10% by mass or less.

[0034]

(Molar Basicity (P))

A molar basicity P is expressed by a molar ratio (mol% (CaO + MgO)/mol% (SiO₂ + Al₂O₃)) of the sum of CaO and MgO to the sum of SiO₂ and Al₂O₃. Specifically, when a total molar ratio of components contained in rock wool is set as 100 mol%, the molar basicity P is obtained by dividing the sum (mol%) of CaO and MgO by the sum (mol%) of SiO₂ and Al₂O₃. Note that, in a case where other trace components (corresponding to unavoidable impurities) are contained, in calculation of the molar ratio, calculation is performed by excluding the other trace components.

[0035]

The molar basicity P is a ratio of SiO₂ and Al₂O₃ which form a glass skeleton of the inorganic fiber, and a ratio of CaO and MgO which divide the skeleton of the inorganic fiber, and is an index of safety of the skeleton of the inorganic fiber. In rock wool of this embodiment, the molar basicity P is 0.4 to 2.0, preferably 0.5 to 1.7, and more preferably 0.6 to 1.6.

[0036]

When the molar basicity P is low, viscosity of a composition for manufacturing an inorganic fiber becomes excessively high, and thus the composition is not appropriately melted. As a result, productivity deteriorates. Note that, when the molar basicity P is high, the glass skeleton becomes unstable, and atoms migrate when being heated, and crystallization is likely to occur.

Accordingly, even when the transition metal compound is added in a small amount, heat resistance becomes satisfactory. Note that, when the molar basicity P is excessively high, there is a possibility that crystallization is likely to occur and embrittlement may occur, and thus the molar basicity P is preferably set within the above-described numerical range.

[0037]

In the inorganic fiber and the composition for manufacturing an inorganic fiber according to this embodiment, the transition metal compound is at least one kind of compound selected from the group consisting of Fe, Mn, Cu, Ni, Co, Zr, V, Nb, Mo, W, and Y. Compounds of Fe, Mn, Cu, Ni, Co, Zr, V, Nb, Mo, W, and Y react with sulfur and form sulfides (FeS, MnS, CuS, NiS, CoS, and the like) in a process of manufacturing an inorganic fiber.

[0038]

For example, the inorganic fiber and the composition for manufacturing an inorganic fiber has the following composition, but there is no limitation to the composition.

SiO₂: 25% by weight to 45% by weight, and preferably 25% by weight to 40% by weight

Al₂O₃: 5% by weight to 25% by weight, and preferably 7% by weight to 20% by weight

CaO: 15% by weight to 50% by weight, and preferably 20% by weight to 46% by weight

MgO: 3% by weight to 20% by weight, and preferably 5% by weight to 15% by weight

Transition metal compound (Fe₂O₃, MnO, or the like): 0.1% by weight to 14% by weight, and preferably 1% by weight to 12% by weight

Na₂O: 0% by weight to 10% by weight, preferably 0% by

weight to 5% by weight, more preferably 0% by weight to 3% by weight, and still more preferably 0% by weight to 2% by weight

K₂O: 0% by weight to 10% by weight, preferably 0% by weight to 5% by weight, more preferably 0% by weight to 3% by weight, and still more preferably 0% by weight to 2% by weight

SO₃: 0.1% by weight to 10% by weight, and preferably 0.5% by weight to 6.1% by weight
[0039]

At this time, viscosity adjustment with an alkali metal or phosphor may be performed. Specifically, when at least one or more kinds selected from the group consisting of P₂O₅, Li₂O, Na₂O, and K₂O are contained, and the content of P₂O₅ + Li₂O + Na₂O + K₂O is set to be larger, that is, 3% by weight to 10% by weight in terms of an oxide from the viewpoint of productivity, melt viscosity can be adjusted.

[0040]

(Crystallization Peak Temperature)

In the inorganic fiber and the composition for manufacturing an inorganic fiber according to this embodiment, a crystallization peak temperature is 920°C or lower, preferably 900°C or lower, and more preferably 895°C or lower. Here, the crystallization peak temperature is a temperature when components which constitute an inorganic fiber are crystallized, and can be obtained from a value of an exothermic peak at the time of temperature rising, for example, by a differential thermal analyzer (DTA) or differential scanning calorimetry (DSC). In this embodiment, for example, the crystallization peak temperature can be defined as an exothermic peak temperature when being heated up to 1000°C at a temperature rising rate of 20°C/minute by

using the differential thermal analyzer (DTA).

[0041]

In the inorganic fiber and the composition for manufacturing an inorganic fiber according to this embodiment, a softening and deforming temperature (softening point) is set to be higher than the crystallization peak temperature. That is, since microcrystals exist before the inorganic fiber is softened and deformed due to heating, softening does not proceed, and curvature and fusion of fibers do not occur even when being exposed to a high temperature.

[0042]

Here, the softening point is a temperature at which the inorganic fiber and the composition for manufacturing an inorganic fiber start to be significantly softened and deformed, and can be measured and obtained, for example, by a method defined in JIS R 3103-1: 2001.

[0043]

(Heating Shrinkage Rate)

When being measured by a method described in examples, a heating shrinkage rate of the composition for manufacturing an inorganic fiber according to this embodiment is 14% or less after heating at 1110°C, preferably 12% or less, more preferably 11% or less, and still more preferably 10% or less.

[0044]

(Mechanism of Heat Resistance Exhibition)

A surface tension acts on a fiber surface of an inorganic fiber to reduce the surface as much as possible. When the fiber is softened and enters a deformation possible state, the fiber is thickened or deformed due to an influence of the surface tension. In addition, when softening of the

fiber proceeds, fiber intersections are fused, and the fiber is finally melted. Heat resistance of an inorganic fiber and an inorganic fiber heat-insulating material becomes more excellent as a temperature at which a fiber shape is not changed and a shape as a heat insulating material having voids between fibers can be maintained is higher.

[0045]

The inorganic fiber is amorphous in a non-heated state. Here, amorphous is a state in which atoms do not have a regular arrangement like a crystal, and crystalline is a stable structure in which atoms constituting a substance have spatial regularity, adjacent atoms are three-dimensionally periodically arranged.

[0046]

Amorphous glass is softened and deformed when being heated from room temperature. However, a state of glass having a special composition, which is called crystallized glass, begins to vary from amorphous to crystalline before reaching a softening and deforming temperature, and thus the glass varies into an agglomerate of microcrystals without being softened and deformed.

[0047]

Accordingly, with regard to curvature and fusion of an inorganic fiber, the present inventors have focused on importance of whether or not a crystalline state exists before being softened and deformed. Specifically, in the inorganic fiber of this embodiment, since values of the molar basicity P and the total content Q of the transition metal compound and sulfur (SO_3) are within predetermined ranges, and microcrystals exist before being softened and deformed due to heating, softening does not proceed and curvature and fusion of the fiber do not occur even when being exposed to

a high temperature of 1100°C or higher.

[0048]

<Method of Manufacturing Inorganic Fiber>

In a method of manufacturing an inorganic fiber according to this embodiment, a known method that has been used in manufacturing of an inorganic fiber in the related art can be used except that the composition (inorganic fiber raw material) for manufacturing an inorganic fiber which has the same composition as the above-described composition of the inorganic fiber.

[0049]

The method of manufacturing an inorganic fiber according to this embodiment is characterized in that the composition for manufacturing an inorganic fiber is melted (melting process) and the resultant melt is fiberized (fiberization process) to obtain an inorganic fiber. More specifically, in the method of manufacturing an inorganic fiber according to the invention, the composition for manufacturing an inorganic fiber is melted in a cupola, an electric furnace, or the like, and the resultant melt is fiberized by spinning, blowing, or the like to obtain an inorganic fiber.

[0050]

In the case of performing manufacturing of the inorganic fiber by using the electric furnace, a range of a raw material is wider in comparison to the cupola, and thus the electric furnace is suitable. In the case of using the electric furnace, blowing is not performed, and thus a sulfur component is likely to be contained in the inorganic fiber. In addition, the cupola blows air into a powder by using coke as a heat source and a reducing agent. From the viewpoint of environment protection, the cupola is provided

with a desulfurization device. In the method of manufacturing an inorganic fiber according to this embodiment, since the transition metal compound and sulfur are caused to react with each other and are converted into a sulfide, a sulfur component is suppressed from being emitted into an environment.

[0051]

<Method of Manufacturing Inorganic Fiber Product>

The inorganic fiber according to this embodiment is collected in a cotton collection chamber, and is defiberized and granulated into granular cotton in correspondence with a use. Alternatively, a binder is added to the inorganic fiber and is hardened in a curing furnace, the resultant inorganic fiber is adjusted to have predetermined density and thickness, and is processed into an inorganic fiber product (molded product, secondary product) having a board shape, a mat shape, a felt shape, a blanket shape, a strip shape, a tubular shape, or the like.

[0052]

<Inorganic Fiber Product>

Various kinds of inorganic fiber products (secondary products) can be obtained from the inorganic fiber according to this embodiment. For example, shaped products such as bulks, blankets, blocks, ropes, yarns, woven products, inorganic fibers coated with a surfactant, shotless bulks from which shots (non-fiberized objects) are reduced or removed, boards manufactured by using a solvent such as water, molds, paper, felts, and wet felts impregnated with colloidal silica are obtained. In addition, shaped products after processing the shaped products with collide or the like are obtained. In addition, amorphous materials (mastics, casters, coating materials, and the like) manufactured by

using a solvent such as water are also obtained. In addition, structures in which the shaped products, the amorphous products, and various heat-generating bodies are combined are also obtained.

[0053]

Examples of specific uses of the inorganic fiber according to this embodiment include refractory coating materials for protecting steel frames or the like, heat insulating materials for various buildings, cover materials for various pipes, joint materials in heat treatment devices and furnaces such as an industrial furnace and an incinerator, joint materials for filling a gap in refractory tiles, heat insulating bricks, iron skins, refractory mortar, and the like, sealing materials, packing materials, cushioning materials, heat insulating materials, refractory materials, fireproof materials, heat reserving materials, protective materials, covering materials, filtering materials, filter materials, insulating materials, filling materials, repair materials, heat-resistant materials, non-combustible materials, soundproof materials, sound-absorbing materials, frictional materials (for example, additives for brake pads), rolls for transporting glass plates and steel plates, automobile catalyst carrier holding materials, various fiber reinforced composite materials (for example, reinforcing fibers for fiber reinforced cement, fiber reinforced plastic, and the like, reinforcing fibers for heat-resistant materials and refractory materials, reinforcing fibers for adhesives and coating materials), and the like.

[Example]

[0054]

Hereinafter, the invention will be described in detail on the basis of specific examples, but the invention is not

limited thereto.

[0055]

<Preparation of Sample>

Reagents were mixed (total: 60 to 65 g) in compositions shown in Table 1 to Table 4. At this time, carbon (2 to 3 g) was added. The mixed reagents were put into a crucible, and were heated and melted in an electric furnace at 1500°C. A temperature was raised up to 1500°C and the temperature was retained for 15 to 30 minutes, and then the resultant melt was poured into water to be rapidly cooled and vitrified. Glass obtained through rapid cooling was pulverized with a mortar and a ball mill, and uniaxial press molding was performed by applying a load of 300 to 400 kg to prepare a pellet, that is, a composition (size: $\phi 7$ mm $\times$ 17 mm) for manufacturing an inorganic fiber.

[0056]

<Test 1: Evaluation of Heat Resistance and Crystallization Peak Temperature>

(Heat Resistance)

As evaluation for heat resistance, a heating shrinkage rate of a sample was measured. Specifically, a sample was placed in an electric furnace, and was heated up to 1110°C in accordance with a temperature rising rate simulating a heating curve of ISO834. A diameter of each sample was measured before and after heating, and the shrinkage rate was measured by the dimensional change. Specifically, calculation was performed with an expression of a heating shrinkage rate (%) = (sample diameter before heating - sample diameter after heating)/sample diameter before heating $\times$ 100.

[0057]

In the following discussion, in the case of performing heating under the above-described heating conditions, when

the shrinkage rate can be appropriately measured without melting of a sample pellet, this is determined as existence of heat resistance.

[0058]

(Crystallization Peak Temperature)

A crystallization peak temperature of a sample was obtained with an exothermic peak temperature when being heated up to 1000°C at a temperature rising rate of 20°C/minute by using differential thermal analyzer (DTA).

[0059]

(Result of Test 1)

Results of Test 1 are shown in Table 1 to Table 4, and FIG. 1 to FIG. 6. Note that, in the following tables, in a column of a composition (% by mass), trace components (corresponding to unavoidable impurities) are collectively noted as "others", and in the column of a composition (mol%), calculation was performed by excluding "other" components.

[0060]

[Table 1]

	Composition (% by mass)										Composition (mol%)										Physical properties		
	SiO ₂	Al ₂ O ₃	CaO	MgO	Fe ₂ O ₃	Na ₂ O	K ₂ O	TiO ₂	SO ₃	Others	Fe ₂ O ₃ +SO ₃	SiO ₂	Al ₂ O ₃	CaO	MgO	Fe ₂ O ₃	Na ₂ O	K ₂ O	TiO ₂	SO ₃	Molar basicity	Shrink-age rate (%)	Crystallization temperature (°C)
Example 1	30.7	14.6	40.9	8.3	3.0	0.3	0.4	0.7	1.0	0.1	4.0	31.2	8.7	44.5	12.6	1.2	0.3	0.3	0.5	0.7	1.4	4.2	-
Example 2	28.5	15.0	45.8	7.7	0.7	0.0	0.4	0.9	0.6	0.4	1.3	28.5	8.9	49.2	11.5	0.3	0.0	0.3	0.7	0.4	1.6	10.6	-
Example 3	33.3	12.3	43.4	7.5	0.2	0.0	0.3	1.3	0.8	0.4	1.0	33.5	7.2	46.1	11.0	0.1	0.0	0.2	0.9	0.6	1.4	11.2	-
Example 4	32.6	13.5	42.4	7.4	0.9	0.3	0.6	1.0	0.9	0.4	1.8	32.6	7.9	45.6	11.1	0.4	0.3	0.4	0.8	0.7	1.4	11.5	895
Example 5	33.4	11.8	42.2	7.8	1.5	0.0	0.6	1.1	1.2	0.4	2.7	33.4	6.9	45.2	11.6	0.6	0.0	0.4	0.8	0.9	1.4	11.6	-
Example 6	32.4	12.9	42.6	7.6	0.9	0.3	0.6	1.0	1.4	0.4	2.3	32.4	7.6	45.6	11.3	0.3	0.3	0.4	0.8	1.1	1.4	11.3	-
Example 7	31.4	14.1	42.5	7.7	1.1	0.3	0.6	0.7	1.4	0.4	2.4	31.5	8.3	45.7	11.6	0.4	0.2	0.4	0.5	1.0	1.4	10.8	-
Example 8	25.7	16.0	44.5	8.1	2.6	0.3	0.5	1.0	1.0	0.3	3.6	26.2	9.6	48.5	12.3	1.0	0.3	0.3	0.8	0.8	1.7	7.4	-
Example 9	41.4	12.9	33.8	6.5	2.2	0.2	0.6	0.9	1.1	0.3	3.3	42.2	7.8	36.9	9.9	0.9	0.2	0.4	0.7	0.8	0.9	14.0	-
Example 10	26.0	13.3	45.7	8.5	2.0	0.3	0.5	1.0	2.3	0.4	4.2	26.1	7.8	49.2	12.8	0.7	0.3	0.3	0.8	1.7	1.8	2.6	795
Example 11	26.2	15.1	44.2	8.4	3.0	0.3	0.5	0.8	1.1	0.3	4.1	26.6	9.1	48.1	12.7	1.1	0.3	0.3	0.6	0.9	1.7	5.0	-
Example 12	32.1	12.5	40.8	8.1	1.8	0.2	0.5	0.9	2.7	0.4	4.5	32.3	7.4	43.9	12.1	0.7	0.2	0.3	0.7	2.1	1.4	9.4	-
Example 13	30.9	12.0	41.6	7.3	1.1	0.2	0.6	1.1	4.7	0.4	5.8	31.2	7.1	45.0	11.0	0.4	0.2	0.4	0.8	3.5	1.5	5.0	-
Example 14	33.3	12.5	40.6	8.2	0.5	0.3	0.4	0.9	3.0	0.4	3.5	33.2	7.4	43.4	12.1	0.2	0.3	0.3	0.7	2.2	1.4	7.4	-
Example 15	32.4	11.4	41.3	7.8	0.7	0.2	0.5	1.1	4.2	0.3	4.9	32.4	6.7	44.3	11.6	0.3	0.2	0.3	0.8	3.1	1.4	5.8	-
Example 16	31.6	12.0	40.3	7.7	2.7	0.3	0.5	0.9	2.6	1.4	5.2	32.3	7.2	44.2	11.8	1.0	0.3	0.3	0.7	2.0	1.4	9.2	-
Example 17	31.9	12.5	41.7	7.8	0.7	0.2	0.5	0.9	3.3	0.4	4.0	32.0	7.4	44.7	11.6	0.3	0.2	0.3	0.7	2.5	1.4	8.3	-
Example 18	31.1	12.1	43.3	7.6	0.8	0.3	0.5	0.9	3.1	0.4	3.9	31.1	7.1	46.3	11.4	0.3	0.3	0.3	0.7	2.3	1.5	7.3	-
Example 19	31.3	13.7	40.2	7.9	4.0	0.3	0.5	0.7	0.9	0.3	4.9	32.0	8.3	44.0	12.1	1.6	0.3	0.3	0.6	0.7	1.4	9.3	-
Example 20	32.0	12.8	41.4	7.8	2.9	0.0	0.5	0.9	1.3	0.4	4.2	32.4	7.6	44.8	11.7	1.1	0.0	0.3	0.7	1.0	1.4	7.6	887
Example 21	31.4	12.9	38.7	7.5	5.6	0.3	0.5	0.8	1.8	0.5	7.4	32.5	7.9	43.0	11.5	2.2	0.3	0.3	0.6	1.4	1.3	2.0	-
Example 22	33.1	11.0	41.9	7.7	0.6	0.3	0.5	1.1	3.4	0.4	4.1	33.0	6.4	44.6	11.5	0.2	0.3	0.3	0.8	2.6	1.4	6.6	-
Example 23	31.7	12.3	40.3	7.7	0.7	0.3	0.5	0.9	5.1	0.4	5.8	31.9	7.3	43.5	11.5	0.3	0.3	0.3	0.7	3.8	1.4	4.8	-
Example 24	30.5	12.4	39.9	7.9	2.8	0.3	0.5	1.0	4.3	0.4	7.1	31.0	7.5	43.4	12.0	1.1	0.3	0.3	0.8	3.3	1.4	2.0	857
Example 25	29.3	14.9	39.3	7.7	2.9	0.3	0.5	1.0	3.5	0.4	6.4	30.2	9.1	43.4	11.8	1.1	0.3	0.3	0.8	2.7	1.4	2.8	-
Example 26	29.7	16.2	37.0	6.4	2.6	0.3	0.5	0.9	6.1	0.4	8.6	31.1	10.0	41.5	10.0	1.0	0.3	0.3	0.7	4.8	1.3	2.2	-
Example 27	38.2	13.9	30.9	6.4	2.5	0.3	0.5	1.0	5.9	0.3	8.5	39.8	8.5	34.4	10.0	1.0	0.3	0.4	0.8	4.6	0.9	3.8	-
Example 28	38.6	15.1	30.0	6.1	2.9	0.3	0.5	0.7	5.3	0.4	8.2	40.5	9.4	33.7	9.5	1.2	0.3	0.4	0.6	4.2	0.9	4.5	-
Example 29	33.0	13.8	37.4	7.1	4.9	0.3	0.6	0.9	1.5	0.4	6.5	34.2	8.4	41.6	10.9	1.9	0.3	0.4	0.7	1.2	1.2	9.9	-
Example 30	33.5	14.0	37.1	7.1	1.2	0.3	0.6	0.9	4.9	0.4	6.1	34.3	8.4	40.7	10.7	0.5	0.3	0.4	0.7	3.8	1.2	9.2	-

[0061]

[Table 2]

	Composition (% by mass)										Composition (mol%)										Physical properties		
	SiO ₂	Al ₂ O ₃	CaO	MgO	Fe ₂ O ₃	Na ₂ O	K ₂ O	TiO ₂	SO ₃	Others	Fe ₂ O ₃ +SO ₃	SiO ₂	Al ₂ O ₃	CaO	MgO	Fe ₂ O ₃	Na ₂ O	K ₂ O	TiO ₂	SO ₃	Molar basicity	Shrink -age rate (%)	Crystallization temperature (°C)
Example 31	34.2	14.2	37.9	7.0	1.3	0.3	0.6	0.7	3.5	0.3	4.8	34.8	8.5	41.3	10.7	0.5	0.3	0.4	0.6	2.7	1.2	9.8	-
Example 32	35.4	15.1	39.0	5.9	1.3	0.3	0.6	0.9	1.2	0.4	2.5	36.2	9.1	42.7	9.0	0.5	0.3	0.4	0.7	0.9	1.1	12.5	-
Example 33	33.5	9.9	41.4	8.1	0.1	0.2	0.5	1.1	4.7	0.4	4.8	33.1	5.8	43.9	12.0	0.0	0.2	0.3	0.8	3.5	1.4	2.3	-
Example 34	35.8	11.4	39.9	6.9	0.8	0.3	0.6	1.1	2.7	0.5	3.6	35.9	6.7	42.8	10.3	0.3	0.3	0.4	0.8	2.1	1.2	10.9	-
Example 35	29.5	13.9	39.8	7.6	1.6	0.3	0.5	1.0	5.4	0.4	7.1	30.1	8.4	43.5	11.6	0.6	0.3	0.3	0.8	4.2	1.4	3.4	-
Example 36	40.7	14.9	33.7	5.7	1.1	0.2	0.6	0.9	1.7	0.4	2.8	41.8	9.0	37.0	8.7	0.4	0.2	0.4	0.7	1.3	0.9	13.6	-
Example 37	34.4	9.9	42.5	7.4	0.1	0.3	0.6	0.8	3.7	0.4	3.7	34.0	5.7	45.0	10.9	0.0	0.3	0.4	0.6	2.7	1.4	4.3	-
Example 38	35.7	11.6	39.5	7.1	0.5	0.3	0.6	1.1	3.2	0.4	3.7	35.8	6.9	42.4	10.5	0.2	0.3	0.4	0.8	2.4	1.2	11.2	-
Example 39	29.5	13.2	41.3	7.7	1.3	0.2	0.5	0.8	5.1	0.3	6.4	29.9	7.9	44.8	11.7	0.5	0.2	0.3	0.6	3.9	1.5	3.0	-
Example 40	28.3	15.3	41.4	8.1	4.4	0.2	0.5	0.9	0.5	0.4	4.8	29.1	9.3	45.6	12.4	1.7	0.2	0.3	0.7	0.4	1.5	9.2	-
Example 41	32.3	12.7	42.7	7.5	0.7	0.3	0.6	1.0	1.8	0.4	2.5	32.2	7.4	45.7	11.2	0.3	0.3	0.4	0.7	1.3	1.4	11.2	-
Example 42	36.6	13.4	36.0	6.8	1.4	0.2	0.6	0.9	3.8	0.4	5.1	37.3	8.1	39.3	10.4	0.5	0.2	0.4	0.7	2.9	1.1	10.0	-
Example 43	36.6	12.6	37.2	7.2	1.8	0.3	0.6	0.9	2.4	0.3	4.2	37.1	7.5	40.3	10.9	0.7	0.3	0.4	0.7	1.8	1.1	11.5	-
Example 44	36.0	13.3	37.2	7.1	2.7	0.3	0.6	0.8	1.7	0.4	4.4	36.7	8.0	40.6	10.8	1.0	0.3	0.4	0.6	1.3	1.1	10.7	-
Example 45	33.4	9.4	42.5	7.4	4.1	0.4	0.5	0.9	1.0	0.4	5.1	33.5	5.6	45.8	11.1	1.5	0.3	0.3	0.7	0.8	1.5	8.8	-
Example 46	36.8	7.7	42.4	8.0	1.3	0.2	0.3	0.7	2.3	0.4	3.6	36.0	4.5	44.6	11.6	0.5	0.2	0.2	0.5	1.7	1.4	8.5	-
Example 47	29.3	15.6	43.7	6.7	0.9	0.0	0.3	0.9	2.3	0.4	3.2	29.8	9.3	47.5	10.1	0.4	0.0	0.2	0.7	1.8	1.5	4.8	-
Example 48	30.6	14.6	42.1	7.5	1.0	0.2	0.3	1.0	2.4	0.3	3.4	30.9	8.7	45.6	11.3	0.4	0.2	0.2	0.7	1.8	1.4	9.3	-
Example 49	32.0	13.2	41.9	7.7	1.3	0.0	0.3	0.9	2.2	0.6	3.6	32.2	7.8	45.2	11.5	0.5	0.0	0.2	0.7	1.7	1.4	9.5	890
Example 50	30.3	14.5	46.4	4.3	0.6	0.0	0.2	0.8	2.4	0.3	3.0	30.9	8.7	50.7	6.6	0.2	0.0	0.2	0.6	1.8	1.4	8.0	-
Example 51	29.0	14.6	46.2	4.6	2.0	0.1	0.3	0.8	1.9	0.4	3.9	29.8	8.9	50.8	7.1	0.8	0.1	0.2	0.6	1.5	1.5	3.2	-
Example 52	29.9	14.9	46.3	4.6	0.9	0.0	0.2	0.9	2.0	0.4	2.9	30.5	9.0	50.6	7.0	0.4	0.0	0.1	0.7	1.5	1.5	3.7	-
Example 53	27.3	19.4	41.4	7.7	0.4	0.0	0.2	0.8	2.4	0.3	2.8	28.0	11.7	45.5	11.7	0.2	0.0	0.1	0.6	1.9	1.4	7.1	-
Example 54	30.5	14.4	46.0	4.0	1.7	0.0	0.2	0.9	2.0	0.3	3.7	31.3	8.7	50.6	6.1	0.7	0.0	0.2	0.7	1.5	1.4	5.6	-
Example 55	25.9	20.6	39.7	6.6	4.1	0.2	0.2	0.9	1.6	0.3	5.7	27.4	12.8	45.1	10.4	1.6	0.2	0.2	0.7	1.3	1.4	6.4	-
Example 56	35.3	17.3	36.0	6.0	1.2	0.2	0.3	0.8	2.4	0.4	3.7	36.5	10.6	39.9	9.3	0.5	0.2	0.2	0.7	1.9	1.0	11.2	-
Example 57	33.0	18.4	39.2	3.4	2.5	0.0	0.3	0.8	2.0	0.4	4.5	34.9	11.5	44.5	5.4	1.0	0.0	0.2	0.7	1.6	1.1	11.8	-
Example 58	35.9	15.9	39.4	3.1	1.9	0.2	0.3	0.8	2.0	0.3	3.9	37.5	9.8	44.1	4.8	0.7	0.2	0.2	0.7	1.6	1.0	11.6	-
Example 59	35.3	16.6	39.1	3.3	1.8	0.2	0.3	0.9	2.1	0.3	3.9	37.0	10.3	43.9	5.1	0.7	0.2	0.2	0.7	1.6	1.0	11.3	-
Example 60	32.9	17.0	40.9	3.5	1.7	0.2	0.3	1.0	2.2	0.4	3.9	34.4	10.5	45.8	5.5	0.7	0.2	0.2	0.8	1.7	1.1	10.9	-
Example 61	32.7	17.2	41.2	3.3	1.9	0.2	0.3	0.7	2.2	0.3	4.1	34.3	10.7	46.2	5.1	0.7	0.2	0.2	0.5	1.7	1.1	11.6	-
Example 62	31.7	16.4	40.8	5.9	1.2	0.0	0.3	1.0	2.3	0.3	3.5	32.6	10.0	45.0	9.0	0.5	0.0	0.2	0.8	1.8	1.3	10.6	22

[0062]

[Table 3]

	Composition (% by mass)												Composition (mol%)										Physical properties		
																							Shrink- age rate (%)	Crystal- lization tempera- ture (°C)	
	SiO ₂	Al ₂ O ₃	CaO	MgO	Fe ₂ O ₃	Na ₂ O	K ₂ O	TiO ₂	SO ₃	MnO	Others	Fe ₂ O ₃ +MnO +SO ₃	SiO ₂	Al ₂ O ₃	CaO	MgO	Fe ₂ O ₃	Na ₂ O	K ₂ O	TiO ₂	SO ₃	MnO			Molar basicity
Example 63	29.6	14.1	38.4	7.9	1.9	0.2	0.3	0.5	1.8	5.3	0.0	9.0	30.2	8.4	41.9	12.0	0.7	0.2	0.2	0.4	1.3	4.6	1.4	0.9	-
Example 64	31.9	13.0	41.2	8.2	0.3	0.0	0.3	1.0	2.0	2.1	0.0	4.5	31.8	7.6	44.0	12.1	0.1	0.0	0.2	0.7	1.5	1.8	1.4	7.0	-
Example 65	30.5	13.9	39.2	7.9	1.9	0.2	0.3	0.8	2.1	3.3	0.1	7.3	31.0	8.3	42.6	11.9	0.7	0.2	0.2	0.6	1.6	2.8	1.4	1.9	-
Example 66	30.2	16.1	36.5	6.6	1.4	0.2	0.4	0.8	2.3	5.4	0.0	9.1	31.3	9.9	40.5	10.1	0.5	0.2	0.3	0.6	1.8	4.8	1.2	4.0	-
Example 67	31.3	15.7	37.4	6.9	1.9	0.0	0.3	1.0	2.2	3.2	0.0	7.3	32.2	9.6	41.3	10.7	0.7	0.0	0.2	0.8	1.7	2.8	1.2	7.8	-
Comparative Example 1	42.4	12.2	35.0	6.5	1.2	0.3	0.6	0.7	0.8	-	0.3	1.9	42.7	7.3	37.8	9.7	0.4	0.3	0.4	0.5	0.6	-	0.9	Melted	-
Example 68	34.3	15.5	26.9	8.2	11.3	1.6	1.0	0.7	0.3	-	0.3	11.6	37.4	10.0	31.4	13.3	4.6	1.6	0.7	0.6	0.2	-	0.9	1.6	-
Example 69	36.9	16.2	21.1	8.9	13.8	1.7	0.9	0.1	0.1	-	0.3	13.9	41.0	10.6	25.1	14.7	5.8	1.8	0.6	0.1	0.1	-	0.8	1.8	-
Example 70	36.9	11.7	32.3	5.3	9.8	1.1	0.8	0.7	0.2	1.1	0.2	11.1	39.7	7.4	37.2	8.4	4.0	1.1	0.6	0.5	0.2	1.0	1.0	3.2	-
Example 71	35.6	13.5	33.8	5.6	6.7	1.4	0.8	0.9	0.3	1.4	0.0	8.4	37.7	8.4	38.2	8.8	2.6	1.4	0.5	0.7	0.2	1.3	1.0	4.9	-
Example 72	31.6	14.1	36.5	6.9	7.1	0.3	0.5	1.2	1.4	-	0.3	8.5	33.3	8.8	41.3	10.8	2.8	0.3	0.4	0.9	1.1	-	1.2	5.3	-
Example 73	29.6	13.4	38.8	7.4	0.7	0.0	0.3	0.6	2.5	6.6	0.1	9.8	30.0	8.0	42.2	11.3	0.3	0.0	0.2	0.5	1.9	5.7	1.4	1.3	-
Example 74	30.3	16.5	36.8	6.1	0.8	0.2	0.3	1.0	1.5	6.4	0.0	8.5	31.4	10.1	40.9	9.4	0.3	0.2	0.2	0.8	1.1	5.6	1.2	3.3	-
Comparative Example 2	40.0	13.0	38.1	6.2	1.2	0.2	0.3	1.0	0.0	-	0.0	1.2	40.3	7.7	41.1	9.2	0.5	0.1	0.2	0.8	0.0	-	1.0	Melted	-
Comparative Example 3	31.1	23.0	36.9	6.4	1.2	0.2	0.3	0.9	0.0	-	0.0	1.2	32.6	14.2	41.5	10.0	0.5	0.2	0.2	0.7	0.0	-	1.1	Melted	-

[0063]

[Table 4]

	Composition (% by mass)																			Transition metal oxide +SO3
	SiO ₂	Al ₂ O ₃	CaO	MgO	Fe ₂ O ₃	Na ₂ O	K ₂ O	TiO ₂	SO ₃	Others	CuO	NiO	CoO	ZrO ₂	V ₂ O ₅	Nb ₂ O ₅	MoO ₃	WO ₃	Y ₂ O ₃	
Example 75	30.4	13.4	39.1	7.8	1.7	0.0	0.3	0.7	2.8	0.3	3.5	-	-	-	-	-	-	-	-	8.0
Example 76	32.4	15.0	41.2	7.5	0.5	0.1	0.3	0.8	1.2	0.0	-	1.0	-	-	-	-	-	-	-	2.7
Example 77	30.2	17.2	39.6	10.8	0.1	0.2	0.3	0.9	0.3	0.1	-	-	0.4	-	-	-	-	-	-	0.8
Example 78	32.5	16.4	36.4	5.8	2.0	0.2	0.2	0.8	1.4	0.4	-	-	-	4.0	-	-	-	-	-	7.3
Example 79	31.0	14.7	38.3	5.7	2.0	0.2	0.3	0.9	2.0	0.3	-	-	-	-	4.1	-	-	-	-	8.1
Example 80	44.1	10.0	18.3	17.3	1.8	0.0	0.3	0.9	1.7	0.0	-	-	-	-	-	5.1	-	-	-	8.6
Example 81	31.8	13.9	38.0	6.9	2.0	0.2	0.3	0.8	1.7	0.3	-	-	-	-	-	-	4.1	-	-	7.8
Example 82	32.1	13.5	38.9	7.3	2.0	0.2	0.3	0.7	1.7	0.4	-	-	-	-	-	-	-	2.8	-	6.5
Example 83	45.2	13.6	19.0	12.5	2.0	0.1	0.3	0.6	1.8	0.3	-	-	-	-	-	-	-	-	4.5	8.3

	Composition (mol%)																		Physical properties	
	SiO ₂	Al ₂ O ₃	CaO	MgO	Fe ₂ O ₃	Na ₂ O	K ₂ O	TiO ₂	SO ₃	CuO	NiO	CoO	ZrO ₂	V ₂ O ₅	Nb ₂ O ₅	MoO ₃	WO ₂	Y ₂ O ₃	Molar basicity	Shrinkage rate (%)
Example 75	31.0	8.0	42.8	11.9	0.6	0.0	0.2	0.6	2.1	2.7	-	-	-	-	-	-	-	-	1.4	3.1
Example 76	32.6	8.9	44.5	11.2	0.2	0.1	0.2	0.6	0.9	-	0.8	-	-	-	-	-	-	-	1.3	11.9
Example 77	30.1	10.1	42.2	16.0	0.0	0.2	0.2	0.7	0.2	-	-	0.3	-	-	-	-	-	-	1.4	11.9
Example 78	34.4	10.2	41.3	9.1	0.8	0.2	0.2	0.7	1.1	-	-	-	2.0	-	-	-	-	-	1.1	9.2
Example 79	32.8	9.2	44.1	8.9	0.8	0.2	0.2	0.7	1.6	-	-	-	-	1.4	-	-	-	-	1.3	9.4
Example 80	44.2	5.9	20.1	25.8	0.7	0.0	0.2	0.7	1.3	-	-	-	-	-	1.2	-	-	-	0.9	7.5
Example 81	33.2	8.5	42.4	10.7	0.8	0.2	0.2	0.7	1.4	-	-	-	-	-	-	2.0	-	-	1.3	6.6
Example 82	33.2	8.3	43.2	11.3	0.8	0.2	0.2	0.6	1.3	-	-	-	-	-	-	-	0.8	-	1.3	9.0
Example 83	47.0	8.3	21.1	19.3	0.8	0.2	0.2	0.5	1.4	-	-	-	-	-	-	-	-	1.2	0.7	9.4

[0064]

FIG. 1 is a graph obtained by plotting the molar basicity P of each sample in the horizontal axis, and the total content Q of a transition metal compound ($\text{Fe}_2\text{O}_3/\text{MnO}$) and sulfur in the vertical axis. An upper drawing in FIG. 1 is a graph obtained by extracting samples in which the heating shrinkage rate at 1110°C is 14% or less among respective samples. In addition, a lower drawing in FIG. 1 is a graph obtained by extracting samples melted at 1110°C .
[0065]

As indicated by a broken line in FIG. 1, in samples having excellent heat resistance (the shrinkage rate at 1110°C is 14% or less), the total content Q of the transition metal compound and sulfur was 0.5% by mass or greater, and P and Q satisfied the following Expression (1).

$$-3.3 \times P + 5.1 \leq Q \quad (1)$$

[0066]

An upper drawing in FIG. 2 is a graph obtained by extracting samples in which the heating shrinkage rate at 1110°C is 12% or less among respective samples. In addition, a lower drawing in FIG. 2 is a graph obtained by extracting samples in which the heating shrinkage rate at 1110°C is greater than 12%.

[0067]

As indicated by a broken line in FIG. 2, in samples having more excellent heat resistance (the heating shrinkage rate at 1110°C is 12% or less), the total content Q of the transition metal compound and sulfur was 0.5% by mass or greater, and P and Q satisfied the following Expression (2).

$$-7.5 \times P + 11.0 \leq Q \quad (2)$$

[0068]

An upper drawing in FIG. 3 is a graph obtained by

extracting samples in which the heating shrinkage rate at 1110°C is 10% or less among respective samples. In addition, a lower drawing in FIG. 3 is a graph obtained by extracting samples in which the heating shrinkage rate at 1110°C is greater than 10%.

[0069]

As indicated by a broken line in FIG. 3, in samples having still more excellent heat resistance (the heating shrinkage rate at 1110°C is 10% or less), the total content Q of the transition metal compound and sulfur was 2.5% by mass or greater, and P and Q satisfied the following Expression (3).

$$-6.7 \times P + 11.9 \leq Q \quad (3)$$

[0070]

FIG. 4 is a graph obtained by plotting the total content Q of the transition metal compound and sulfur of each sample (molar basicity $P = 1.4$) in Test 1 in the horizontal axis, and the crystallization peak temperature in the vertical axis. As illustrated in FIG. 4, it could be seen that the higher the total content Q of the transition metal compound and sulfur (SO_3) is, the further the crystallization peak temperature is lowered, and the further crystallization is promoted.

[0071]

FIG. 5 is a graph obtained by plotting the molar basicity P of each sample (the total content Q of the transition metal compound and sulfur is 4.2% by mass) in Test 1 in the horizontal axis, and the crystallization peak temperature in the vertical axis. As illustrated in FIG. 5, it could be seen that the higher the molar basicity P is, the further the crystallization peak temperature is lowered, and the further crystallization is promoted.

[0072]

FIG. 6 is a graph obtained by plotting the crystallization peak temperature of each sample in Test 1 in the horizontal axis, and the heating shrinkage rate at 1110°C in the vertical axis. As illustrated in FIG. 6, it could be seen that the lower the crystallization peak temperature is, the lower the heating shrinkage rate is and the further the heat resistance is improved.

[0073]

<Test 2: Measurement of Melt Viscosity>

Samples in which the molar basicity P is 0.4, 0.6, 1.6, and 1.8 were prepared, and melt viscosity was measured. Measurement was performed by using a typical ball pull-up type viscometer. Specifically, a platinum ball connected to a platinum wire was submerged in the melt maintained at a constant temperature, and viscosity was obtained from a load when pulling up the platinum ball at a predetermined speed.

[0074]

(Results of Test 2)

Results of Test 2 are shown in the following Table 5. In samples in which the molar basicity P was 0.4 and 1.8, respectively, at a point of time at which a temperature lowered from 1500°C by 25°C to 50°C, viscosity rose to a certain extent at which measurement was difficult. In contrast, in samples in which the molar basicity P was 0.6 and 1.6, respectively, there was a temperature range of approximately 100°C to 200°C until measurement of viscosity became difficult.

[0075]

[Table 5]

Temperature (°C)	Molar basicity (P)			
	0.4	0.6	1.6	1.8
1500	121	38	9	24
1475	452			Measurement was difficult
1450	Measurement was difficult		10	
1425			16	
1400		151	Measurement was difficult	
1350		446		
1300		1649		
1275		Measurement was difficult		

*Unit of viscosity is Poise

[0076]

Viscosity when a raw material was melted is an index that greatly affects manufacturability of the inorganic fiber. When manufacturing the inorganic fiber, a raw material is melted in a cupola or an electric furnace, and a melt maintained at approximately 1500°C is allowed to flow out from the bottom of the furnace, and is fiberized by a spinning method or a blowing method. The melt is stretched in a fiberization process, but the melt is cooled down in the process. That is, for satisfactory fiberization, it is preferable that an increase in viscosity in accordance with a decrease in a temperature of the melt is gradual. Accordingly, from the results in Test 2, it could be seen that the molar basicity P is preferably within a range of 0.6 to 1.6 ($0.6 \leq P \leq 1.6$) in order to satisfactorily fiberize the inorganic fiber.

[0077]

<Summary of Test 1>

From the results, it was newly found that the molar basicity P and the total content Q of the transition metal

compound and sulfur (SO_3) affect heat resistance of rock wool, respectively. Specifically, in rock wool and a composition for manufacturing rock wool, when the molar basicity P and the total content Q of the transition metal compound and sulfur (SO_3) are within the above-described predetermined ranges, microcrystals exist before being softened and deformed due to heating, softening does not proceed and curvature and fusion of the fiber do not occur even when being exposed to a high temperature of 1100°C or higher.

[0078]

<Test 2: Preparation of Inorganic Fiber>

Hereinafter, with regard to the composition for manufacturing an inorganic fiber based on the specific examples, an inorganic fiber was actually manufactured, and heat resistance was measured. The relationship illustrated in FIG. 1 to FIG. 3 was verified by actually preparing an inorganic fiber. Note that, the invention is not limited thereto.

[0079]

<Preparation of Fiber>

In compositions shown in Table 6, natural stones such as basalt, and various raw materials such as slag and silica are poured into an electric furnace or cupola, and the raw materials were melted by a similar method as in a method of manufacturing a typical fiber. Then, the melted raw materials were allowed to flow out from the bottom of the furnace and were fiberized by a spinning method. A binder adhered to the fiber, and an inorganic fiber molded body (volume density: 0.08 to 0.12 g/cm³) was obtained by allowing the fiber to pass through a curing furnace.

[0080]

<Evaluation for Heat Resistance>

As an evaluation for the heat resistance, a heating shrinkage rate of the fiber molded body was measured. Specifically, a molded body sample cut to 50 mm × 50 mm was placed in an electric furnace, and the sample was heated up to 1110°C in accordance with a temperature rising rate simulating a heating curve of ISO834. Lengths of the sample in a vertical direction and a horizontal direction were measured before and after heating, and the shrinkage rate was measured by the dimensional change. Specifically, calculation was performed with an expression of a heating shrinkage rate (%) = (sample length before heating - sample length after heating)/sample length before heating × 100. Note that, a shrinkage rate shown in Table 6 is an average value of a shrinkage rate in the vertical direction and a shrinkage rate in the horizontal direction.

[0081]

Results of the test are shown in Table 6 and FIG. 7.

[0082]

[Table 6]

	Composition (% by mass)												Composition (mol%)											Physical properties	
	SiO ₂	Al ₂ O ₃	CaO	MgO	Fe ₂ O ₃	Na ₂ O	K ₂ O	TiQ ₂	SO ₃	MnO	Others	Fe ₂ O ₃ +MnO+SO ₃	SiO ₂	Al ₂ O ₃	CaO	MgO	Fe ₂ O ₃	Na ₂ O	K ₂ O	TiQ ₂	SO ₃	MnO	Molar basicity		
Example 84	36.7	16.0	23.4	5.8	13.6	1.6	1.3	1.0	0.1	0.2	0.3	13.9	41.5	10.7	28.4	9.9	5.8	1.7	0.9	0.8	0.1	0.2	0.7	2.5	
Example 85	36.1	15.0	25.1	8.1	11.7	1.8	0.9	0.7	0.2	0.2	0.3	12.1	39.4	9.7	29.4	13.2	4.8	1.9	0.6	0.6	0.2	0.2	0.9	3.1	
Example 86	35.4	11.5	32.5	5.4	9.6	1.3	0.9	0.7	0.3	1.5	0.9	11.4	38.3	7.3	37.7	8.6	3.9	1.4	0.6	0.6	0.2	1.4	1.0	3.4	
Example 87	35.3	10.9	34.8	5.3	8.5	1.1	0.9	0.7	0.3	1.3	0.9	10.1	37.7	6.8	39.9	8.4	3.4	1.2	0.6	0.6	0.3	1.2	1.1	3.5	
Example 88	36.6	15.1	26.2	8.4	9.7	1.9	0.9	0.6	0.3	0.2	0.2	10.2	39.4	9.6	30.2	13.4	3.9	1.9	0.6	0.5	0.2	0.2	0.9	5.1	
Example 89	31.9	12.6	45.6	5.8	1.2	0.3	0.3	0.7	0.9	0.5	0.3	2.5	32.1	7.5	49.2	8.7	0.5	0.3	0.2	0.6	0.6	0.4	1.5	6.6	
Comparative Example 4	45.6	10.0	35.0	2.3	1.9	1.7	2.2	0.6	0.3	0.1	0.3	2.3	47.1	6.1	38.7	3.5	0.7	1.7	1.4	0.5	0.2	0.1	0.8	Melted	
Comparative Example 5	40.7	14.5	35.3	4.3	1.2	1.1	1.0	0.9	0.7	0.2	0.2	2.0	42.0	8.8	39.0	6.5	0.5	1.1	0.7	0.7	0.5	0.2	0.9	Melted	
Comparative Example 6	41.3	11.1	39.1	5.3	0.1	0.3	0.3	0.8	1.4	0.1	0.2	1.6	41.3	6.5	41.9	7.9	0.0	0.3	0.2	0.6	1.0	0.1	1.0	Melted	

[0083]

FIG. 7 is a graph obtained by plotting the molar basicity P of each sample in the horizontal axis, and the total content Q of a transition metal compound ($\text{Fe}_2\text{O}_3/\text{MnO}$) and sulfur in the vertical axis.

In addition, two broken lines in FIG. 7 indicate the following relational Expressions illustrated in FIG. 1 to FIG. 3.

$$-3.3 \times P + 5.1 \leq Q \quad (1)$$

$$-6.7 \times P + 11.9 \leq Q \quad (3)$$

[0084]

As illustrated in FIG. 7, it could be confirmed that results obtained by evaluating the fiber molded body show a tendency matching the results of the composition for manufacturing an inorganic fiber as illustrated in FIG. 1 to FIG. 3. That is, it could be confirmed that a relationship between the heat resistance and the composition is also established in not only the composition for manufacturing an inorganic fiber but also the inorganic fiber, and thus it is considered that probability is extremely high.

CLAIMS

[Claim 1]. An inorganic fiber,

wherein a total amount Q of a transition metal compound and SO_3 is 2.5% by mass or greater,

wherein the total amount of the transition metal compound is less than 2.0% by mass,

wherein an amount of SO_3 is 0.5% by weight to 6.1% by weight,

a molar basicity P expressed by a molar ratio ($\text{mol}\% (\text{CaO} + \text{MgO}) / \text{mol}\% (\text{SiO}_2 + \text{Al}_2\text{O}_3)$) of the sum of CaO and MgO to the sum of SiO_2 and Al_2O_3 is 0.6 or greater, and

Expression (1): $-3.3 \times P + 5.1 \leq Q$ (1) is satisfied.

[Claim 2]. The inorganic fiber according to claim 1,

wherein the transition metal compound is at least one kind of compound selected from the group consisting of Fe, Mn, Cu, Ni, Co, Zr, V, Nb, Mo, W, and Y.

[Claim 3]. The inorganic fiber according to claim 1 or 2,

wherein a heating shrinkage rate at 1110°C is 14% or less.

[Claim 4]. The inorganic fiber according to any one of claims 1 to 3, the inorganic fiber having a composition containing:

25% by weight to 45% by weight of SiO_2 ;

5% by weight to 25% by weight of Al_2O_3 ;

15% by weight to 50% by weight of CaO ;

3% by weight to 20% by weight of MgO ;

0.1% by weight to 14% by weight of transition metal compound; and

0.5% by weight to 6.1% by weight of SO_3 .

[Claim 5]. The inorganic fiber according to claim 4, further containing:

0% by weight to 10% by weight of Na_2O ; and

0% by weight to 10% by weight of K_2O .

[Claim 6]. The inorganic fiber according to claim 5,

wherein the inorganic fiber contains at least one or more kinds selected from the group consisting of P_2O_5 , Li_2O , Na_2O , and K_2O , and

a total amount of P_2O_5 , Li_2O , Na_2O , and K_2O is 3% by weight to 10% by weight.

[Claim 7]. The inorganic fiber according to any one of claims 1 to 6,

the inorganic fiber is at least one or more kinds selected from the group consisting of rock wool, stone wool, slag wool, mineral wool, glass wool, and mineral glass wool.

[Claim 8]. An inorganic fiber product, comprising:

the inorganic fiber according to any one of claims 1 to 7.

[Claim 9]. The inorganic fiber product according to claim 8,

wherein the inorganic fiber product is a heat insulating material or a refractory material.

[Claim 10]. A method of manufacturing an inorganic fiber product, comprising:

molding the inorganic fiber according to any one of

claims 1 to 7.

[Claim 11]. A composition for manufacturing an inorganic fiber,

wherein a total amount Q of a transition metal compound and SO₃ is 2.5% by mass or greater,

wherein the total amount of the transition metal compound is less than 2.0% by mass,

wherein an amount of SO₃ is 0.5% by weight to 6.1% by weight,

a molar basicity P expressed by a molar ratio (mol% (CaO + MgO)/mol% (SiO₂ + Al₂O₃)) of the sum of CaO and MgO to the sum of SiO₂ and Al₂O₃ is 0.6 or greater, and

Expression (1): $-3.3 \times P + 5.1 \leq Q$ (1) is satisfied.

[Claim 12]. A method of manufacturing an inorganic fiber, comprising:

melting the composition for manufacturing an inorganic fiber according to claim 11; and

making the resultant melt into a fiber to obtain an inorganic fiber.