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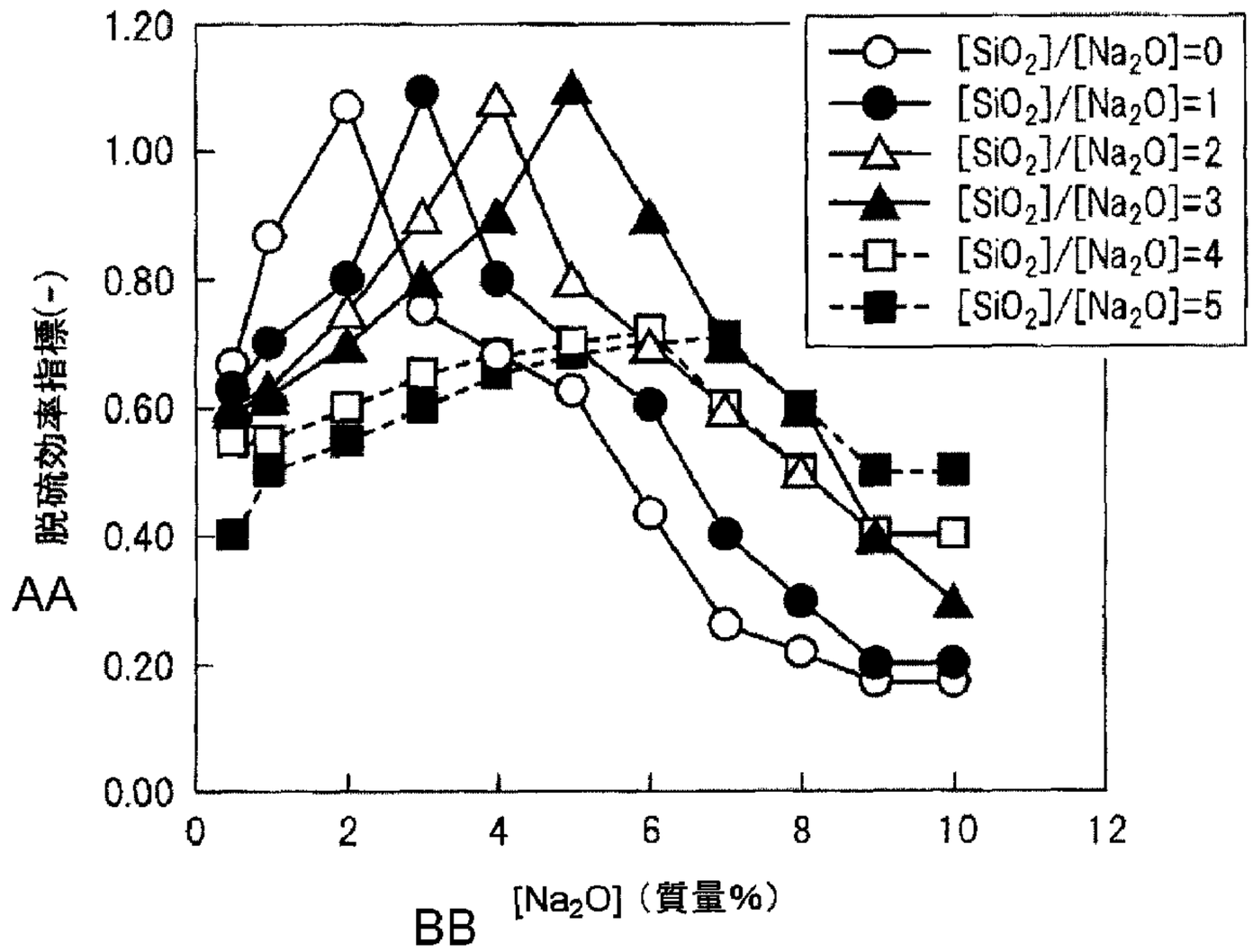
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(54) Titre : FLUX DE DESULFURATION D'ACIER EN FUSION RESPECTUEUX DE L'ENVIRONNEMENT
(54) Title: ENVIRONMENTALLY FRIENDLY FLUX FOR MOLTEN STEEL DESULFURIZATION

[図2]



AA Index to desulfurization efficiency (-)
BB $[Na_2O]$ (mass%)

(57) Abrégé/Abstract:
This environmentally friendly flux for the desulfurization of a molten steel contains CaO and Al_2O_3 so that $[CaO]/[Al_2O_3]$ is in the range of 1.6-3.0 where [CaO] and $[Al_2O_3]$ are the contents in mass% of CaO and Al_2O_3, respectively, and further contains both one

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(57) Abrégé(suite)/Abstract(continued):
or more alkali metal oxides selected from Na_2O, K_2O, and Li_2O and SiO_2 so that $[SiO_2]/[R_2O]$ is in the range of 0.1-3, $[R_2O]$ is in the range of 0.5-5 mass%, and $[SiO_2]$ is in the range of 0.05-15 mass% where $[SiO_2]$ is the content in mass% of SiO_2 and $[R_2O]$ is the total content in mass% of Na_2O, K_2O, and Li_2O.

ABSTRACT OF THE DISCLOSURE

An environmentally friendly flux for molten steel desulfurization includes CaO and Al_2O_3 so that $[CaO]/[Al_2O_3]$ is within a range of 1.6 to 3.0, and includes one or more alkali metal oxides of Na_2O, K_2O, and Li_2O, and SiO_2 so that $[SiO_2]/[R_2O]$ is within a range of 0.1 to 3, $[R_2O]$ is within a range of 0.5 mass% to 5 mass%, and $[SiO_2]$ is within a range of 0.05 mass% to 15 mass% in a case in which the [CaO], the $[Al_2O_3]$, the $[SiO_2]$, and the $[R_2O]$ represent the mass% of CaO, the mass% of Al_2O_3, the mass% of SiO_2, and the total amount of the mass% of Na_2O, the mass% of K_2O, and the mass% of Li_2O respectively.

SPECIFICATION

TITLE OF INVENTION

ENVIRONMENTALLY FRIENDLY FLUX FOR MOLTEN STEEL DESULFURIZATION

Field of the Invention

[0001]

The present invention relates to a flux used during refining of highly clean steel. The invention particularly relates to a flux that is used to perform desulfurization in a secondary refining process after a converter process or in a refining process inside or outside an electric furnace during steel making. Here, the flux is a collective term of various compounds which react with molten iron so as to have a function of removing impurities.

Description of Related Art

[0002]

For high-tensile steel having favorable formability, high-strength line pipes, high-strength steel plates, and the like, there is a demand for an extreme decrease in the amount of S which is an impurity of steel. Therefore, desulfurization of molten steel is performed in a secondary refining process after a converter process or in a reduction stage of an electric furnace process during steel making. For desulfurization of molten steel, a CaO-based desulfurization flux is mainly used, and there are frequent cases in which a

flux including CaF_2 having a high desulfurization ability is used to decrease the S content within a short period of time.

[0003]

However, since the desulfurization flux including CaF_2 is highly reactive, and easily erodes away refractories in a refining reactor, there is a problem in that the service life of the refractories is shortened. In addition, slag discharged after refining is generally used for roadbed materials and the like; however, when a large amount of CaF_2 is present in slag which is formed during desulfurization using a flux including CaF_2, there is a concern that F eluted from CaF_2 may have an adverse influence on the environment. Therefore, in this case, it is necessary to perform stricter management of slag components or further limit the use of slag.

[0004]

As a molten steel desulfurization flux which does not include CaF_2, but has a high desulfurization ability, for example, Patent Citation 1 discloses a desulfurization flux including Na_2O. However, Patent Citation 1 does not disclose the Na_2O content (mass%) in the desulfurization flux.

[0005]

Patent Citation 2 discloses a desulfurization flux including K_2O. Patent Citation 3 discloses a desulfurization flux including Na_2O or K_2O. However, those desulfurization fluxes are for hot metal desulfurization. In addition, the Na_2O and K_2O contents in the desulfurization flux are 15 mass% or more. Thus, when large amounts of Na_2O and K_2O are present in the desulfurization flux, there is a problem in that Na_2O and K_2O evaporate during a desulfurization treatment. In addition, there is a concern that large amounts of Na_2O and K_2O may be present in slag after desulfurization treatment.

[0006]

Patent Citation 4 discloses a method in which a desulfurizing agent containing Na_2CO_3 is used. However, the desulfurizing agent is a flux for hot metal desulfurization, and, in Patent Citation 4, since the Na_2CO_3 content is high, there is a problem in that Na_2O evaporates or remains in slag.

[0007]

Patent Citations 5 to 8 disclose methods in which Na_2O is used, but all the methods are targeted at hot metal desulfurization. In the hot metal desulfurization, the treatment temperature or the C and O contents in hot metal are significantly different from those in molten steel desulfurization. Therefore, when the methods of Patent Citations 5 to 8 are applied to molten steel desulfurization with no change, there is a concern that the problem of evaporation of Na_2O may become significant, or a large amount of Na_2O may remain in slag after desulfurization treatment.

[0008]

As described above, for high-tensile steel having favorable workability, high-strength line pipes, high-strength steel plates, and the like, there is a demand for a decrease in S which is an impurity of steel as much as possible, and desulfurization of molten steel is performed in a secondary refining process (a refining process after a converter process or an electric furnace process) during steel making. At this time, there are frequent cases in which a flux including CaF_2 having a high desulfurization ability is used to decrease S within a short period of time.

[0009]

However, as described above, since the desulfurization flux including CaF_2 is highly reactive, there is a problem in that refractories in a refining reactor are easily melted away, and the service life of the refractories is shortened. In addition, slag

discharged after refining is generally used for roadbed materials and the like; however, since slag includes CaF_2 when a desulfurization flux including CaF_2 is used for desulfurization, and there is a problem of elution of F, and therefore the use of slag is significantly limited.

[0010]

Therefore, with regard to hot metal desulfurization, a number of techniques in which a desulfurization flux including Na_2O or K_2O instead of CaF_2 is used are proposed. However, as described above, since the conditions of hot metal desulfurization are significantly different from the conditions of molten steel desulfurization, it is not possible to apply the hot metal desulfurization techniques to molten steel desulfurization with no change.

[0011]

In a case where the Na_2O content (mass%) or the K_2O content (mass%) is high, there is a concern that a problem may occur in which easily evaporating Na_2O or K_2O attaches to the exhaust duct in a secondary refining facility, or the Na_2O or K_2O content in slag becomes high after desulfurization such that recycled slag has an adverse influence on the environment.

Patent Citation

[0012]

[Patent Citation 1] Japanese Unexamined Patent Application, First Publication No. H03-264624

[Patent Citation 2] Japanese Unexamined Patent Application, First Publication No. 2000-226284

[Patent Citation 3] Japanese Unexamined Patent Application, First Publication No. H06-235011

[Patent Citation 4] Japanese Unexamined Patent Application, First Publication No. 2002-241823

[Patent Citation 5] Japanese Unexamined Patent Application, First Publication No. H08-209212

[Patent Citation 6] Japanese Unexamined Patent Application, First Publication No. 2001-335819

[Patent Citation 7] Japanese Unexamined Patent Application, First Publication No. 2001-335820

[Patent Citation 8] Japanese Unexamined Patent Application, First Publication No. 2003-253315

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

[0013]

Therefore, the present invention has been made in consideration of the above problems, and an objective of the present invention is to provide an environmentally friendly desulfurization flux for molten steel desulfurization which has a high desulfurization ability even when not including CaF_2.

Methods for Solving the Problem

[0014]

The present invention has been made to solve the above problems, and the purports thereof are as follows.

[0015]

(1) An environmentally friendly flux for molten steel desulfurization according to an aspect of the present invention includes CaO and Al_2O_3 so that $[CaO]/[Al_2O_3]$ is within a range of 1.6 to 3.0, and includes one or more alkali metal oxides of Na_2O, K_2O, and Li_2O, and SiO_2 so that $[SiO_2]/[R_2O]$ is within a range of 0.1 to 3, $[R_2O]$ is within a range of 0.5 mass% to 5 mass%, and $[SiO_2]$ is within a range of 0.05 mass% to 15 mass% in a case in which the $[CaO]$, the $[Al_2O_3]$, the $[SiO_2]$, and the $[R_2O]$ represent the mass% of CaO, the mass% of Al_2O_3, the mass% of SiO_2, and the total amount of the mass% of Na_2O, the mass% of K_2O, and the mass% of Li_2O respectively.

[0016]

(2) The environmentally friendly flux for molten steel desulfurization according to the above (1) may further include 1 mass% to 10 mass% of MgO.

[0017]

(3) In the environmentally friendly flux for molten steel desulfurization according to the above (1) or (2), the $[SiO_2]$ may be 0.05 mass% to 9.3 mass%.

[0018]

(4) In the environmentally friendly flux for molten steel desulfurization according to any one of the above (1) to (3), the $[SiO_2]$ may be 0.05 mass% to 8.0 mass%.

[0019]

(5) In the environmentally friendly flux for molten steel desulfurization according to any one of the above (1) to (4), the $[SiO_2]/[R_2O]$ may be 0.1 to 2.

[0020]

(6) In the environmentally friendly flux for molten steel desulfurization according to any one of the above (1) to (5), some or all of the alkali metal oxides may have a chemical bond with the SiO_2.

[0021]

(7) In the environmentally friendly flux for molten steel desulfurization according to any one of the above (1) to (6), the alkali metal oxides may be Na_2O.

[0022]

(8) In a molten steel desulfurization method according to an aspect of the present invention, the environmentally friendly flux for molten steel desulfurization according to any one of the above (1) to (9) is supplied to molten steel.

[0023]

(9) In a molten steel desulfurization method according to an aspect of the present invention, slag including one or more of Na_2O, K_2O, and Li_2O, as well as CaO, Al_2O_3, and SiO_2 is formed on the surface of molten steel so that $[CaO]/[Al_2O_3]$ is within a range of 1.6 to 3.0, $[SiO_2]/[R_2O]$ is within a range of 0.1 to 3, $[R_2O]$ is within a range of 0.5 mass% to 5 mass%, and $[SiO_2]$ is within a range of 0.05 mass% to 15 mass% in a case in which the $[CaO]$, the $[Al_2O_3]$, the $[SiO_2]$, and the $[R_2O]$ represent the mass% of CaO, the mass% of Al_2O_3, the mass% of SiO_2, and the total amount of the mass% of Na_2O, the mass% of K_2O, and the mass% of Li_2O respectively.

Effects of the Invention

[0024]

According to the aspects of the present invention, it is possible to manufacture high-grade steel having an extremely small amount of S without the occurrence of problems of elution of F from slag after desulfurization, attachment of Na_2O or K_2O to a facility due to evaporation, a decrease in productivity due to a decrease in desulfurization efficiency, an increase in desulfurization costs, and the adverse influence of slag including a large amount of Na_2O or K_2O after desulfurization on the environment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025]

FIG. 1 is a view showing the relationship between the desulfurization efficiency parameter and the amount (mass%) of R_2O (one or more of Na_2O, K_2O, and Li_2O).

FIG. 2 is a view showing the relationship between the desulfurization efficiency parameter and the Na_2O content (mass%) with respect to a variety of $[SiO_2]/[Na_2O]$s.

FIG. 3 is a view showing the relationship between the desulfurization rate constant and $[CaO]/[Al_2O_3]$.

FIG. 4 is a view showing the relationship between $[SiO_2]/[Na_2O]$ and the desulfurization rate constant in a case in which $[CaO]/[Al_2O_3]$ is 2.

DETAILED DESCRIPTION OF THE INVENTION

[0026]

Hereinafter, [CaO], $[Al_2O_3]$, $[SiO_2]$, [MgO], and $[R_2O]$ represent the mass% of CaO, the mass% of Al_2O_3, the mass% of SiO_2, the mass% of MgO, and the mass% of R_2O. Meanwhile, hereinafter, there are cases in which the amounts (mass%) of the various components are represented by [chemical formula of component]. In addition, in a case in which a compound from which a metallic oxide such as CaO (including complex oxides thereof) is obtained through thermal decomposition is included, the mass percentage of a metal oxide in the compound is evaluated using the mass of the thermally decomposed compound, and byproducts such as CO_2 or H_2O which are generated due to thermal decomposition are not included in the mass percentage of a flux. Herein, the R_2O corresponds to Na_2O, K_2O, and Li_2O, and the $[R_2O]$ represents the total amount of

Na_2O, K_2O, and Li_2O. Among Na_2O, K_2O, and Li_2O, the amount of components not included in a flux is evaluated to be zero.

[0027]

The inventors firstly studied use of oxides of alkali metals such as Na_2O, K_2O, and Li_2O instead of CaF_2. As described above, a flux including Na_2O or K_2O has a high desulfurization ability. In addition, Li_2O is also an oxide of an alkali metal, similarly to the case of Na_2O or K_2O, Li_2O is expected to have a high desulfurization ability.

[0028]

However, as described above, the oxides (R_2O) of the alkali metals such as Na_2O, K_2O, and Li_2O have a characteristics of being easily evaporated at a high temperature. Since ease of evaporation is dependent on [R_2O], the amount of R_2O in a flux is preferably as small as possible, but the desulfurization ability of a flux enhances as [R_2O] increases.

[0029]

Therefore, in a case in which R_2O is added to a desulfurization flux in order to enhance the desulfurization ability, to what extent the amount of [R_2O] in the desulfurization flux can be decreased while a desulfurization ability necessary for a desulfurization flux is secured becomes a key to the solution to the problems. In order to suppress [R_2O] to a low level while a desulfurization ability is secured, the composition of main components that compose a flux is important.

[0030]

The inventors used a CaO-Al_2O_3-based desulfurization flux which is generally used as a base component in a desulfurization flux, and investigated the desulfurization ability by changing [Na_2O], [K_2O], and [Li_2O] in the desulfurization flux through laboratory scale experiments.

[0031]

The chemical compositions of molten steel used in the experiments are shown in Table 1.

[0032]

[Table 1]

(mass%)

C	Si	Mn	P	S	Al	N	O
0.05	0.2	1.0	0.005	0.004	0.03	0.03	0.0015

[0033]

The experimental conditions are as follows.

Melting furnace: resistance melting furnace, amount of molten steel: 10 kg, temperature of molten steel: 1600°C

Experimental procedure: melting - composition adjustment - Al deoxidization - desulfurization - cooling

Desulfurization method: a desulfurization flux is injected into the molten steel using a refractory pipe.

Desulfurization flux composition:

CaO-Al_2O_3-R_2O

$[CaO]/[Al_2O_3]=2.0$

Na_2O, K_2O, or Li_2O: 0 mass% to 10 mass%

[0034]

The experimental results are shown in FIG. 1. The desulfurization efficiency parameter (the vertical axes in FIGS. 1 and 2) and the desulfurization rate constant (the vertical axis in FIG. 3) are defined as follows.

Desulfurization efficiency parameter = (desulfurization rate constant)/(amount of R_2O evaporated)

Desulfurization rate constant = -ln(final [S]/initial [S])/time, time=15 minutes

Amount evaporated: (initial [R_2O]-final [R_2O])/(initial [R_2O])

[0035]

Since desulfurization is performed within as short a time as possible in the industrial process from the viewpoint of productivity improvement, in the experiments, values at 15 minutes after the initiation of desulfurization were used as the desulfurization rate constant. It is found from FIG. 1 that, in the case of Na_2O, the desulfurization efficiency parameter becomes the maximum at an initial content of "2 mass%." Similarly, in the case of K_2O or Li_2O, the desulfurization efficiency parameter becomes the maximum at an initial content of "2 mass%."

[0036]

As such, a high desulfurization efficiency parameter means that "the amount of R_2O evaporated is small, and the desulfurization rate constant is large", that is, a desulfurization reaction proceeds favorably. From this fact, it can be said that it is not necessary to add a large amount of R_2O (Na_2O, K_2O, and/or Li_2O) to a desulfurization flux in order to supply a high desulfurization ability. That is, even when [R_2O] is simply increased, the amount evaporated increases, and the majority of R_2O is simply wasted.

[0037]

Actually, in a case in which a large amount of a desulfurization flux is produced, it is difficult to control the R_2O content to be 2 mass% because of content fluctuation. However, the factor that significantly influences desulfurization reaction or evaporation is not the component content, but the component activity, that is, the lability in consideration of the influence of coexisting components. From this fact, the inventors

obtained an idea of controlling the activity of components that compose a desulfurization flux.

[0038]

Since SiO_2 is firstly considered as a component that has a large influence on the activity of Na_2O, K_2O, or Li_2O, the inventors investigated the influence of $[SiO_2]$ on the activity of Na_2O through similar laboratory scale desulfurization experiments. The chemical compositions of molten steel used in the experiments are shown in Table 1, and the experimental conditions are as follows.

[0039]

Melting furnace: resistance melting furnace, amount of molten steel: 10 kg, temperature of molten steel: 1600°C

Experimental procedure: melting - composition adjustment - Al deoxidization - desulfurization - cooling

Desulfurization method: a desulfurization flux is injected into the molten steel using a refractory pipe.

Desulfurization flux composition:

$CaO-Al_2O_3-SiO_2-Na_2O$

$[CaO]/[Al_2O_3]=2.0$

$[SiO_2]/[Na_2O]=0$ to 5

Na_2O: 0 mass% to 10 mass%

[0040]

The experimental results are shown in FIG. 2. The vertical axis in FIG. 2 indicates the desulfurization efficiency parameter similarly to the vertical axis in FIG. 1. It is found from FIG. 2 that $[Na_2O]$ at which the desulfurization efficiency parameter becomes the maximum increases as $[SiO_2]/[Na_2O]$, which is a mass% ratio, increases.

[0041]

$[Na_2O]$ at which $[SiO_2]/[Na_2O]=3$, and the desulfurization efficiency parameter becomes the maximum is 5 mass%. When $[SiO_2]$ is increased with the above $[SiO_2]/[Na_2O]$ as a criterion, the $[Na_2O]$ at which the desulfurization efficiency parameter becomes the maximum also increases. However, when $[Na_2O]$ increased to more than the criterion, the manufacturing costs of a desulfurization flux increases, and, furthermore, $[Na_2O]$ in slag also increases after desulfurization.

[0042]

Generally, when $[Na_2O]$ in slag exceeds 2 mass% after desulfurization, the slag becomes inappropriate for civil engineering aggregate or cement aggregate. Therefore, the inventors separately analyzed the relationship between $[Na_2O]$ in slag after desulfurization and $[Na_2O]$ in a desulfurization flux, and obtained the maximum acceptable amount of $[Na_2O]$ in the desulfurization flux. As a result of the analysis, it was found that the maximum acceptable amount of $[Na_2O]$ is approximately 5 mass%. Therefore, $[Na_2O]$ in a desulfurization flux is preferably 5 mass% or less. Similarly, $[K_2O]$ and $[Li_2O]$ in a desulfurization flux are also preferably 5 mass% or less. It is preferable that the $[Na_2O]$, $[K_2O]$, and $[Li_2O]$ are as small as possible.

[0043]

The inventors further investigated $[CaO]/[Al_2O_3]$ regarding CaO and Al_2O_3 which were main components of a desulfurization flux. Desulfurization experiments were performed by making the desulfurization flux contain 2.5 mass% of Na_2O and 5 mass% of SiO_2 as other components, and changing $[CaO]/[Al_2O_3]$. The chemical compositions of molten steel used for the experiments are shown in Table 1, and the experimental conditions are as follows.

[0044]

Melting furnace: resistance melting furnace, amount of molten steel: 10 kg, temperature of molten steel: 1600°C

Experimental procedure: melting - composition adjustment - Al deoxidization - desulfurization - cooling

Desulfurization method: a desulfurization flux is injected into the molten steel using a refractory pipe.

Desulfurization flux composition:

$CaO-Al_2O_3-SiO_2-Na_2O$

$[CaO]/[Al_2O_3]$=1.0 to 4.0

SiO_2: 5 mass%, Na_2O: 2.5 mass%

[0045]

The experimental results are shown in FIG. 3. The vertical axis in FIG. 3 indicates the desulfurization rate constant. It is found from FIG. 3 that the desulfurization rate constant becomes a high value of 0.10 or more in a range of $[CaO]/[Al_2O_3]$=1.6 to 3.0.

[0046]

For desulfurization of molten steel, CaO-based fluxes are generally used, and, among them, a $CaO-Al_2O_3$-based flux is frequently used. In a case in which the $CaO-Al_2O_3$-based flux is used, the composition region appropriate for desulfurization is generally a region of $[CaO]/[Al_2O_3]$ of 1.0 to 2.33 in a $CaO-Al_2O_3$ binary phase diagram.

[0047]

This region is a region in which a liquid phase is present in a flux at the desulfurization temperature (approximately 1600°C) of molten steel, and some solid-phase CaO is generated. When the flux is in a liquid phase, desulfurization rapidly

proceeds, and, when solid-phase CaO is present in the liquid phase even at a small amount, the activity of CaO in the liquid phase becomes 1, and a desulfurization reaction can easily proceed.

[0048]

However, in a case in which Na_2O and SiO_2 are present in a desulfurization flux, there is a possibility of a change in the desulfurization ability due to the composition conditions. Therefore, the inventors found from the results shown in FIG. 3 obtained through the molten steel desulfurization experiments that the optimal $[CaO]/[Al_2O_3]$ for desulfurization was 1.6 to 3.0.

[0049]

Similarly to SiO_2, Al_2O_3 is also an oxide having an influence on the reactivity of R_2O, and, when Al_2O_3 is excessively present in a desulfurization flux, the reactivity of R_2O degrades. This fact is also reflected in the desulfurization experimental results shown in FIG. 3.

[0050]

Hereinafter, a molten steel desulfurization flux according to an aspect of the present invention will be described. Except in a case in which CaF_2 is inevitably included in the starting materials of a flux, the molten steel desulfurization flux according to the embodiment basically does not include CaF_2. Even in a case in which CaF_2 is inevitably included, CaF_2 may be limited to 1 mass% or less and preferably 0.1 mass% or less in terms of outer percentage.

[0051]

The environmentally friendly flux for molten steel desulfurization according to the embodiment (hereinafter sometimes referred to as the "present flux") substantially does not include CaF_2,

(i) includes CaO and Al_2O_3 as main components so that $[CaO]/[Al_2O_3]$ becomes within a range of 1.6 to 3.0,

(ii) includes 0.5 mass% to 5 mass% of one or more of Na_2O, K_2O, and Li_2O (R_2O), and 0.05 mass% to 15 mass% of SiO_2 so that $[SiO_2]/[R_2O]$ becomes within a range of 0.1 to 3, and, furthermore, includes 10 mass% or less of MgO according to necessity.

[0052]

In the present flux, the reason why $[CaO]/[Al_2O_3]$ is set to 1.6 to 3.0 is to secure a sufficient desulfurization rate as described above. In order to obtain a higher desulfurization rate, $[CaO]/[Al_2O_3]$ is preferably 1.6 to 2.8.

[0053]

In the present flux, the reason why $[R_2O]$ is set to 0.5 mass% to 5 mass% is as follows.

[0054]

Based on the experimental results shown in FIGS. 1 and 2, the minimum Na_2O content (mass%) at which the effect of addition of Na_2O sufficiently develops is set to 0.5 mass% at which the desulfurization efficiency parameter exceeds 0.60. The maximum content of 5 mass% is a threshold limit value in order to prevent $[Na_2O]$ in slag from exceeding 2 mass% after desulfurization in consideration of the amount of Na_2O reduced during a desulfurization treatment.

[0055]

Since the effects of K_2O, or Li_2O are the same as the effects of Na_2O, similarly to Na_2O, $[K_2O]$ was set to 0.5 mass% to 5 mass%, and $[Li_2O]$ was set to 0.5 mass% to 5 mass%.

[0056]

Since the effects of K_2O, Li_2O, and Na_2O are the same, two or more of Na_2O, K_2O, and Li_2O may be additively used. The combinations are Na_2O+K_2O, Na_2O+Li_2O, K_2O+Li_2O, and $Na_2O+K_2O+Li_2O$. In conclusion, the total of the amounts of one or more of Na_2O, K_2O, and Li_2O, that is, $[R_2O]$ is set to 0.5 mass% to 5 mass%.

[0057]

Na_2O, K_2O, and Li_2O are expensive, and there are cases in which Na_2O, K_2O, and Li_2O evaporate so as to attach to and deposit on a facility, or melt away refractories in a refining reactor. Particularly, the amount of R_2O in slag is preferably as small as possible after desulfurization treatment from the viewpoint of the recycling of the slag. Therefore, the R_2O content ($[R_2O]$) in a desulfurization flux is preferably as small as possible. From such a viewpoint, the upper limit of $[R_2O]$ is preferably 3 mass% or less. In addition, in a case in which the effect of R_2O is obtained more sufficiently, $[R_2O]$ is preferably 1 mass% or more.

[0058]

In the present flux, the reason why $[SiO_2]/[R_2O]$ is set to 0.1 to 3 is as follows.

[0059]

As shown in FIG. 2, in a case in which $[SiO_2]$ (that is, herein, $[SiO_2]/[Na_2O]$) is zero, the Na_2O content at which the desulfurization efficiency parameter becomes maximum is 2 mass%. Therefore, even when $[SiO_2]$ is zero, the effect (improvement of the desulfurization ability) of Na_2O develops. However, in order to stabilize Na_2O and suppress evaporation as much as possible, SiO_2 is preferably present in the flux even at a small amount. Therefore, the lower limit of $[SiO_2]/[Na_2O]$ was set to 0.1.

[0060]

The upper limit of $[SiO_2]/[Na_2O]$ of 3 is a condition under which the maximum value of the desulfurization efficiency parameter shown in FIG. 2 is obtained at the maximum acceptable value of $[Na_2O]$ of 5 mass%. In this case, the desulfurization efficiency parameter exceeds 0.6 throughout the entire range in which $[Na_2O]$ is 0.5 mass% to 5 mass%. Definitely, in FIG. 2, even when $[SiO_2]/[Na_2O]$ is 4 or more, there is a range of $[Na_2O]$ in which the desulfurization efficiency parameter exceeds 0.6, but the range is narrow. In addition, in the range, while evaporation of Na_2O can be sufficiently suppressed, the desulfurization ability per the unit amount of Na_2O significantly degrades, and therefore $[SiO_2]/[Na_2O]$ of 4 or more is not preferable from the viewpoint of securing the effects of Na_2O.

[0061]

For K_2O and Li_2O as well, $[SiO_2]/[K_2O]$ was set to 0.1 to 3, and $[SiO_2]/[Li_2O]$ was set to 0.1 to 3 respectively for the same reason. Even a case in which two or more of Na_2O, K_2O, and Li_2O are additively used in combination is the same as the above case. That is, in the present flux, $[SiO_2]/[R_2O]$ is set to 0.1 to 3. $[SiO_2]/[R_2O]$ is preferably 0.1 to 2, more preferably 0.5 to 2, and still more preferably 1 to 2.

FIG. 4 shows the relationship between $[SiO_2]/[Na_2O]$ and the desulfurization rate constant in a case in which $[CaO]/[Al_2O_3]$ is 2. It is found from FIG. 4 that the desulfurization rate constant is maximized at $[SiO_2]/[Na_2O]$ of 1.5. In addition, when $[SiO_2]/[Na_2O]$ is 2 or less, in a case in which $[SiO_2]/[Na_2O]$ is sufficiently small (for example, 0.1), a similar desulfurization rate constant is obtained. Therefore, in a case in which a sufficient desulfurization efficiency parameter is secured, and a processing time is shortened, $[SiO_2]/[R_2O]$ may be 0.1 to 2. In this case, the intensity of the bond

between SiO_2 and R_2O can be appropriately controlled, and the desulfurization effect of R_2O can be further enhanced while suppressing evaporation of R_2O.

[0062]

From the viewpoint of the desulfurization efficiency (per the unit amount of R_2O), environmental protection through resource saving, and cost reduction, among R_2O (alkali metal oxides), Na_2O has higher performance. Therefore, R_2O may be Na_2O. That is, in a case in which R_2O is used at a high temperature and a low oxygen partial pressure or a case in which R_2O is used in combination with a deoxidizing material such as Al, it is possible to suppress the loss of R_2O due to evaporation using Na_2O or Li_2O compared to K_2O since the boiling point of K is relatively low. In addition, since Li_2O is a rare oxide, Na_2O helps resource saving and cost reduction compared to Li_2O.

[0063]

Furthermore, in a case in which R_2O is introduced into the network of SiO_2 so as to further suppress the evaporation of R_2O, some or all of R_2O may have a chemical bond with SiO_2. In this case, for example, 10% or more of R_2O with respect to the total amount of R_2O preferably has a bond with SiO_2. Particularly, in a case in which the evaporation suppression effect of R_2O is secured using the chemical bond, the present flux may include waste material such as soda-lime glass, glass cullet, and slag including R_2O or SiO_2. In this case, environmental protection or cost reduction through recycling and stabilization can be achieved at the same time. For example, the present flux may include a hybrid oxide in which some or all of R_2O has a chemical bond with SiO_2, and the $[SiO_2]/[R_2O]$ of the oxide is not particularly limited, and may be 0.01 or more.

[0064]

$[SiO_2]$ in the present flux is naturally determined from $[R_2O]$ (0.5 mass% to 5 mass%) and $[SiO_2]/[R_2O]$ (=0.1 to 3), and is 0.05 mass% to 15 mass%. When

$[SiO_2]/[R_2O]$ increases through evaporation of R_2O during a desulfurization reaction, the desulfurization efficiency is degraded. In a case in which the degradation of the desulfurization efficiency is suppressed, the $[SiO_2]$ is preferably 0.05 mass% to 9.3 mass%, and more preferably 0.05 mass% to 8.0 mass%. Here, inclusion of SiO_2 in the flux is important in order to suppress evaporation of R_2O; however, in a case in which the basicity of slag is adjusted more flexibly, $[SiO_2]$ may be limited to, for example, 0.6 mass% or 0.45 mass% or less.

[0065]

In the present flux, 10 mass% or less of MgO is desirably added to the flux. The reason why the amount of MgO added is set to 10 mass% or less as an optional component is as follows.

[0066]

MgO is generally a component that composes a refractory, and is added to a desulfurization flux for the purpose of suppressing the melting-away of refractories due to the desulfurization flux. In a case in which the effect of suppressing the melting away of refractories is sufficiently secured, 1 mass% or more of MgO is preferably added. However, when the amount of MgO ([MgO]) exceeds 10 mass%, the melting point of a desulfurization flux increases, and the desulfurization effect of a flux does not develop. Therefore, the amount of MgO is limited to 10 mass% or less.

[0067]

The composition of the present flux is determined, for example, as follows. Firstly, the types of R_2O (at least one) in the flux are determined, and $[Na_2O]$, $[K_2O]$, and $[Li_2O]$ which correspond to the types of R_2O are set so as to satisfy $[R_2O]$ of 0.5 mass% to 5 mass%. Next, $[SiO_2]$ is set so as to satisfy a predetermined range of the ratio of

[SiO_2] to [R_2O]. After that, [MgO] is set according to necessity, and the total of [R_2O], [SiO_2], and [MgO] is subtracted from 100, thereby obtaining [CaO]+[Al_2O_3].

[0068]

After [CaO]+[Al_2O_3] is obtained, [CaO] and [Al_2O_3] are set so as to satisfy a predetermined range of [CaO]/[Al_2O_3]. Thereby, the amounts (mass%) of all the components of the flux are determined. Meanwhile, starting materials used to manufacture the flux (flux starting materials) contain impurities inevitably, and the impurities are inevitably introduced into the desulfurization flux, but the amounts of the inevitably contained components (inevitable impurities) are excluded from the above content calculation.

[0069]

Next, a method of manufacturing the present flux will be described. A desulfurization flux is generally a mixture of oxide powder. A desulfurization flux can be used in a mixture form in which the powder is mixed; however, when the desulfurization flux is used after all or some of the oxide powder is mixed, fused or sintered, cooled, and crushed in advance, the desulfurization effect can be obtained more reliably.

[0070]

In a case in which R_2O is stabilized by suppressing evaporation of R_2O, since the above fusing or sintering accelerates the bond between R_2O, and SiO_2 or Al_2O_3, and contributes to the stabilization of R_2O, the manufacturing method preferably includes a process in which a mixture including R_2O for which [SiO_2] or [Al_2O_3] is adjusted is fused or sintered. Particularly, the desulfurization effect is improved simply by fusing or sintering the powder mixture (mixed powder) of R_2O and SiO_2, and then mixing in other starting materials (for example, starting materials including other components).

[0071]

In soda-lime glass, glass cullet, used slag after refining, and the like, since waste material mainly including Na_2O or SiO_2 includes Na_2O and SiO_2, Na_2O is stabilized, and the waste material is a preferable material of the present flux. In a case in which the waste material is used, Na_2O or SiO_2 is added as necessary to the waste material or other starting materials, and the composition is adjusted so that $[SiO_2]/[Na_2O]$ becomes within a range of 0.1 to 3.

[0072]

Since CaO, Na_2O, K_2O, and Li_2O are often present in a carbonate form, a corresponding carbonate powder may be blended in the flux as CaO, Na_2O, K_2O, and Li_2O. In this case, it is necessary to estimate the mass of CO_2 generated during a decomposition reaction at a high temperature in advance and blend the carbonates.

[0073]

For example, the present flux may include 43 mass% to 75 mass% of CaO, 17.5 mass% to 38.5 mass% of Al_2O_3, 0.05 mass% to 15 mass% of SiO_2, and 0.5 mass% to 5 mass% of R_2O. In addition, the present flux may include 10% or less of MgO according to necessity. For example, in a case in which the present flux does not include MgO, the present flux may include 20 mass% to 38.5 mass% of Al_2O_3, 0.05 mass% to 15 mass% of SiO_2, and 0.5 mass% to 5 mass% of R_2O with the remainder composed of CaO and inevitable impurities (outer percentage). In addition, for example, in a case in which the present flux includes MgO, the present flux may include 17.5 mass% to 38.5 mass% of Al_2O_3, 0.05 mass% to 15 mass% of SiO_2, 0.5 mass% to 5 mass% of R_2O, and 10 mass% or less of MgO (preferably 1 mass% to 10 mass%) with the remainder composed of CaO and inevitable impurities (outer percentage). Additionally, in the present flux, as

described above, $[CaO]/[Al_2O_3]$ is in a range of 1.6 to 3.0, and $[SiO_2]/[R_2O]$ is in a range of 0.1 to 3.

[0074]

When molten steel desulfurization is performed using the present flux, it is possible to manufacture high-grade steel having an extremely small S content without occurrence of an environmental issue due to elution of F from slag after desulfurization, attachment of a large amount of evaporated Na_2O, K_2O, and Li_2O to a facility, a decrease in productivity due to a decrease in desulfurization efficiency, and an increase in desulfurization costs.

[0075]

The present flux can be used for molten steel desulfurization in a secondary refining process after a converter process, ladle refining in which an electrode heating method such as a ladle furnace (LF) is used, molten steel desulfurization in a reduction period of an electric furnace process, secondary refining after electric furnace process, and the like.

[0076]

Hereinafter, molten steel desulfurization methods according to first and second embodiments of the present invention will be described. In the molten steel desulfurization method according to the first embodiment, the environmentally friendly flux for molten steel desulfurization according to the above embodiment is supplied to molten steel (into molten steel or onto the surface of molten steel).

[0077]

A method of adding the desulfurization flux to molten steel (supply method) is not particularly limited. Examples of the addition method that can be used include an injection method in which the flux is blown into molten steel through a nozzle immersed

in the molten steel, a method in which a lumpy flux is added to the surface of molten steel from the above, a method in which flux powder is sprayed together with gas, and the like. The desulfurization treatment time is preferably 30 minutes to 40 minutes. The specific consumption of flux is preferably 3 kg/t to 4 kg/t (per ton of molten steel). In addition, other starting materials such as calcined lime may be supplied to molten steel separate. Even in this case, since a local reaction (a decrease in the evaporation rate of R_2O in the flux, acceleration of a slagging reaction between the flux and slag on the surface of the molten steel, and acceleration of a desulfurization reaction between the flux and molten steel) is important, the effect of the environmentally friendly flux for molten steel of the embodiment can be sufficiently obtained.

[0078]

In the molten steel desulfurization method according to the second embodiment, a plurality of types of oxides are supplied to the surface of molten steel so that slag (including a solid-liquid mixture of slag and a flux) having the same composition as the environmentally friendly flux for molten steel desulfurization according to the above embodiment is formed.

[0079]

The environmentally friendly flux for molten steel desulfurization according to the above embodiment is supplied from the outside of a reactor (a variety of furnaces and the like), and is, for example, powder or lump; however, in the molten steel desulfurization method according to the present embodiment, slag may be formed on the surface of molten steel so that the composition becomes the same as the composition of the flux.

On the surface of molten steel before initiation of desulfurization, there are cases in which slag generated in the prior process (residual slag) is somewhat present. In this

case, since a desulfurization reaction proceeds in a state in which a desulfurization flux supplied from the outside of the reactor and the residual slag are mixed, the composition of the slag (slag during desulfurization) on the molten steel may be in a state in which the desulfurization flux supplied from the outside of the reactor and the existing slag are mixed.

[0080]

Furthermore, the composition of the slag during desulfurization does not only mean the composition of the slag on the molten steel immediately after initiation of desulfurization.

[0081]

Since Na_2O, K_2O, and Li_2O easily evaporate, the composition of the slag on the molten steel immediately after initiation of desulfurization need not satisfy the composition of the environmentally friendly flux for molten steel desulfurization of the embodiment. That is, in addition to the fact that the composition of the residual slag is basically different from the composition of the environmentally friendly flux for molten steel desulfurization of the embodiment, R_2O (Na_2O, K_2O, and Li_2O) evaporate in a process in which a desulfurization reaction proceeds, and the composition of desulfurization slag present on the surface of the molten steel may satisfy the composition of the environmentally friendly flux for molten steel desulfurization of the embodiment.

[0082]

When the rate of the desulfurization reaction is taken into account, the composition of the slag present on the surface of the molten steel may satisfy the composition of the environmentally friendly flux for molten steel desulfurization of the embodiment until at least the first half (at a point in time at the half of the desulfurization treatment time) of the desulfurization treatment time. In this case, the second half of the

desulfurization time can be effectively used for the desulfurization reaction, and a more favorable desulfurization effect can be obtained compared to a case in which the slag on the surface of the molten steel is adjusted in the second half of the desulfurization treatment time.

[0083]

In the molten steel desulfurization method according to the second embodiment, when a desulfurization flux comes into contact with molten steel, the composition may be adjusted so as to become the composition of the environmentally friendly flux for molten steel desulfurization flux of the embodiment. For example, instead of mixing some of the components of a desulfurization flux and other components, some of the components and other components may be separately added (supplied) using, for example, different supply mechanisms or supply apparatuses. That is, as long as the composition is adjusted to the composition of the environmentally friendly flux for molten steel desulfurization of the embodiment on the molten steel, the addition method (supply method) is not limited to a specific method.

[0084]

Therefore, in the molten steel desulfurization method according to the second embodiment, slag including one or more alkali metal oxides of Na_2O, K_2O, and Li_2O, CaO, Al_2O_3, and SiO_2 wherein $[CaO]/[Al_2O_3]$ is within a range of 1.6 to 3.0, $[SiO_2]/[R_2O]$ is within a range of 0.1 to 3, $[R_2O]$ is within a range of 0.5 mass% to 5 mass%, and $[SiO_2]$ is within a range of 0.05 mass% to 15 mass%, is formed on the surface of molten steel. Meanwhile, a desulfurization flux in which some or all of R_2O has a chemical bond with SiO_2 may be used. Here, since the composition of the slag formed on the surface of the molten steel is the same as the composition of the environmentally friendly flux for

molten steel desulfurization of the above-mentioned embodiment, the amounts of each component will not be described here.

Meanwhile, evaporation of R_2O can be suppressed more in the molten steel desulfurization method according to the first embodiment than in the molten steel desulfurization method according to the second embodiment.

[Examples]

[0085]

Next, examples of the present invention will be described, but the conditions in the examples are simply an example of conditions employed to confirm the feasibility and effects of the present invention, and the present invention is not limited to the example of conditions. The present invention can employ a variety of conditions within the scope of the purport of the present invention as long as the objective of the present invention can be achieved.

[0086]

(Example)

Molten steel prepared using a 400 t-capacity converter was desulfurized in an RH vacuum degasser. After desulfurization, a sample was taken from the molten steel, and the S content in the sample (molten steel) was analyzed. The chemical compositions of the molten steels used in the actual tests are shown in Table 2. The conditions in the actual tests are as follows.

Desulfurization process: RH vacuum degasser, ladle capacity: 400 t, molten steel temperature: 1620°C

Desulfurization method: blowing of powder into the molten steel using an injection lance or onto the surface of the molten steel using a lance

Desulfurization time: 35 minutes

Specific consumption of flux (per ton of molten steel): 3.5 kg/t

[0087]

[Table 2]

(mass%)

STEEL GRADE	C	Si	Mn	P	Al	Ti	Nb	N	O
A	0.05	0.2	1.0	0.005	0.03	0.05	0.02	0.003	0.0015
B	0.08	0.8	1.5	0.004	0.04	0.13	0.04	0.0035	0.0020
C	0.16	1.0	1.3	0.003	0.035	0.15	0.08	0.003	0.0022

[0088]

The condition Nos. of the actual tests are shown in Table 3.

PAGE 58/69 * RCVD AT 2/18/2014 10:55:10 AM [Eastern Standard Time] * SVR:FOOOO3/7 * DNIS:3905 * CSID:5143974382 * DURATION (mm-ss):15-55

[0089]

[Table 3]

NO.	STEEL GRADE	COMPOSITION OF DESULFURIZATION FLUX (mass%)							[CaO]/[Al_2O_3] (–)	[SiO_2]/([Na_2O]+[K_2O]+[Li_2O]) (–)	NOTE
		[CaO]	[SiO_2]	[Al_2O_3]	[Na_2O]	[K_2O]	[Li_2O]	[MgO]			
1	A	61	0.4	38.1	0.5	0	0	0	1.6	0.8	MIXED POWDER
2	B	59	0.3	34.7	0	1.0	0	5.0	1.7	0.3	PARTIALLY-FUSED PRODUCT
3	C	62	3.6	34.4	0	0	2.0	0	1.8	1.8	PARTIALLY-FUSED PRODUCT
4	A	62	4.0	31.0	2.0	0	0	1.0	2.0	2.0	USE OF SODA-LIME GLASS
5	B	66	0.5	30.0	0	3.5	0	0	2.2	0.1	MIXED POWDER
6	C	60	15.0	25.0	0	0	5.0	0	2.4	3.0	MIXED POWDER
7	A	62	1.2	25.8	0.5	0.5	0	10.0	2.4	1.2	PARTIALLY-FUSED PRODUCT
8	B	64	9.4	24.6	0	2.0	2.0	0	2.6	2.3	MIXED POWDER
9	C	66	7.4	23.6	2.0	1.0	1.0	0	2.8	1.9	MIXED POWDER
10	A	60	10.0	20.0	3.0	0	2.0	7.0	3.0	2.0	USE OF GLASS CULLET
11	B	56	2.0	35.0	7.0	0	0	0	1.6	0.3	MIXED POWDER
12	C	52	16.0	26.0	0	6.0	0	0	2.0	2.7	PARTIALLY-FUSED PRODUCT
13	A	55	22.1	22.9	0	0	8.0	0	2.4	2.8	PARTIALLY-FUSED PRODUCT
14	B	55	4.1	37.9	3.0	0	0	0	1.45	1.4	USE OF SODA-LIME GLASS
15	C	63	5.4	30.0	0	1.65	0	0	2.1	3.3	PARTIALLY-FUSED PRODUCT
16	A	63	0.8	26.3	0.2	0.1	0	0	2.4	2.7	MIXED POWDER
17	B	59	14.9	21.1	3.0	2.0	2.0	0	2.8	2.1	USE OF GLASS CULLET
18	C	55	0	32.4	2.0	0	3.0	12.0	1.7	0	MIXED POWDER
19	A	53	16.5	26.5	0	4.0	0	0	2.0	4.1	MIXED POWDER
20	B	71	4.8	22.2	2.0	0	0	0	3.2	2.4	MIXED POWDER
21	C	64	4.0	32.0	0	0	0	0	2.0	–	MIXED POWDER
22	A	60	$40CaF_2$						–	–	PARTIALLY-SINTERED PRODUCT

[0090]

The note column in Table 3 will be described as follows.

MIXED POWDER: a flux of a powder mixture of the oxides

PARTIALLY-FUSED PRODUCT: a flux obtained by melting, cooling, and crushing a powder mixture of R_2O and SiO_2 in advance, and then mixing the obtained pre-melted powder with powder of other components

PARTIALLY-SINTERED PRODUCT: a flux obtained by sintering, cooling, and crushing a powder mixture of R_2O and SiO_2 in advance, and then mixing the obtained sintered powder with powder of other components

USE OF SODA-LIME GLASS: a flux obtained by crushing soda-lime glass and mixing the obtained glass powder with powder of the oxides

USE OF GLASS CULLET: a flux obtained by crushing glass cullet and mixing the obtained glass powder with powder of the oxides

[0091]

The results of the actual tests are shown in Table 4. The desulfurization ratio is defined to be ((the S content before desulfurization-the S content after desulfurization)/the S content before desulfurization)×100.

[0092]

[Table 4]

NO.	INITIAL S CONTENT (ppm)	FINAL S CONTENT (ppm)	DESULFURIZATION RATIO (%)	NOTE
1	47	8	83	EXAMPLE
2	40	6	85	EXAMPLE
3	44	7	84	EXAMPLE
4	36	5	86	EXAMPLE
5	50	8	84	EXAMPLE
6	42	7	83	EXAMPLE
7	36	6	83	EXAMPLE
8	38	7	82	EXAMPLE
9	44	8	82	EXAMPLE
10	49	9	82	EXAMPLE
11	50	12	76	COMPARATIVE EXAMPLE
12	48	11	77	COMPARATIVE EXAMPLE
13	44	11	75	COMPARATIVE EXAMPLE
14	50	11	78	COMPARATIVE EXAMPLE
15	53	14	74	COMPARATIVE EXAMPLE
16	50	15	70	COMPARATIVE EXAMPLE
17	45	13	71	COMPARATIVE EXAMPLE
18	52	14	73	COMPARATIVE EXAMPLE
19	50	15	70	COMPARATIVE EXAMPLE
20	52	13	75	COMPARATIVE EXAMPLE
21	50	17	66	COMPARATIVE EXAMPLE
22	40	8	80	COMPARATIVE EXAMPLE

[0093]

[Table 5]

	[SiO2] (mass%)	[Al2O3]	[CaO]	[MgO]	[MnO]	[Fe2O3]	[FeO]	[Na2O]	[P2O5]
SODA-LIME GLASS	75	–	9.5	–	–	–	–	15.5	–
GLASS CULLET	64	0.6	0.2	0.2	–	–	–	35	–
CONVERTER SLAG	14	1.6	48	7.1	4.3	10	12	0	3

[0094]

Nos. 1 to 10 are examples that satisfy the conditions of the present invention. In the examples, the S content is sufficiently decreased, and a high desulfurization ratio of 82% or more is obtained. In addition, Na-based compounds, K-based compounds, and Li-based compounds are not attached to the inside of the exhaust duct, and [Na_2O], [K_2O], and [Li_2O] in slag were 2 mass% or less after desulfurization. Therefore, under the conditions of Nos. 1 to 10, Na_2O, K_2O, and Li_2O (R_2O) can be efficiently used, and the obtained slag can be sufficiently used for a variety of uses.

[0095]

Meanwhile, in Nos. 6, 8, and 10, since the existing slag is mixed in the desulfurization flux, the composition of the desulfurization flux is a composition after mixing of the slag. In addition, in No. 10, the composition of the slag during desulfurization reaches a composition shown in Table 3 when the desulfurization reaction process proceeds, and the composition of the slag is a composition of the second half of the desulfurization (20 minutes/35 minutes of the desulfurization treatment time). Additionally, in No. 10, even in a case in which a flux having a composition shown in Table 3 was used, the same desulfurization ratio (84%) was obtained.

Here, the chemical compositions of soda-lime glass used in Nos. 4 and 14, slag (converter slag) used in Nos. 6, 8, and 10, and glass cullet used in Nos. 10 and 17 are shown in Table 5.

[0096]

Nos. 11 to 22 are comparative examples that do not satisfy the conditions of the present invention. Among the comparative examples, the maximum desulfurization ratio was 80% which was obtained in No. 22 in which CaF_2 was used, and the desulfurization ratio was as low as 68% to 78% in other Nos.

[0097]

The amount of Na_2O was excessive in No. 11, the amount of K_2O was excessive in No. 12, and the amount of Li_2O was excessive in No. 13. Therefore, in Nos. 11 to 13, the desulfurization ratios were low, and the amounts of R_2O attached to the facility due to evaporation were large. In addition, large amounts of Na_2O, K_2O, and Li_2O were included in slag after desulfurization, and recycling of the slag was not possible.

[0098]

Since the content ratio $[CaO]/[Al_2O_3]$ is too low in No 14, and the content ratio $[SiO_2]/[K_2O]$ is too high in No. 15, the desulfurization ratios were low in Nos. 14 and 15. Since the total amount of Na_2O and K_2O is small in No. 16, and the total amount of Na_2O, K_2O, and Li_2O is too large in No. 17, the target desulfurization ratio of 82% or more was not achieved in Nos. 16 and 17.

[0099]

The amount of MgO was large, and the amount of SiO_2 was small in No. 18, the amount of SiO_2 was large in No. 19, and the content ratio $[CaO]/[Al_2O_3]$ was too high in No. 20. Therefore, the target desulfurization ratio of 82% or more was not achieved in Nos. 18 to 20. In addition, in No. 21, since the flux did not include any of Na_2O, K_2O, and Li_2O, the target desulfurization ratio of 82% or more was not achieved.

[0100]

In No. 22, since the flux contained CaF_2, a relatively high desulfurization ratio was obtained compared to other comparative examples, but the desulfurization ratio failed to exceed 82%. Furthermore, in No. 22, the obtained slag had a high content of F, and could not be recycled.

Industrial Applicability

[0101]

As described above, according to the present invention, it is possible to manufacture high-grade steel having an extremely small amount of S without occurrence of problems of elution of F from slag after desulfurization, attachment of Na_2O or K_2O to a facility due to evaporation, a decrease in productivity due to a decrease in desulfurization efficiency, an increase in desulfurization costs, and the adverse influence of slag including a large amount of Na_2O or K_2O after desulfurization on the environment. Therefore, the present invention is highly available in steel-making techniques of steel industry.

What is claimed is:

1. An environmentally friendly flux for molten steel desulfurization comprising:

CaO and Al_2O_3 so that $[CaO]/[Al_2O_3]$ is within a range of 1.6 to 3.0; and

one or more alkali metal oxides of Na_2O, K_2O, and Li_2O, and SiO_2 so that $[SiO_2]/[R_2O]$ is within a range of 0.1 to 3, $[R_2O]$ is within a range of 0.5 mass% to 5 mass%, and $[SiO_2]$ is within a range of 0.05 mass% to 15 mass%,

in a case in which the $[CaO]$, the $[Al_2O_3]$, the $[SiO_2]$, and the $[R_2O]$ represent mass% of CaO, mass% of Al_2O_3, mass% of SiO_2, and a total amount of mass% of Na_2O, mass% of K_2O, and mass% of Li_2O respectively.

2. The environmentally friendly flux for molten steel desulfurization according to Claim 1, further comprising 1 mass% to 10 mass% of MgO.

3. The environmentally friendly flux for molten steel desulfurization according to Claim 1 or 2,

wherein the $[SiO_2]$ is 0.05 mass% to 9.3 mass%.

4. The environmentally friendly flux for molten steel desulfurization according to Claim 1 or 2,

wherein the $[SiO_2]$ is 0.05 mass% to 8.0 mass%.

5. The environmentally friendly flux for molten steel desulfurization according to Claim 1 or 2,

wherein the $[SiO_2]/[R_2O]$ is 0.1 to 2.

6. The environmentally friendly flux for molten steel desulfurization according to Claim 1 or 2,

wherein some or all of the alkali metal oxides have a chemical bond with the SiO_2.

7. The environmentally friendly flux for molten steel desulfurization according to Claim 1 or 2,

wherein the alkali metal oxides are Na_2O.

8. A molten steel desulfurization method comprising

supplying the environmentally friendly flux for molten steel desulfurization according to Claim 1 or 2 to a molten steel.

9. A molten steel desulfurization method comprising

forming a slag on a surface of a molten steel, the slag including one or more of Na_2O, K_2O, and Li_2O, as well as CaO, Al_2O_3, and SiO_2 so that $[CaO]/[Al_2O_3]$ is within a range of 1.6 to 3.0, $[SiO_2]/[R_2O]$ is within a range of 0.1 to 3, $[R_2O]$ is within a range of 0.5 mass% to 5 mass%, and $[SiO_2]$ is within a range of 0.05 mass% to 15 mass%,

in a case in which the $[CaO]$, the $[Al_2O_3]$, the $[SiO_2]$, and the $[R_2O]$ represent mass% of CaO, mass% of Al_2O_3, mass% of SiO_2, and a total amount of mass% of Na_2O, mass% of K_2O, and mass% of Li_2O respectively.

FIG. 1

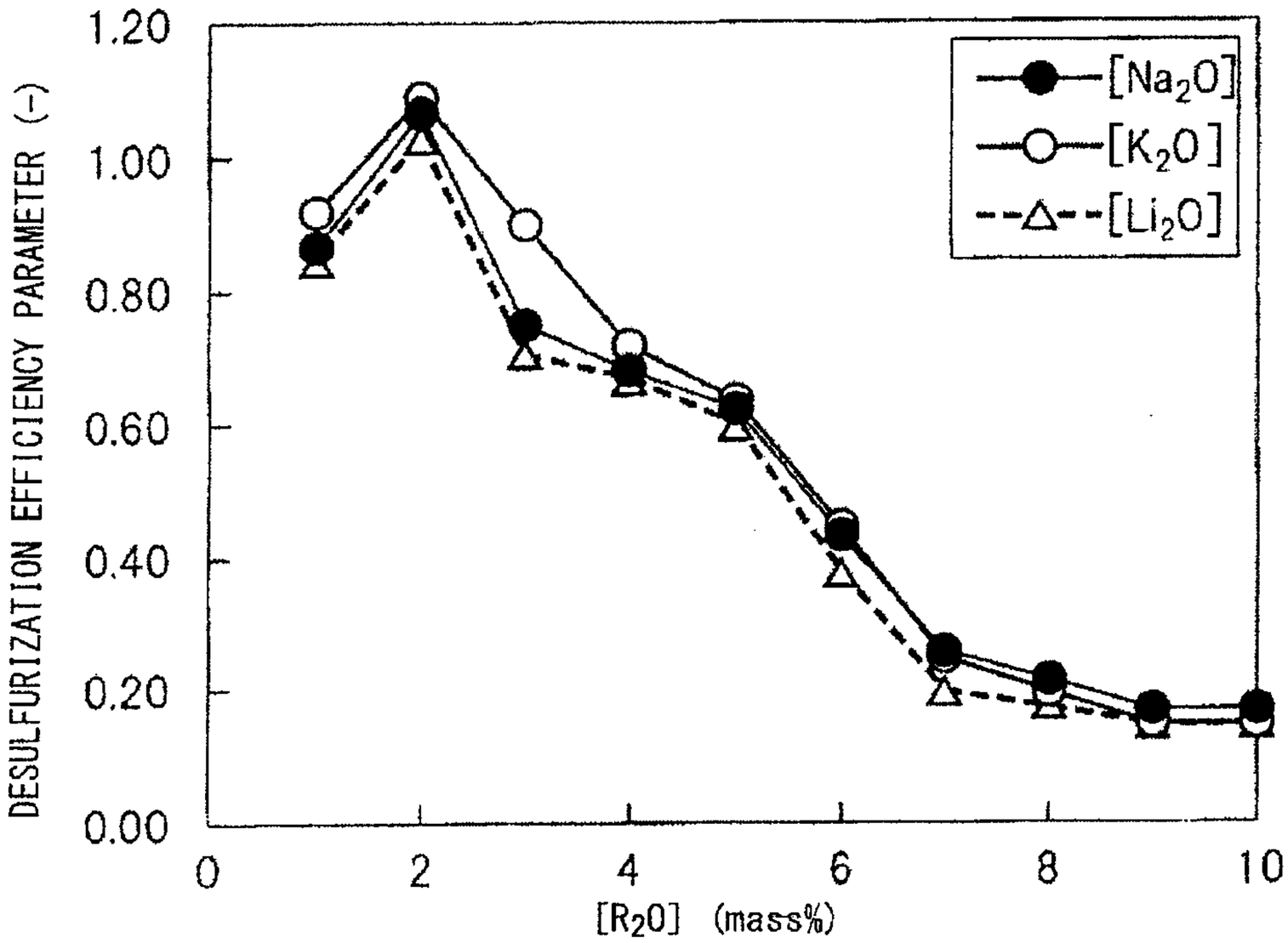

1.20
1.00
0.80
0.60
0.40
0.20
0.00
DESULFURIZATION EFFICIENCY PARAMETER (-)
0
2
4
6
8
10
[R2O] (mass%)
[Na2O]
[K2O]
[Li2O]

FIG. 2

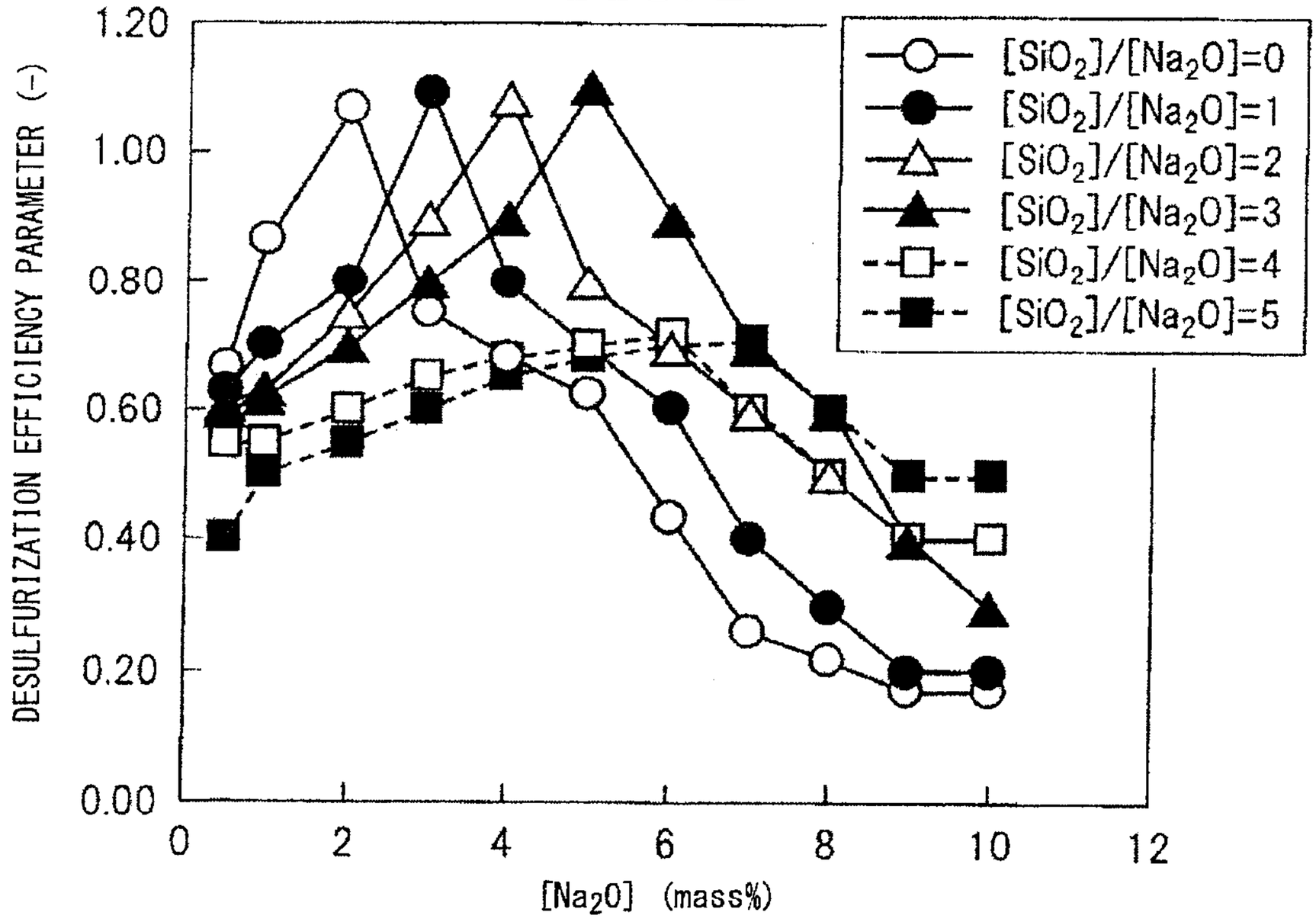

1.20
1.00
0.80
0.60
0.40
0.20
0.00
DESULFURIZATION EFFICIENCY PARAMETER (-)
0
2
4
6
8
10
12
[Na2O] (mass%)
[SiO2]/[Na2O]=0
[SiO2]/[Na2O]=1
[SiO2]/[Na2O]=2
[SiO2]/[Na2O]=3
[SiO2]/[Na2O]=4
[SiO2]/[Na2O]=5

FIG. 3

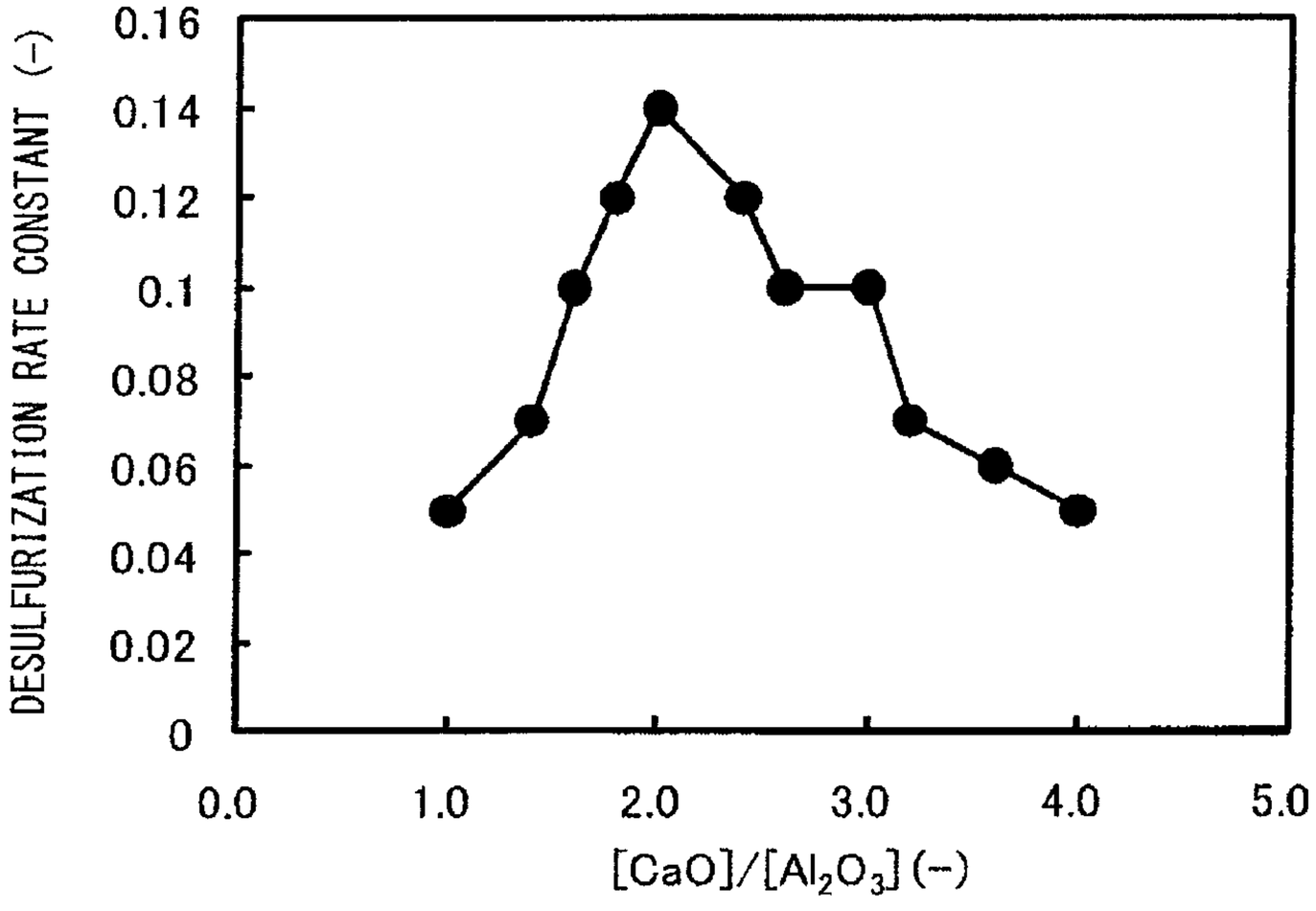
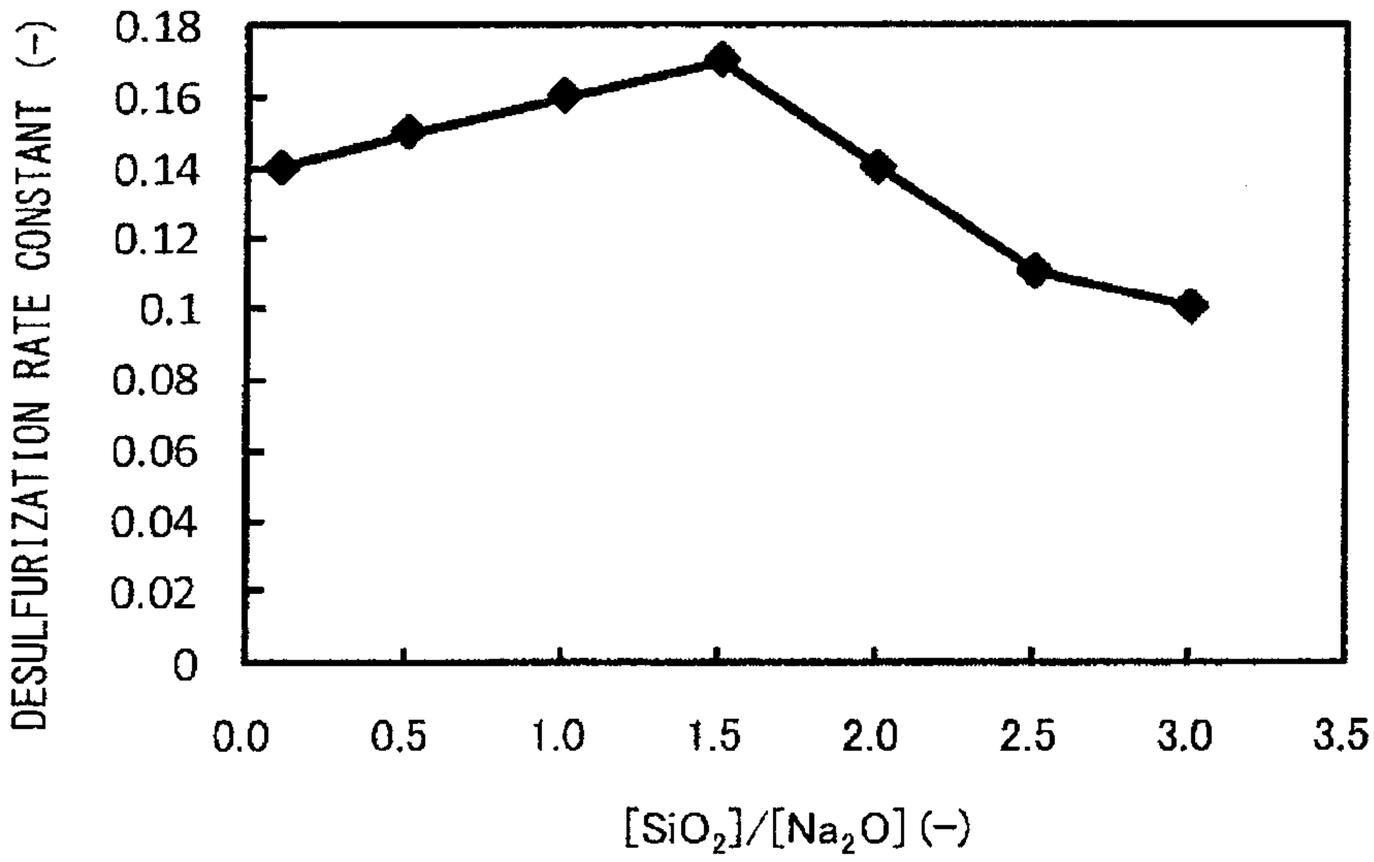
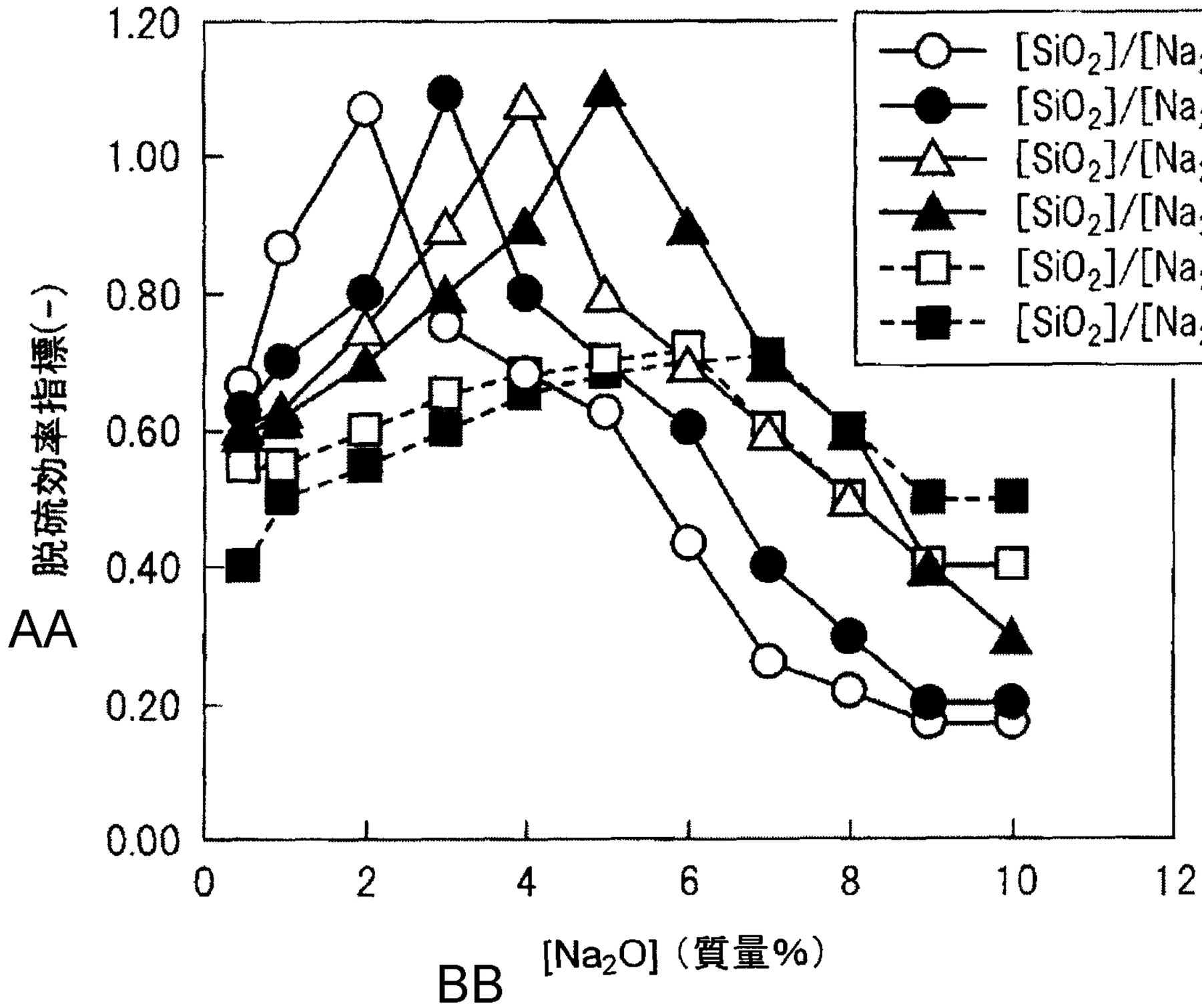

DESULFURIZATION RATE CONSTANT (-)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.0
1.0
2.0
3.0
4.0
5.0
[CaO]/[Al2O3] (-)

FIG. 4


DESULFURIZATION RATE CONSTANT (-)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
[SiO2]/[Na2O] (-)

[図2]



AA　Index to desulfurization efficiency (-)

BB　[Na_2O] (mass%)