

TWO-COMPONENT SILICON WAFER CLEANING AGENT AND CLEANING METHOD

TECHNICAL FIELD

[0001] The present disclosure relates to the technical field of solar cell production, and in particular to a two-component silicon wafer cleaning agent and a cleaning method.

BACKGROUND

[0002] In recent years, the photovoltaic solar industry has demanded larger and thinner silicon wafers to reduce manufacturing losses and costs. However, the large size and thinning of silicon wafers have increased the technical difficulty during the multi-wire cutting process. The content of silicon powder within the cutting loop cylinder has significantly increased, and the area of silicon wafers involved in cutting and cleaning has also doubled. As the terminal process in silicon wafer production, the cleaning process has a significant impact on the production yield of downstream solar cells, making it crucial. Cleaning agents, as important chemical materials in the cleaning process, greatly affect the normal operation of this process and the yield of silicon wafers due to their performance and quality. Currently, silicon wafer cleaning agents available in the market and patented products are mainly alkaline formulations, with both single-component and two-component formulations. However, they are all used in the same way by adding the cleaning agent to the cleaning bath in a certain proportion. Existing formulated products have issues such as incomplete cleaning of silicon wafer surfaces and residue of cleaning agents on the surfaces, leading to white spot defects on silicon wafers during the texturing process in solar cell production, which has been a persistent problem. The thinning of silicon wafers is bound to become an industry trend, and in the future, G10 and G12 thin silicon wafers (with thicknesses of 140 μm , 130 μm , 120 μm , 110 μm , and 100 μm) will successively become mainstream products. Therefore, the cleaning of large-size thin silicon wafers will surely become a key technology that restricts industry development and urgently needs to be addressed.

SUMMARY

[0003] The object of the present disclosure is to overcome the above-mentioned shortcomings of the prior art and provide a two-component silicon wafer cleaning agent and a cleaning method. The cleaning agent exhibits excellent cleaning performance, the cleaning method is simple, and there are no residues left on the surface of the silicon wafer after cleaning.

[0004] To achieve the aforementioned objectives, the technical solution adopted in the present disclosure is as follows: a two-component silicon wafer cleaning agent, comprising a component A and a component B, wherein the component A comprises the following components in

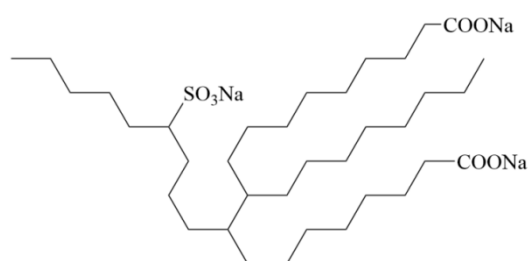
percentage by weight: 5-10% of an inorganic base, 0.5-1.5% of an organic base, 4-8% of a dispersant, 3-5% of an oxidation inhibitor and the balance of water; and the component B comprises the following components in percentage by weight: 12-15% of an alcohol ether solvent and the balance of water.

[0005] The primary function of the component A is to remove contaminants from the surface of the silicon wafer, while the component B primarily serves to eliminate organic substances, such as the dispersant in the component A, from the wafer surface. The cleaning agent B can be easily rinsed off. Utilizing the component A and the component B in separate cleaning steps enhances the cleaning yield of the silicon wafers. In the present disclosure, the combination of the organic base and the inorganic base is selected to maintain high alkalinity, which is conducive to providing a stable rate of alkaline etching reaction for silicon powder. A small amount of the oxidation inhibitor is selected to effectively prevent the occurrence of oxidized wafers during the cleaning process, without compromising the cleaning efficiency. The alcohol ether solvent facilitates the desorption of silicon powder particles and can remove organic substances from the surface of the silicon wafer.

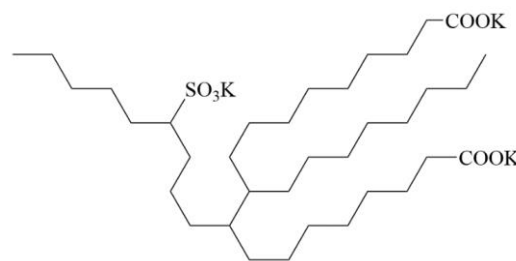
[0006] Preferably, the inorganic base is at least one of sodium hydroxide and potassium hydroxide; and the organic base is at least one of monoethanolamine, diethanolamine, a triethanolamine, a 2-(2-aminoethoxy)ethanol and tetrabutylammonium hydroxide.

[0007] Further preferably, the organic base is a compound of the 2-(2-aminoethoxy)ethanol and the triethanolamine; and a weight ratio of the 2-(2-aminoethoxy)ethanol to the triethanolamine is (1-3):1. 2-(2-aminoethoxy)ethanol possesses excellent alkaline value reserve capacity and pH stability, while triethanolamine demonstrates good detergency. The combination of these two can synergistically enhance the yield of silicon wafers significantly.

[0008] Preferably, the dispersant is at least one of a sodium dimer acid sulfonate and a potassium dimer acid sulfonate, a structural formula of the sodium dimer acid sulfonate is shown as a formula (I), and a structural formula of the potassium dimer acid sulfonate is shown as a formula (II):



(I)



(II).

[0009] The dimeric acid sulfonate in the present disclosure features multiple adsorption and dispersion sites, as well as a spatial structure with branched long carbon chains, resulting in dispersion activity that is significantly stronger than that of currently used straight-chain sulfonates

or carboxylates.

[0010] Preferably, the oxidation inhibitor is at least one of sodium glycolate, a sodium lactate, and a sodium oxalate. Further preferably, the oxidation inhibitor is a compound of the sodium lactate and the sodium oxalate, and a weight ratio of the sodium lactate to the sodium oxalate is (3-5):1. Sodium lactate serves as an antioxidant synergist and pH regulator; sodium oxalate, with its excellent reducing properties, can be used as a remover for stains and ink marks. The combination of these two not only inhibits the oxidation of silicon wafers but also prevents excessive corrosion of the wafers by alkali, thereby reducing the whiteness rate during texturing.

[0011] Preferably, the alcohol ether solvent is at least one of a 2-isopropoxyethanol, 2-butoxyethanol, 2-(pentyloxy)ethanol, 2-(hexyloxy)ethanol, 2-(2-ethylhexyloxy)ethanol and a 1-methoxy-2-propanol. The aforementioned alcohol ether solvent possesses high surface tension and surface activity, enabling it to displace and adsorb onto the surface of the silicon wafer to remove the component A. After rinsing, the alcohol ether solvent can also be thoroughly removed.

[0012] Further preferably, the alcohol ether solvent is a compound of the 2-isopropoxyethanol and the 1-methoxy-2-propanol, and a weight ratio of the 2-isopropoxyethanol to the 1-methoxy-2-propanol is 1:(2-5).

[0013] 2-Isopropoxyethanol, with a surface tension of 39.8 dyn/cm, is an excellent desorbing agent that can enhance the desorption efficiency of silicon powder from the surface of silicon wafers. 1-methoxy-2-propanol significantly reduces the surface tension of the cleaning agent system, improving the wettability of the cleaning agent on silicon wafers and thereby increasing the contaminant removal rate. By selecting and combining these two components, the present disclosure greatly improves the cleaning effect of the cleaning agent, enhancing the cleaning yield and reducing the whiteness rate during texturing.

[0014] At the same time, the present disclosure also discloses a two-component silicon wafer cleaning method, which comprises the following steps:

(1) putting the silicon wafer into a tank No. 1 (a bubbling overflow pre-cleaning tank) of a cleaning machine, adding pure water, wherein a temperature is 50-65°C, and a soaking time is 60-120 seconds;

(2) after the step (1) is finished, transferring the silicon wafer into a tank No. 2 (a chemical tank) of the cleaning machine, wherein the tank contains an aqueous solution containing 2.5-6 wt.% of the component A, the temperature is 50-65°C, and the soaking time is 60-120 seconds;

(3) after the step (2) is finished, transferring the silicon wafer into a tank No. 3 (a chemical tank) of the cleaning machine, wherein the tank contains an aqueous solution containing 7-10 wt.% of the component A, the temperature is 50-65°C, and the soaking time is 60-120 seconds;

(4) after the step (3) is finished, transferring the silicon wafer into a tank No. 4 (a chemical

tank) of the cleaning machine, wherein the tank contains an aqueous solution containing 4-6 wt.% of the component B, the temperature is 50-65°C, and the soaking time is 60-120 seconds; and

(5) after the step (4) is finished, sequentially transferring the silicon wafer into a tank No. 5 to a tank No. 9, wherein the temperature is 50-54°C, 54-58°C, 58-62°C, 62-66°C and 66-70°C respectively, and respectively soaking for 60-120 seconds.

[0015] The purpose of controlling the temperature is to enhance the removal rate of impurities. As the temperature rises, the activity of the cleaning agent gradually increases. However, if the temperature is too high, the reaction process becomes difficult to control, which can instead reduce the production yield. In the step (5), the temperature is increased in a gradient manner, resulting in a higher removal rate of contaminants.

[0016] Cleaning with the component A twice followed by cleaning with the component B can improve the cleaning quality. If the step (3) is omitted and the cleaning time of the step (2) is extended, the rate of contaminated wafers increases. Conversely, if the step (2) is omitted and the cleaning time of the step (3) is extended, the silicon wafers are prone to excessive etching, leading to uneven coloration of the wafers. By controlling the concentration of the cleaning agents and cleaning in steps, a high cleaning yield can be ensured.

[0017] Preferably, after the completion of the step (5), the silicon wafer is transferred to a slow-lifting tank, where pure water is added. The temperature is maintained at 80-90°C for a duration of 60-120 seconds, followed by the separation of the silicon wafer.

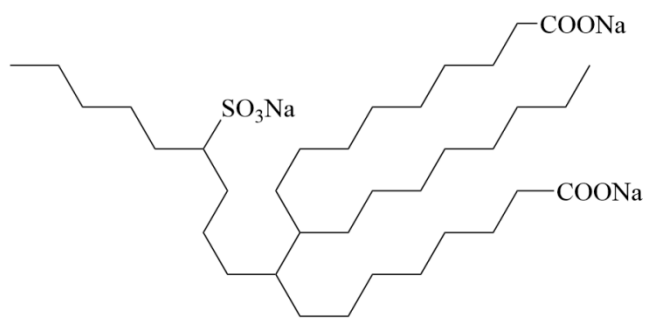
[0018] Compared with the prior art, the beneficial effects of the present disclosure are as follows: The present disclosure provides a two-component cleaning agent, which effectively solves the problem of low cleaning yield for large-sized thin silicon wafers by selecting the components of the cleaning agent. At the same time, the present disclosure offers a cleaning method that significantly improves cleaning efficiency and reduces the rate of white spot formation during texturing by selecting appropriate cleaning conditions. Furthermore, the present disclosure does not use hydrogen peroxide for cleaning, thereby enhancing the safety of the cleaning process.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0019] In order to better explain the purpose, the technical solution and the advantages of the present disclosure, the present disclosure will be further described below with reference to specific embodiments.

[0020] Unless otherwise specified, all materials used in the embodiments and comparative embodiments are obtained through commercial channels, and the same materials are used in both the embodiments and comparative embodiments.

[0021] The structural formula of sodium dimer acid sulfonate is as follows:



[0022] Silicon wafer: 218 mm*210 mm*110 μm.

[0023] Embodiments 1-6

[0024] According to the embodiment of the cleaning agent, the components of the cleaning agent in the Embodiments 1-6 are shown in Table 1.

[0025] Comparative Embodiments 1-3

[0026] Comparative Embodiments 1-3 are cleaning agents, and their formulas are shown in Table 1.

[0027] Table 1 (weight percentage)

Items			Emb odim ent 1	Emb odim ent 2	Emb odim ent 3	Emb odim ent 4	Emb odim ent 5	Emb odim ent 6	Com parat ive Emb odim ent 1	Com parat ive Emb odim ent 2	Com parat ive Emb odim ent 3
Com pone nt A	Inor gani c base	Sodium hydroxid e	8	6	10	8	8	8	9	8	8
	Org anic base	2-(2-Aminoet hoxyl)eth anol	0.5	1	0.3	0.3	0.5	0.5	/	0.5	0.5
		Triethan olamine	0.5	0.5	0.2	0.7	0.5	0.5	/	0.5	0.5
	Dis pers ant	Sodium dimer acid sulfonate	6	4	8	6	6	6	6	6	6

	Oxidation inhibitor	Sodium lactate	3	2.5	4	3	2	3	3	/	6
		Sodium oxalate	1	0.5	1	1	2	1	1	/	2
	Water		Add to 100	Add to 100	Add to 100	Add to 100	Add to 100	Add to 100	Add to 100	Add to 100	Add to 100
Component B	Alcohol ether solvent	2-Isopropoxyethanol	4	3	2	4	4	6	4	4	4
		1-Methoxy-2-propanol	8	12	10	8	8	6	8	8	8
	Water		Add to 100	Add to 100	Add to 100	Add to 100	Add to 100	Add to 100	Add to 100	Add to 100	Add to 100

[0028] Embodiment 7

[0029] According to an embodiment of the cleaning agent in the present disclosure, the difference between the components of this embodiment's cleaning agent and those of Embodiment 1 is only that sodium dodecylbenzenesulphonate is used for replacing sodium dimer acid sulfonate.

[0030] Embodiment 8

[0031] According to an embodiment of the cleaning agent in the present disclosure, the difference between the components of this embodiment's cleaning agent and those of Embodiment 1 is only that the organic base component is solely 2-(2-aminoethoxy)ethanol, with a weight percentage of 1%.

[0032] Embodiment 9

[0033] According to an embodiment of the cleaning agent in the present disclosure, the difference between the components of this embodiment's cleaning agent and those of Embodiment 1 is only that the organic base component is solely triethanolamine, with a weight percentage of 1%.

[0034] Embodiment 10

[0035] According to an embodiment of the cleaning agent in the present disclosure, the difference

between the components of this embodiment's cleaning agent and those of Embodiment 1 is only that the oxidation inhibitor component is solely sodium lactate, with a weight percentage of 4%.

[0036] Embodiment 11

[0037] According to an embodiment of the cleaning agent in the present disclosure, the difference between the components of this embodiment's cleaning agent and those of Embodiment 1 is only that the oxidation inhibitor component is solely sodium oxalate, with a weight percentage of 4%.

[0038] Embodiment 12

[0039] According to an embodiment of the cleaning agent in the present disclosure, the difference between the components of this embodiment's cleaning agent and those of Embodiment 1 is only that the component B is solely composed of 2-isopropoxyethanol and water, wherein a weight percentage of 2-isopropoxyethanol is 12%.

[0040] Embodiment 13

[0041] According to an embodiment of the cleaning agent in the present disclosure, the difference between the components of this embodiment's cleaning agent and those of Embodiment 1 is only that the component B is solely composed of 1-methoxy-2-propanol and water, wherein a weight percentage of 1-methoxy-2-propanol is 12%.

[0042] Embodiment 14

[0043] According to an embodiment of the cleaning method in the present disclosure, the cleaning agent used in the embodiment is Embodiment 1, and the specific cleaning steps are as follows:

(1) putting the silicon wafer into a tank No. 1 (a bubbling overflow pre-cleaning tank) of a cleaning machine, adding pure water, wherein a temperature is 60°C, and a soaking time is 100 seconds;

(2) after the step (1) is finished, transferring the silicon wafer into a tank No. 2 (a chemical tank) of the cleaning machine, wherein the tank contains an aqueous solution containing 4 wt.% of the component A, the temperature is 60°C, and the soaking time is 100 seconds;

(3) after the step (2) is finished, transferring the silicon wafer into a tank No. 3 (a chemical tank) of the cleaning machine, wherein the tank contains an aqueous solution containing 8 wt.% of the component A, the temperature is 60°C, and the soaking time is 100 seconds;

(4) after the step (3) is finished, transferring the silicon wafer into a tank No. 4 (a chemical tank) of the cleaning machine, wherein the tank contains an aqueous solution containing 5 wt.% of the component B, the temperature is 60°C, and the soaking time is 100 seconds;

(5) after the step (4) is finished, sequentially transferring the silicon wafer into a tank No. 5 to a tank No. 9, wherein the temperature is 50°C, 55°C, 60°C, 65°C and 70°C respectively, and respectively soaking 100 seconds; and

(6) finally, transferring the silicon wafer into a tank No. 10 (a slow lifting tank), adding pure water, lifting from the bottom to the top of the tank at 80°C, sustaining the lift for 100 seconds, and finally drying at 90°C for 3 minutes to obtain a cleaned silicon wafer.

[0044] Embodiment 15

[0045] According to an embodiment of the cleaning method in the present disclosure, the cleaning agent used in the embodiment is Embodiment 2, and the difference between the cleaning method of this embodiment and those of Embodiment 1 is that the concentration of the component A in the step (2) is 6 wt.%, and the soaking time is 80 seconds, and the concentration of the component A in the step (3) is 10 wt.%, and the soaking time is 80 seconds; and the concentration of the component B in the step (4) is 6 wt.%.

[0046] Embodiment 16

[0047] According to an embodiment of the cleaning method in the present disclosure, the cleaning agent used in the embodiment is Embodiment 3, and the difference between the cleaning method of this embodiment and those of Embodiment 1 is that the concentration of the component A in the step (2) is 2.5 wt.%, and the soaking time is 120 seconds, and the concentration of the component A in the step (3) is 7 wt.%, and the soaking time is 120 seconds; and the concentration of the component B in the step (4) is 4 wt.%.

[0048] Embodiments 17-26

[0049] According to the embodiments of the cleaning method in the present disclosure, the difference between the Embodiments 17-26 and the Embodiment 14 is only that different cleaning agents are used, and the cleaning agents used in the Embodiments 17-26 are respectively the Embodiments 4-13.

[0050] Embodiment 27

[0051] A cleaning method, the difference between the cleaning method of this embodiment and those of Embodiment 14 is only that the step (2) is omitted, and the cleaning time of the step (3) is extended to 180 seconds.

[0052] Embodiment 28

[0053] A cleaning method, the difference between the cleaning method of this embodiment and those of Embodiment 14 is only that the step (3) is omitted, and the cleaning time of the step (2) is extended to 240 seconds.

[0054] Comparative Embodiments 4-6

[0055] Comparative Embodiments 4-6 are cleaning methods, and the difference between Comparative Embodiments 4-6 and Embodiment 14 is only that different cleaning agents are used. Specifically, the cleaning agents used in Comparative Embodiments 4-6 are the same as those used in Comparative Embodiments 1-3, respectively.

[0056] A total of 1000 silicon wafers of the same type were cleaned using the methods described in Embodiments 14-28 and Comparative Embodiments 4-6, with the cleaning solution in the bath being replaced after every 200 wafers. The cleaning yield was recorded. The criteria for judging the cleaning yield were: uniform surface color, no spots, and no contaminants. Table 2 shows the test results.

[0057] Table 2

Items	Cleaning yield/%
Embodiment 14	99.7
Embodiment 15	99.5
Embodiment 16	99.6
Embodiment 17	99.1
Embodiment 18	99.2
Embodiment 19	99.2
Embodiment 20	98.9
Embodiment 21	98.6
Embodiment 22	98.4
Embodiment 23	98.5
Embodiment 24	98.2
Embodiment 25	98.1
Embodiment 26	98.5
Embodiment 27	98.1
Embodiment 28	98.2
Comparative Embodiment 4	97.5
Comparative Embodiment 5	97.3
Comparative Embodiment 6	97.9

[0058] As can be seen from Table 2, the cleaning yields of Embodiments 14-28 are all higher than those of Comparative Embodiments 4-6. This result indicates that the use of the solution proposed in the present disclosure can effectively enhance the cleaning effect of silicon wafers and reduce production costs.

[0059] A comparison of the test results between Embodiment 14 and Comparative Embodiment 4 shows that if organic bases are not added to maintain the alkalinity of inorganic bases, the initial rate of alkaline etching reaction is very fast but subsequently slows down, leading to unsatisfactory cleaning results.

[0060] A comparison of the test results between Embodiment 14 and Comparative Embodiment 5 shows that if oxidation inhibitors are not added, the silicon wafers are prone to oxidation during

the cleaning process and are easily over-etched by the alkali in the cleaning agent.

[0061] A comparison of the test results between Embodiment 14 and Comparative Embodiment 6 shows that excessive addition of oxidation inhibitors can also have adverse effects. The metal ions in the oxidation inhibitors can adhere to the surface of the silicon wafers, reducing the cleaning yield. Only when the amounts of each component are within the range specified in the present disclosure can a high cleaning yield be ensured.

[0062] A comparison of the test results between Embodiment 14 and Embodiments 27-28 shows that if only a low-concentration component A is used for a single cleaning, even increasing the cleaning time cannot achieve the cleaning effect described in the embodiment; additionally, using a high-concentration component A for cleaning results in a decreased cleaning yield.

[0063] Furthermore, a comparison of the test results between Embodiment 14 and Embodiment 17 shows that the ratio of 2-(2-aminoethoxy)ethanol to triethanolamine in the organic base has a certain impact on the cleaning effect. When the weight ratio of 2-(2-aminoethoxy)ethanol to triethanolamine is not within the range of (1-3):1, the cleaning yield is relatively lower. In addition, a comparison of the test results between Embodiment 14 and Embodiments 21-22 shows that if only 2-(2-aminoethoxy)ethanol or only triethanolamine is used in the organic base, the cleaning quality of the silicon wafers significantly deteriorates.

[0064] A comparison of the test results between Embodiment 14 and Embodiment 18 shows that when the ratio of sodium lactate to sodium oxalate exceeds (3-5):1, the cleaning effect becomes poorer. Furthermore, a comparison of the test results between Embodiment 14 and Embodiments 23-24 shows that sodium lactate and sodium oxalate can synergistically enhance the cleaning yield significantly.

[0065] A comparison of the test results between Embodiment 14 and Embodiment 19 shows that the ratio of 2-isopropoxyethanol to 1-methoxy-2-propanol has a certain impact on the cleaning yield. Furthermore, a comparison of the test results between Embodiment 14 and Embodiments 25-26 shows that the combination of 2-isopropoxyethanol and 1-methoxy-2-propanol helps improve the cleaning quality of the silicon wafers.

[0066] A comparison of the test results between Embodiment 14 and Embodiment 20 shows that by selecting sodium dimer acid sulfonate with a branched structure, the uniformity of the cleaning agent system is increased, which can effectively enhance the cleaning yield of the silicon wafers in the present disclosure.

[0067] Finally, it should be noted that the above embodiments are only used to illustrate the technical solution of the present disclosure rather than limit the protection scope of the present disclosure. Although the present disclosure is described in detail with reference to the preferred embodiments, a person of ordinary skill in the art should understand that the technical solutions of

the present disclosure can be modified or equivalently replaced, but do not depart from the spirit and scope of the technical solutions of the present disclosure.

CLAIMS

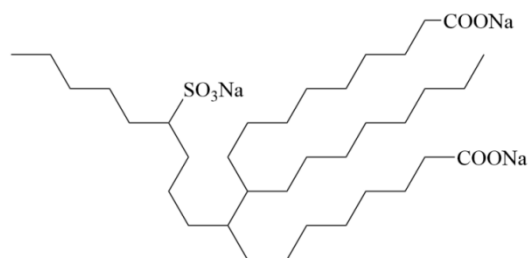
What is claimed is:

1. A two-component silicon wafer cleaning agent, comprising a component A and a component B, wherein the component A comprises the following components in percentage by weight: 5-10% of an inorganic base, 0.5-1.5% of an organic base, 4-8% of a dispersant, 3-5% of an oxidation inhibitor and the balance of water; and the component B comprises the following components in percentage by weight: 12-15% of an alcohol ether solvent and the balance of water.

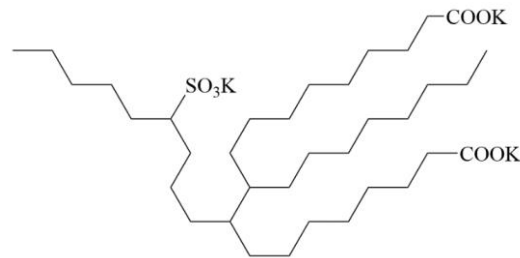
2. The two-component silicon wafer cleaning agent according to claim 1, wherein the inorganic base is at least one of sodium hydroxide and potassium hydroxide; and the organic base is at least one of monoethanolamine, diethanolamine, a triethanolamine, a 2-(2-aminoethoxy)ethanol and tetrabutylammonium hydroxide.

3. The two-component silicon wafer cleaning agent according to claim 1, wherein the organic base is a compound of the 2-(2-aminoethoxy)ethanol and the triethanolamine; and a weight ratio of the 2-(2-aminoethoxy)ethanol to the triethanolamine is (1-3):1.

4. The two-component silicon wafer cleaning agent according to claim 1, wherein the dispersant is at least one of a sodium dimer acid sulfonate and a potassium dimer acid sulfonate, a structural formula of the sodium dimer acid sulfonate is shown as a formula (I), and a structural formula of the potassium dimer acid sulfonate is shown as a formula (II):



(I)



(II).

5. The two-component silicon wafer cleaning agent according to claim 1, wherein the oxidation inhibitor is at least one of sodium glycolate, a sodium lactate, and a sodium oxalate.

6. The two-component silicon wafer cleaning agent according to claim 5, wherein the oxidation inhibitor is a compound of the sodium lactate and the sodium oxalate, and a weight ratio of the sodium lactate to the sodium oxalate is (3-5):1.

7. The two-component silicon wafer cleaning agent according to claim 1, wherein the alcohol ether solvent is at least one of a 2-isopropoxyethanol, 2-butoxyethanol, 2-(pentyloxy)ethanol, 2-(hexyloxy)ethanol, 2-(2-ethylhexyloxy)ethanol and a 1-methoxy-2-propanol.

8. The two-component silicon wafer cleaning agent according to claim 7, wherein the alcohol ether solvent is a compound of the 2-isopropoxyethanol and the 1-methoxy-2-propanol,

and a weight ratio of the 2-isopropoxyethanol to the 1-methoxy-2-propanol is 1:(2-5).

9. A silicon wafer cleaning method, comprising the following steps:

(1) putting the silicon wafer into pure water for cleaning, wherein a soaking time is 60-120 seconds;

(2) after the step (1) is finished, putting the silicon wafer into an aqueous solution containing 2.5-6 wt.% of the component A for cleaning, wherein the soaking time is 60-120 seconds;

(3) after the step (2) is finished, putting the silicon wafer into an aqueous solution containing 7-10 wt.% of the component A for cleaning, wherein the soaking time is 60-120 seconds;

(4) after the step (3) is finished, putting the silicon wafer into an aqueous solution containing 4-6 wt.% of the component B for cleaning, wherein the soaking time is 60-120 seconds; and

(5) after the step (4) is finished, putting the silicon wafer into pure water for cleaning, wherein a soaking temperature is 50-70°C, and the soaking time is 300-600 seconds; the component A comprises the following components in percentage by weight: 5-10% of the inorganic base, 0.5-1.5% of the organic base, 4-8% of the dispersant, 3-5% of the oxidation inhibitor and the balance of water; the component B comprises the following components in percentage by weight: 12-15% of the alcohol ether solvent and the balance of water.

10. The cleaning method according to claim 9, wherein in the steps (1) to (4), the silicon wafer is cleaned at a temperature of 50-65°C; and in the step (5), the silicon wafer is sequentially soaked for 60-120 seconds at temperatures of 50-54°C, 54-58°C, 58-62°C, 62-66°C and 66-70°C.