

DESCRIPTION

TANTALUM SPUTTERING TARGET

TECHNICAL FIELD

[0001]

The present invention relates to a high purity tantalum sputtering target that has a uniform and fine structure and which yields stable plasma and superior film evenness, in other words, uniformity. Note that, the generic term of "high purity tantalum" will be used in the present specification, since the high purity tantalum according to the present invention contains (is added with) molybdenum, and niobium as needed, and the additive amount of these elements is small.

BACKGROUND ART

[0002]

In recent years, the sputtering method for forming a film from materials such as metal or ceramics has been used in numerous fields such as electronics, corrosion resistant materials and ornaments, catalysts, as well as in the manufacture of cutting/polishing materials and abrasion resistant materials.

[0003]

Although the sputtering method itself is a well-known in the foregoing fields, recently, particularly in the electronics field, a tantalum sputtering target suitable for forming films of complex shapes, forming circuits or forming barrier films is in demand.

Generally, this tantalum target is produced by repeating the hot forging and annealing (heat treatment) of an ingot or billet formed by performing electron beam melting and casting to a tantalum raw material, and thereafter performing rolling and finish processing such as mechanical processing and polishing thereto.

In this kind of production process, the hot forging performed to the ingot or billet will destroy the cast structure, disperse or eliminate the pores and segregations, and, by further annealing this, recrystallization will occur, and the densification and strength of the structure can be improved to a certain degree.

The molten and cast ingot or billet generally has a crystal grain size of 50 mm or more. As a result of subjecting the ingot or billet to hot forging and recrystallization annealing, the cast structure is destroyed and uniform and fine (100

μm or less) crystal grains as a whole can be obtained.

[0004] Meanwhile, if sputtering is to be performed using a target produced as described above, it is said that the recrystallized structure of the target becomes even finer and more uniform, more uniform deposition is possible with a target in which the crystal orientation is aligned toward a specific direction, and a film with low generation of arcing and particles and stable characteristics can be obtained.

Measures are being taken to achieve a finer and more uniform recrystallized structure and aligning the crystal orientation toward a specific direction in the production process of the target (refer to Patent Document 1 and Patent Document 2).

10 [0005] Moreover, disclosed is a high purity Ta target for forming a TaN film to be used as a barrier layer in a Cu wiring film which is obtained by containing 0.001 to 20 ppm of an element selected among Ag, Au and Cu as an element having self-sustained discharge characteristics, causing the total amount of Fe, Ni, Cr, Si, Al, Na, and K as impurity elements to be 100 ppm or less, and using a high purity Ta in which the value obtained by subtracting such impurity elements is within the range of 99.99 to 99.999% (refer to Patent Document 3).

When reviewing these Patent Documents, there is no disclosure to the effect of the inclusion of a specific element realizing a finer structure and thereby stabilizing the plasma.

20 [0006] Particularly, Patent Document 3 increases the discharge amount of Ta ions by adding an infinitesimal amount of an element up to 0.001 ppm as a result of containing an element selected among Ag, Au and Cu in an amount of 0.001 to 20 ppm. However, since the additive element is a trace amount, it is considered that there is a problem of difficulty in adjusting the content and in adding evenly (variation).

25 As shown in Table 1 of Patent Document 3, the inclusion of amounts of Mo, W, Ge, and Co is respectively tolerable at less than 10 ppm, 20 ppm, 10 ppm, and 10 ppm. This alone adds up to impurities in an amount that is less than 50 ppm.

[0007] Accordingly, as described above, although Patent Document 3 describes "causing the total amount of Fe, Ni, Cr, Si, Al, Na, and K as impurity elements to be 100 ppm or less, and using a high purity Ta in which the value obtained by subtracting such impurity elements is within the range of 99.99 to 99.999%," the lower limit of the actual purity falls below (tolerates) 99.99%.

30 This is a level that is lower than conventional high purity tantalum, and it is strongly assumed that the characteristics of high purity tantalum cannot be utilized.

Amendment under Article 34

[0008] [Patent Document 1] Published Japanese Translation of WO2002-518593

[Patent Document 2] US Patent No. 6,331,233

[Patent Document 3] Japanese Published Unexamined Patent Application No. 2002-60934

DISCLOSURE OF THE INVENTION

[0009]

An object of the present invention is to provide a high purity tantalum sputtering target comprising a uniform and fine structure and which yields stable plasma and superior film evenness (uniformity) by maintaining the high purity of tantalum and adding a specific element.

[0010]

In order to achieve the foregoing object, the present inventors discovered that it is possible to obtain a high purity tantalum sputtering target comprising a uniform and fine structure and which yields stable plasma and superior film evenness (uniformity) by maintaining the high purity of tantalum and adding a specific element.

Based on the foregoing discovery, the present invention provides:

- 1) A tantalum sputtering target containing 1 mass ppm or more and 100 mass ppm or less of molybdenum as an essential component, and having a purity of 99.998% or more excluding molybdenum and gas components;
- 2) A tantalum sputtering target containing 10 mass ppm or more and 100 mass ppm or less of molybdenum as an essential component, and having a purity of 99.998% or more excluding molybdenum and gas components;
- 3) A tantalum sputtering target containing 10 mass ppm or more and 50 mass ppm or less of molybdenum as an essential component, and having a purity of 99.998% or more excluding molybdenum and gas components;
- 4) The tantalum sputtering target according to any one of 1) to 3) above, wherein variation of the molybdenum content in the target is $\pm 20\%$ or less;
- 5) The tantalum sputtering target according to any one of 1) to 4) above, wherein an average crystal grain size is 110 μm or less; and
- 6) The tantalum sputtering target according to 5) above, wherein variation of the crystal grain size is $\pm 20\%$ or less.

[0011]

The present invention additionally provides:

- 7) The tantalum sputtering target according to any one of 1) to 3) above, further containing 0 to 100 mass ppm of niobium, excluding 0 mass ppm, wherein the total amount of molybdenum and niobium is 1 mass ppm or more and 150 mass ppm

or less, and wherein the purity excluding molybdenum, niobium and gas components is 99.998% or more;

8) The tantalum sputtering target according to 7) above, further containing 10 mass ppm or more and 100 mass ppm or less of niobium;

9) The tantalum sputtering target according to 7) above, further containing 10 mass ppm or more and 50 mass ppm or less of niobium;

10) The tantalum sputtering target according to any one of 7) to 9) above, wherein variation of content of niobium and molybdenum in the target is $\pm 20\%$ or less;

11) The tantalum sputtering target according to any one of 7) to 10) above, wherein an average crystal grain size is 110 μm or less; and

12) The tantalum sputtering target according to 11) above, wherein variation of the crystal grain size is $\pm 20\%$ or less.

[Effect of the Invention]

The present invention yields a superior effect of being able to provide a high purity tantalum sputtering target comprising a uniform and fine structure and which yields stable plasma and superior film evenness (uniformity) by maintaining the high purity of tantalum, adding molybdenum as an essential component, and further adding niobium as needed. Moreover, since the plasma stabilization during sputtering can also be realized in the initial stage of sputtering, the present invention additionally yields the effect of being able to shorten the burn-in time.

BEST MODE FOR CARRYING OUT THE INVENTION

High purity tantalum is used as the raw material of the tantalum (Ta) target used in the present invention. An example of this high purity tantalum is shown in Table 1 (refer to the journal of technical disclosure 2005-502770 entitled "High Purity Tantalum and Sputtering Target made of High Purity Tantalum" edited by the Japan Institute of Invention and Innovation).

In Table 1, the total amount of impurities excluding gas components is less than 1 mass ppm; that is, 99.999 to 99.9999 mass%, and this kind of high purity tantalum can be used.

[Table 1] (Analytical Value)

Element	Concentration [ppm wt]	Element	Concentration [ppm wt]	Element	Concentration [ppm wt]	Element	Concentration [ppm wt]
Li	<0.001	Co	<0.001	Cd	<0.01	Tm	<0.005
Be	<0.001	Ni	<0.005	In	<0.005	Yb	<0.005
B	<0.005	Cu	<0.01 - 0.20	Sn	<0.05	Lu	<0.005
F	<0.05	Zn	<0.01	Sb	<0.01	Hf	<0.01
Na	<0.005	Ga	<0.01	Te	<0.01	Ta	Matrix
Mg	<0.005	Ge	<0.01	I	<0.01	W	<0.05 - 0.27
Al	<0.005	As	<0.005	Cs	<0.005	Re	<0.01
Si	<0.001	Se	<0.01	Ba	<0.005	Os	<0.005
P	<0.005	Br	<0.01	La	<0.005	Ir	<0.01
S	<0.005	Rb	<0.005	Ce	<0.005	Pt	<0.05
Cl	<0.01	Sr	<0.005	Pr	<0.005	Au	<0.1
K	<0.01	Y	<0.001	Nd	<0.005	Hg	<0.05
Ca	<0.01	Zr	<0.01	Sm	<0.005	Tl	<0.005
Sc	<0.001	Nb	0.1 - 0.46	Eu	<0.005	Pb	<0.005
Ti	<0.001	Mo	0.05 - 0.20	Gd	<0.005	Bi	<0.005
V	<0.001	Ru	<0.01	Tb	<0.005	Th	<0.0001
Cr	<0.001	Rh	<0.005	Dy	<0.005	U	<0.0001
Mn	<0.001	Pd	<0.005	Ho	<0.005		
Fe	<0.005	Ag	<0.005	Er	<0.005		

[0015] The sputtering target of the present invention is produced with the following process under normal circumstances.

5 To exemplify a specific example, foremost, tantalum; for instance, high purity tantalum of 4N (99.99% or more) is used, and appropriate amount of molybdenum (Mo) or molybdenum (Mo) and niobium (Nb) is added to prepare a target raw material. The purity thereof is increased by melting and refining the target raw material via electron beam melting or the like, and this is case to prepare an ingot or a billet. Needless to say, the high purity tantalum of 99.999 to 99.9999 mass% shown in Table 1 may be used from the start.

Subsequently, this ingot or billet is subject to a series of processing steps of annealing-forging, rolling, annealing (heat treatment), finish processing and the like.

[0016] Specifically, for instance, the foregoing ingot is subject to – extend forging – (first) annealing at a temperature from 1373 K to 1673 K – (first) cold forging – (second) recrystallization annealing from a starting temperature of recrystallization to 1373 K – (second) cold forging – (third) recrystallization annealing from a starting temperature of recrystallization to 1373 K – (first) cold (hot) rolling – (fourth) recrystallization annealing from a starting temperature of recrystallization to 1373 K – (second, as needed) cold (hot) rolling – (fifth, as needed) recrystallization annealing from a starting temperature of recrystallization to 1373 K – finish processing a target

material.

[0017] The forging or rolling performed to the ingot or billet will destroy the cast structure, disperse or eliminate the pores and segregations, and, by further annealing this, recrystallization will occur, and the densification and strength of the structure can be improved to a certain degree by repeating the foregoing cold forging or cold rolling and recrystallization annealing. The recrystallization annealing may only be performed once in the foregoing processing process, the structural defects can be reduced as much as possible by repeating such recrystallization annealing twice. Moreover, the cold (hot) rolling and recrystallization annealing performed from a starting temperature of recrystallization to 1373 K may be performed for only once or more cycles. The final target shape is obtained by subsequently performing finish processing such as machining and polishing.

[0018] The tantalum target is produced based on the foregoing production process under normal circumstances, but this production method is merely an exemplification. Moreover, since the present invention is not an invention of the production process, the target can be produced based on other processes, and this invention covers all of these targets.

A material having a purity level of 6N is often used to leverage the characteristics of the tantalum target, but there was always a problem in that the crystal grains of the target would easily become coarse.

[0019] The present inventors discovered that, in the production of this kind of 6N level target, the crystal grain size was locally fine at the portion where molybdenum of a content of approximately 0.5 mass ppm under normal circumstances had segregated at approximately 1 mass ppm by chance.

Accordingly, as a result of obtaining the hint that the addition of molybdenum may be effective for achieving a finer tantalum target, the present inventors found the opportunity that led to this invention. Moreover, during the foregoing examination, as a result of conducting numerous experiments on materials that are of the same nature as molybdenum or materials that can be added together with molybdenum, the present inventors discovered that niobium is effective.

[0020] Specifically, what is important with the tantalum sputtering target of this invention is that 1 mass ppm or more and 100 mass ppm or less of molybdenum is contained as an essential component in tantalum having a purity of 99.998% or more excluding molybdenum and gas components. As needed, 0 to 100 mass ppm is

further added, provided that this excludes 0 mass ppm. 1 mass ppm as the lower limit of molybdenum is a numerical value for exhibiting the foregoing effect, and 100 mass ppm as the upper limit of molybdenum is the upper limit for maintaining the effect of the present invention.

5 The upper limit of molybdenum is set to 100 mass ppm: because when molybdenum exceeds the limit, segregation of molybdenum will occur, a part of molybdenum in which the recrystallization is incomplete will arise, and the burn-in time will consequently be prolonged.

[0021] Since niobium plays a part (has a function) that is equivalent to the
10 addition of molybdenum, it can be co-doped. Although there is no particular limitation in the lower limit of adding niobium, the upper limit is set to 100 mass ppm. If this upper limited is exceeded, as with molybdenum, segregation of niobium tends to occur, and, therefore, the upper limit is set to 100 mass ppm. What is important upon co-doping molybdenum and niobium is that the total amount of molybdenum and
15 niobium is 1 mass ppm or more and 150 mass ppm or less.

[0022] This is because, outside the foregoing range, unrecrystallized portions arise and variation of the crystal grain size increases as shown in the Comparative Examples described later, and, in addition, the resistivity distribution within the sheet and the electric energy until the initial stabilization tend to increase. Consequently,
20 the uniformity of the film also becomes inferior. This tendency is the same as the case of adding large amounts of molybdenum (independent addition) which exceed the amount prescribed in this invention.

 What is unique in the case of co-doping is that the foregoing problems do not occur if the total amount of molybdenum and niobium is 150 mass ppm or less.

25 The reason for this is not necessarily clear, however, it is considered to be because molybdenum and niobium are respectively different substances in spite of their similarities, and the problem of segregation and effect on crystallization arises as their respective problems. Here, this co-doping also has its limits, and the results showed that any addition in which the total amount of molybdenum and niobium
30 exceeds 150 mass ppm is undesirable.

[0023] The inclusion of molybdenum or molybdenum and niobium forms a uniform and fine structure of the target, thereby stabilizes the plasma, and improves the evenness (uniformity) of the sputtered film. Moreover, since the plasma stabilization during sputtering can also be realized in the initial stage of sputtering,

the burn-in time can be shortened.

In the foregoing case, the purity of tantalum needs to be high purity; that is, 99.998% or more. Here, gas components with a small atomic radius such as oxygen, hydrogen, carbon, nitrogen can be excluded. Since it is generally difficult to exclude gas components unless a special method is employed, and they are difficult to eliminate during the refining in the production process under normal circumstances, gas components are excluded from the purity of tantalum of the present invention.

[0024] As described above, molybdenum or molybdenum and niobium realize the uniform and fine structure of tantalum, but the inclusion of other metal components, metallic non-metal components, oxides, nitrides, carbides and other ceramics is harmful, and impermissible. This is because these impurity elements are considered to inhibit the effect of molybdenum or molybdenum and niobium. In addition, these impurities are clearly different from molybdenum or molybdenum and niobium, and it is difficult to achieve a uniform crystal grain size of the tantalum target, and it does not contribute to the stabilization of the sputtering characteristics.

The tantalum sputtering target of the present invention contains, as a more preferable range, 10 mass ppm or more and 100 mass ppm or less of molybdenum or molybdenum and niobium as essential components, and has a purity of 99.998% or more excluding molybdenum, niobium and gas components.

Moreover, the tantalum sputtering target of the present invention contains 10 mass ppm or more and 50 mass ppm or less of molybdenum or molybdenum and niobium as essential components, and has a purity of 99.998% or more excluding molybdenum, niobium and gas components.

[0025] With the tantalum sputtering target of the present invention, preferably, variation of the content of molybdenum or molybdenum and niobium in the target is $\pm 20\%$ or less.

So as long as the inclusion of an appropriate amount of molybdenum yields the function (property) of forming the uniform and fine structure of the tantalum sputtering target, the uniform dispersion of molybdenum or molybdenum and niobium will contribute even more to the uniform and fine structure of the target.

Needless to say, it is easy to achieve the above with a standard production process, but it is necessary to take note of causing the variation of the content of molybdenum or molybdenum and niobium in the target to be $\pm 20\%$ or less, and to have a clear intent to achieve the same.

[0026] The variation of the content of molybdenum or molybdenum and niobium in the target is measured; for example, in the case of a discoid target, by taking three points (center point, 1/2 point of the radius, and point in the outer periphery or its vicinity) on eight equal lines passing through the center of the disk, and analyzing the content of molybdenum or molybdenum and niobium at a total of 17 points {16 points + center point (since the center point is counted as one point)}.

The variation is calculated at the respective points based on the formula of $\{(\text{maximum value} - \text{minimum value}) / (\text{maximum value} + \text{minimum value})\} \times 100$.

10 With the tantalum sputtering target of the present invention, more preferably, the average crystal grain size is 110 μm or less. The crystal grain size can be refined by the addition of an appropriate amount of molybdenum or molybdenum and niobium and a normal production process, but it is necessary to take note of causing the average crystal grain size to be 110 μm or less, and to have a clear intent to achieve the same.

15 More preferably, the variation of the crystal grain size is $\pm 20\%$ or less.

[0027] The variation of the average crystal grain size in the tantalum target is measured; for example, in the case of a discoid target, by taking three points (center point, 1/2 point of the radius, and point in the outer periphery or its vicinity) on eight equal lines passing through the center of the disk, and measuring the crystal grain size of tantalum at a total of 17 points {16 points + center point (since the center point is counted as one point)}.

The variation of the crystal grain size is calculated at the respective points based on the formula of $\{(\text{maximum value} - \text{minimum value}) / (\text{maximum value} + \text{minimum value})\} \times 100$.

25 [0028] This kind of target structure yields stable plasma and superior evenness (uniformity) of the film. Moreover, since the plasma stabilization during sputtering can also be realized in the initial stage of sputtering, the present invention additionally yields the effect of being able to shorten the burn-in time.

30 [Examples]

[0029] The present invention is now explained in detail with reference to the Examples. These Examples are merely illustrative, and the present invention shall in no way be limited thereby. In other words, the present invention covers the other modes and modifications included in the technical concept of this invention.

[0030] (Example 1)

A raw material obtained by adding molybdenum in an amount equivalent to 1 mass ppm to tantalum having a purity of 99.998% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size was approximately 55 μ m.

After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μ m was obtained.

Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1480 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 150 μ m was obtained.

Subsequently, this was subject to cold rolling and recrystallization annealing at 1173 K, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ .

The average crystal grain size of the target was 110 μ m, and the variation of the crystal grain size was $\pm 20\%$. And, the variation of the molybdenum content was $\pm 20\%$. The results are shown in Table 2.

Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

As the results shown in Table 2, evidently, the fluctuation of the resistance distribution in the sheet is small (2.6 to 3.2%) from the initial stage to the end stage of sputtering in this Example; that is, the fluctuation of the film thickness distribution is small.

The electrical energy required up to the initial stabilization of sputtering was also measured and showed 120 kWh, and decreased, as the results shown in Table 2. Thus, besides shortening the burn-in time, the evenness (uniformity) of the film was favorable and it was possible to improve the quality of the sputter deposition.

[0033]

[Table 2]

	Mo	Average Crystal Grain Size	Variation in Crystal Grain Size	Variation in Mo Content	Resistivity Distribution in Sheet		Electrical Energy up to Initial Stabilization	Uniformity of Film
Example 1	1	110	±20%	±20%	2.6	~ 3.2%	120 kWh	Favorable
Example 2	5	100	±17%	±18%	2.5	~ 3.0%	100kWh	Favorable
Example 3	10	90	±15%	±16%	2.3	~ 2.7%	90kWh	Favorable
Example 4	20	80	±10%	±12%	2.0	~ 2.2%	87kWh	Favorable
Example 5	50	75	±8%	±10%	1.7	~ 1.9%	85kWh	Favorable
Example 6	70	72	±7%	±8%	1.3	~ 1.5%	82kWh	Favorable
Example 7	100	70	±5%	±6%	1.0	~ 1.2%	80kWh	Favorable
Comparative Example 1	0.5	130	±35%	±40%	3.8	~ 6.0%	200kWh	Inferior
Comparative Example 2	150	770 Variation caused by Segregation	±50%	±70%	4.5	~ 7.0%	130kWh	Inferior

[0034] (Example 2)

A raw material obtained by adding molybdenum in an amount equivalent to 5 mass ppm to tantalum having a purity of 99.999% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mmφ. The crystal grain size was approximately 50 μm.

After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mmφ, and a structure in which the average crystal grain size is 200 μm was obtained.

Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mmφ, and a structure in which the average crystal grain size is 100 μm was obtained.

[0035] Subsequently, this was subject to cold rolling and recrystallization annealing, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mmφ. Cold working and recrystallization annealing in the middle and last were adjusted to achieve the following average crystal grain size and variation of the crystal grain size. Although the average crystal grain size and variation will also change depending on the additive amount of molybdenum, the foregoing adjustment was possible in this Example.

The average crystal grain size of the target was 100 μm , and the variation of the crystal grain size was $\pm 17\%$. And, the variation of the molybdenum content was $\pm 18\%$. The results are similarly shown in Table 2.

[0036] Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

10 As the results similarly shown in Table 2, evidently, the fluctuation of the resistance distribution in the sheet is small (2.5 to 3.0%) from the initial stage to the end stage of sputtering in this Example; that is, the fluctuation of the film thickness distribution is small.

The electrical energy required up to the initial stabilization of sputtering was also measured and showed 100 kWh, and decreased, as shown in Table 2. Thus, besides shortening the burn-in time, the evenness (uniformity) of the film was favorable, and it was possible to improve the quality of the sputter deposition.

[0037] (Example 3)

20 A raw material obtained by adding molybdenum in an amount equivalent to 10 mass ppm to tantalum having a purity of 99.999% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size was approximately 45 μm .

After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μm was obtained.

25 Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 100 μm was obtained.

30 [0038] Subsequently, this was subject to cold rolling and recrystallization annealing, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ . Cold working and recrystallization annealing in the middle and last were adjusted to achieve the following average crystal grain size and variation of the crystal grain size. Although the average crystal grain size

and variation will also change depending on the additive amount of molybdenum, the foregoing adjustment was possible in this Example.

The average crystal grain size of the target was 90 μm , and the variation of the crystal grain size was $\pm 15\%$. And, the variation of the molybdenum content was $\pm 16\%$. The results are similarly shown in Table 2.

[0039] Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

10 As the results similarly shown in Table 2, evidently, the fluctuation of the resistance distribution in the sheet is small (2.3 to 2.7%) from the initial stage to the end stage of sputtering in this Example; that is, the fluctuation of the film thickness distribution is small.

The electrical energy required up to the initial stabilization of sputtering was also measured and showed 90 kWh, and decreased, as shown in Table 2. Thus, besides shortening the burn-in time, the evenness (uniformity) of the film was favorable, and it was possible to improve the quality of the sputter deposition.

[0040] (Example 4)

20 A raw material obtained by adding molybdenum in an amount equivalent to 20 mass ppm to tantalum having a purity of 99.999% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size was approximately 40 mm.

25 After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μm was obtained.

30 Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 100 μm was obtained.

[0041] Subsequently, this was subject to cold rolling and recrystallization annealing, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ . Cold working and recrystallization annealing

in the middle and last were adjusted to achieve the following average crystal grain size and variation of the crystal grain size. Although the average crystal grain size and variation will also change depending on the additive amount of molybdenum, the foregoing adjustment was possible in this Example.

5 The average crystal grain size of the target was 80 μm , and the variation of the crystal grain size was $\pm 10\%$. And, the variation of the molybdenum content was $\pm 12\%$. The results are similarly shown in Table 2.

[0042] Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

10 As the results similarly shown in Table 2, evidently, the fluctuation of the resistance distribution in the sheet is small (2.0 to 2.2%) from the initial stage to the end stage of sputtering in this Example; that is, the fluctuation of the film thickness distribution is small.

15 The electrical energy required up to the initial stabilization of sputtering was also measured and showed 87 kWh, and decreased, as shown in Table 2. Thus, besides shortening the burn-in time, the evenness (uniformity) of the film was favorable, and it was possible to improve the quality of the sputter deposition.

20 [0043] (Example 5)

 A raw material obtained by adding molybdenum in an amount equivalent to 50 mass ppm to tantalum having a purity of 99.999% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size was approximately 35 mm.

25 After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μm was obtained.

30 Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 100 μm was obtained.

[0044] Subsequently, this was subject to cold rolling and recrystallization

annealing, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ . Cold working and recrystallization annealing in the middle and last were adjusted to achieve the following average crystal grain size and variation of the crystal grain size. Although the average crystal grain size and variation will also change depending on the additive amount of molybdenum, the foregoing adjustment was possible in this Example.

The average crystal grain size of the target was 75 μm , and the variation of the crystal grain size was $\pm 8\%$. And, the variation of the molybdenum content was $\pm 10\%$. The results are similarly shown in Table 2.

Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

As the results similarly shown in Table 2, evidently, the fluctuation of the resistance distribution in the sheet is small (1.7 to 1.9%) from the initial stage to the end stage of sputtering in this Example; that is, the fluctuation of the film thickness distribution is small.

The electrical energy required up to the initial stabilization of sputtering was also measured and showed 85 kWh, and decreased, as shown in Table 2. Thus, besides shortening the burn-in time, the evenness (uniformity) of the film was favorable, and it was possible to improve the quality of the sputter deposition.

(Example 6)

A raw material obtained by adding molybdenum in an amount equivalent to 70 mass ppm to tantalum having a purity of 99.999% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size was approximately 30 mm.

After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μm was obtained.

Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ ,

and a structure in which the average crystal grain size is 100 μm was obtained.

[0047] Subsequently, this was subject to cold rolling and recrystallization annealing, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ . Cold working and recrystallization annealing in the middle and last were adjusted to achieve the following average crystal grain size and variation of the crystal grain size. Although the average crystal grain size and variation will also change depending on the additive amount of molybdenum, the foregoing adjustment was possible in this Example.

10 The average crystal grain size of the target was 72 μm , and the variation of the crystal grain size was $\pm 7\%$. And, the variation of the molybdenum content was $\pm 8\%$. The results are similarly shown in Table 2.

[0048] Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

As the results similarly shown in Table 2, evidently, the fluctuation of the resistance distribution in the sheet is small (1.3 to 1.5%) from the initial stage to the end stage of sputtering in this Example: the fluctuation of the film thickness distribution is small.

20 The electrical energy required up to the initial stabilization of sputtering was also measured and showed 82 kWh, and decreased, as shown in Table 2. Thus, besides shortening the burn-in time, the evenness (uniformity) of the film was favorable, and it was possible to improve the quality of the sputter deposition.

[0049] (Example 7)

25 A raw material obtained by adding molybdenum in an amount equivalent to 100 mass ppm to tantalum having a purity of 99.999% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size was approximately 25 μm .

30 After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μm was obtained.

Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto

again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 100 μ m was obtained.

[0050] Subsequently, this was subject to cold rolling and recrystallization annealing, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ . Cold working and recrystallization annealing in the middle and last were adjusted to achieve the following average crystal grain size and variation of the crystal grain size. Although the average crystal grain size and variation will also change depending on the additive amount of molybdenum, the foregoing adjustment was possible in this Example.

The average crystal grain size of the target was 70 μ m, and the variation of the crystal grain size was $\pm 5\%$. And, the variation of the molybdenum content was $\pm 6\%$. The results are similarly shown in Table 2.

[0051] Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

As the results similarly shown in Table 2, evidently, the fluctuation of the resistance distribution in the sheet is small (1.0 to 1.2%) from the initial stage to the end stage of sputtering in this Example; that is, the fluctuation of the film thickness distribution is small.

The electrical energy required up to the initial stabilization of sputtering was also measured and showed 80 kWh, and decreased, as shown in Table 2. Thus, besides shortening the burn-in time, the evenness (uniformity) of the film was favorable, and it was possible to improve the quality of the sputter deposition.

[0052] (Comparative Example 1)

A raw material obtained by adding molybdenum in an amount equivalent to 0.5 mass ppm to tantalum having a purity of 99.995% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size was approximately 60 mm.

After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μ m was obtained.

Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 100 μ m was obtained.

[0053] Subsequently, this was subject to cold rolling and recrystallization annealing, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ . Cold working and recrystallization annealing in the middle and last were adjusted to achieve an appropriate average crystal grain size and variation of the crystal grain size, but the foregoing adjustment was not possible in this Comparative Example, and the average crystal grain size of the target was 130 μ m, and variation of the crystal grain size was $\pm 35\%$. And, variation of the molybdenum content was $\pm 40\%$. The results are similarly shown in Table 2.

[0054] Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

As the results similarly shown in Table 2, evidently, the fluctuation of the resistance distribution in the sheet is large (3.8 to 6.0%) from the initial stage to the end stage of sputtering in this Comparative Example; that is, the fluctuation of the film thickness distribution is large.

The electrical energy required up to the initial stabilization of sputtering was also measured and showed 200 kWh, and increased, as shown in Table 2. Thus, it was not possible to shorten the burn-in time, the evenness (uniformity) of the film was inferior, and it was not possible to improve the quality of the sputter deposition.

Similar testing was performed for a case of adding molybdenum in an amount equivalent to 0.5 mass ppm to tantalum having a purity of purity of 99.999%, but the same tendency as this Comparative Example 1 was observed. It was obvious that this also affected the purity of tantalum.

[0055] (Comparative Example 2)

A raw material obtained by adding molybdenum in an amount equivalent to 150 mass ppm to tantalum having a purity of 99.999% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size was approximately 20 mm.

After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μm was obtained.

Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 100 μm was obtained.

Subsequently, this was subject to cold rolling and recrystallization annealing, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ . Cold working and recrystallization annealing in the middle and last were adjusted to achieve an appropriate average crystal grain size and variation of the crystal grain size, but the foregoing adjustment was not possible in this Comparative Example, and the average crystal grain size of the target was supposedly 70 μm , but the variation of the crystal grain size was $\pm 50\%$, and variation caused by segregation was considerable. And, variation of the molybdenum content was $\pm 70\%$. The results are similarly shown in Table 2.

Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

As the results similarly shown in Table 2, evidently, the fluctuation of the resistance distribution in the sheet is large (4.5 to 7.0%) from the initial stage to the end stage of sputtering in this Comparative Example; that is, the fluctuation of the film thickness distribution is large.

The electrical energy required up to the initial stabilization of sputtering was also measured and showed 130 kWh, and increased, as shown in Table 2. Thus, it was not possible to shorten the burn-in time, the evenness (uniformity) of the film was inferior, and it was not possible to improve the quality of the sputter deposition.

If the additive amount of molybdenum added to tantalum having a purity of 99.999% exceeded 100 mass ppm, the crystal grain size coarsened and the variation increased rapidly, and variation of the molybdenum content also become prominent.

This is considered to be a result of the segregation of molybdenum, and it

was discovered that the addition of excessive molybdenum is undesirable.

[0059] (Example 8)

A raw material obtained by adding 1.3 mass ppm of molybdenum and 0.74 mass ppm of niobium in a total amount of 2.04 mass ppm to tantalum having a purity of 99.998% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size in this case was approximately 55 mm.

After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μ m was obtained.

Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 150 μ m was obtained.

Subsequently, this was subject to cold rolling and recrystallization annealing at 1173 K, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ .

The average crystal grain size of the target was 100 μ m, and the variation of the crystal grain size was $\pm 20\%$. And, variation of the content of molybdenum and niobium was $\pm 18\%$. The results are shown in Table 3.

Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

As the results similarly shown in Table 3, evidently, the fluctuation of the resistance distribution in the sheet is small (2.6 to 3.5%) from the initial stage to the end stage of sputtering in this Example; that is, the fluctuation of the film thickness distribution is small.

The electrical energy required up to the initial stabilization of sputtering was also measured and showed 100 kWh, and decreased, as shown in Table 3. Thus, besides shortening the burn-in time, the evenness (uniformity) of the film was favorable, and it was possible to improve the quality of the sputter deposition.

[0062][Table 3]

	Mo	Nb	Content of Mo and Nb	Average Crystal Grain Size	Variation in Crystal Grain Size	Variation in Content of Mo and Nb	Resistivity Distribution in Sheet	Electrical Energy up to Initial Stabilization	Uniformity of Film
Example 8	13	0.74	2.04	100	±20%	±18%	2.6 ~ 3.5%	100kWh	Favorable
Example 9	32	12	44	85	±11%	±11%	2.0 ~ 2.5%	55kWh	Favorable
Example 10	67	2.4	69.4	50	±7%	±8%	1.5 ~ 1.9%	40kWh	Favorable
Example 11	24	75	99	47	±5%	±6%	1.3 ~ 1.6%	35kWh	Favorable
Example 12	97	53	150	40	±4%	±15%	1.6 ~ 1.8%	40kWh	Favorable
Example 13	51.4	95	146.4	42	±5%	±13%	1.5 ~ 1.9%	45kWh	Favorable
Comparative Example 3	95	65	160	34 Unrecrystallized	±60%	±27%	4.0 ~ 6.5%	150kWh	Inferior
Comparative Example 4	60.3	97	157.3	32 Unrecrystallized	±55%	±24%	4.3 ~ 7.4%	150kWh	Inferior

[0063] (Example 9)

5 A raw material obtained by adding 32 mass ppm of molybdenum and 12 mass ppm of niobium in a total amount of 44 mass ppm to tantalum having a purity of 99.998% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size in this case was approximately 55 μ m.

10 After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μ m was obtained.

15 Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 130 μ m was obtained.

[0064] Subsequently, this was subject to cold rolling and recrystallization annealing at 1173 K, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ .

The average crystal grain size of the target was 85 μ m, and the variation of the crystal grain size was $\pm 11\%$. And, variation of the content of molybdenum and niobium was $\pm 11\%$. The results are shown in Table 3.

25 [0065] Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49

points on the wafer was measured to calculate the standard deviation (σ) thereof.

As the results similarly shown in Table 3, evidently, the fluctuation of the resistance distribution in the sheet is small (2.0 to 2.5%) from the initial stage to the end stage of sputtering in this Example; that is, the fluctuation of the film thickness distribution is small.

The electrical energy required up to the initial stabilization of sputtering was also measured and showed 55 kWh, and decreased, as shown in Table 3. Thus, besides shortening the burn-in time, the evenness (uniformity) of the film was favorable, and it was possible to improve the quality of the sputter deposition.

10 [0066] (Example 10)

A raw material obtained by adding 67 mass ppm of molybdenum and 2.4 mass ppm of niobium in a total amount of 69.4 mass ppm to tantalum having a purity of 99.998% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size in this case was approximately 55 mm.

After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μ m was obtained.

Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 130 μ m was obtained.

Subsequently, this was subject to cold rolling and recrystallization annealing at 1173 K, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ .

The average crystal grain size of the target was 50 μ m, and the variation of the crystal grain size was $\pm 7\%$. And, variation of the content of molybdenum and niobium was $\pm 8\%$. The results are shown in Table 3.

Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

As the results similarly shown in Table 3, evidently, the fluctuation of the resistance distribution in the sheet is small (1.5 to 1.9%) from the initial stage to the end stage of sputtering in this Example; that is, the fluctuation of the film thickness distribution is small.

The electrical energy required up to the initial stabilization of sputtering was also measured and showed 40 kWh, and decreased, as shown in Table 3. Thus, besides shortening the burn-in time, the evenness (uniformity) of the film was favorable, and it was possible to improve the quality of the sputter deposition.

[0069] (Example 11)

A raw material obtained by adding 24 mass ppm of molybdenum and 75 mass ppm of niobium in a total amount of 99 mass ppm to tantalum having a purity of 99.998% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size was approximately 55 μ m.

After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μ m was obtained.

Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 120 μ m was obtained.

[0070] Subsequently, this was subject to cold rolling and recrystallization annealing at 1173 K, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ .

The average crystal grain size of the target was 47 μ m, and the variation of the crystal grain size was $\pm 5\%$. And, variation of the content of molybdenum and niobium was $\pm 6\%$. The results are shown in Table 3.

[0071] Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

As the results similarly shown in Table 3, evidently, the fluctuation of the

resistance distribution in the sheet is small (1.3 to 1.6%) from the initial stage to the end stage of sputtering in this Example; that is, the fluctuation of the film thickness distribution is small.

The electrical energy required up to the initial stabilization of sputtering was also measured and showed 35 kWh, and decreased, as shown in Table 3. Thus, besides shortening the burn-in time, the evenness (uniformity) of the film was favorable, and it was possible to improve the quality of the sputter deposition.

[0072] (Example 12)

A raw material obtained by adding 97 mass ppm of molybdenum and 53 mass ppm of niobium in a total amount of 150 mass ppm to tantalum having a purity of 99.998% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size was approximately 55 mm.

After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μ m was obtained.

Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 100 μ m was obtained.

[0073] Subsequently, this was subject to cold rolling and recrystallization annealing at 1173 K, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ .

The average crystal grain size of the target was 40 μ m, and the variation of the crystal grain size was $\pm 4\%$. And, variation of the content of molybdenum and niobium was $\pm 15\%$. The results are shown in Table 3.

[0074] Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

As the results similarly shown in Table 3, evidently, the fluctuation of the resistance distribution in the sheet is small (1.6 to 1.8%) from the initial stage to the

end stage of sputtering in this Example; that is, the fluctuation of the film thickness distribution is small.

The electrical energy required up to the initial stabilization of sputtering was also measured and showed 40 kWh, and decreased, as shown in Table 3. Thus, besides shortening the burn-in time, the evenness (uniformity) of the film was favorable, and it was possible to improve the quality of the sputter deposition.

[0075] (Example 13)

A raw material obtained by adding 51.4 mass ppm of molybdenum and 95 mass ppm of niobium in a total amount of 146.4 mass ppm to tantalum having a purity of 99.998% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size was approximately 55 μ m.

After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μ m was obtained.

Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 100 μ m was obtained.

[0076] Subsequently, this was subject to cold rolling and recrystallization annealing at 1173 K, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ .

The average crystal grain size of the target was 42 μ m, and the variation of the crystal grain size was $\pm 5\%$. And, variation of the content of molybdenum and niobium was $\pm 13\%$. The results are shown in Table 3.

[0077] Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

As the results similarly shown in Table 3, evidently, the fluctuation of the resistance distribution in the sheet is small (1.5 to 1.9%) from the initial stage to the end stage of sputtering in this Example; that is, the fluctuation of the film thickness

distribution is small.

The electrical energy required up to the initial stabilization of sputtering was also measured and showed 45 kWh, and decreased, as shown in Table 3. Thus, besides shortening the burn-in time, the evenness (uniformity) of the film was favorable, and it was possible to improve the quality of the sputter deposition.

[0078] (Comparative Example 3)

A raw material obtained by adding 95 mass ppm of molybdenum and 65 mass ppm of niobium in a total amount of 160 mass ppm to tantalum having a purity of 99.998% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size was approximately 60 μ m.

After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μ m was obtained.

Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 100 μ m was obtained.

[0079] Subsequently, this was subject to cold rolling and recrystallization annealing, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ . Cold working and recrystallization annealing in the middle and last were adjusted to achieve an appropriate average crystal grain size and variation of the crystal grain size, but the foregoing adjustment was not possible in this Comparative Example, and the average crystal grain size of the target was 34 μ m (including unrecrystallized portions), and variation of the crystal grain size was $\pm 60\%$. And, variation of the content of molybdenum and niobium was $\pm 27\%$. The results are similarly shown in Table 3.

[0080] Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

As the results similarly shown in Table 3, evidently, the fluctuation of the

resistance distribution in the sheet is large (4.0 to 6.5%) from the initial stage to the end stage of sputtering in this Comparative Example; that is, the fluctuation of the film thickness distribution is large.

The electrical energy required up to the initial stabilization of sputtering was also measured and showed 150 kWh, and increased, as shown in Table 3. Thus, it was not possible to shorten the burn-in time, the evenness (uniformity) of the film was inferior, and it was not possible to improve the quality of the sputter deposition.

Similar testing was performed for a case of adding molybdenum in an amount equivalent to 0.5 mass ppm to tantalum having a purity of purity of 99.999%, but the same tendency as this Comparative Example 3 was observed. It was obvious that this also affected the purity of tantalum.

[0081] (Comparative Example 4)

A raw material obtained by adding 60.3 mass ppm of molybdenum and 97 mass ppm of niobium in a total amount of 157.3 mass ppm to tantalum having a purity of 99.995% was subject to electron beam melting, and this was cast to prepare an ingot having a thickness of 200 mm and diameter of 200 mm ϕ . The crystal grain size was approximately 60 mm.

After performing extend forging to this ingot or billet at room temperature, this was subject to recrystallization annealing at a temperature of 1500 K. As a result, a material having a thickness of 120 mm and a diameter of 130 mm ϕ , and a structure in which the average crystal grain size is 200 μ m was obtained.

Subsequently, this was subject to extend forging and upset forging at room temperature once again, and recrystallization annealing was performed thereto again at a temperature of 1400 to 1500 K. As a result of repeating forging and heat treatment again, a material having a thickness 120 mm and a diameter 130 mm ϕ , and a structure in which the average crystal grain size is 100 μ m was obtained.

[0082] Subsequently, this was subject to cold rolling and recrystallization annealing, and finish processing so as to obtain a target material having a thickness of 10 mm and a diameter of 450 mm ϕ . Cold working and recrystallization annealing in the middle and last were adjusted to achieve an appropriate average crystal grain size and variation of the crystal grain size, but the foregoing adjustment was not possible in this Comparative Example; and the average crystal grain size of the target was 32 μ m (including unrecrystallized portions), and variation of the crystal

grain size was $\pm 55\%$. And, variation of the content of molybdenum and niobium was $\pm 24\%$. The results are similarly shown in Table 3.

[0083] Since the sheet resistance depends on the film thickness, the distribution of the sheet resistance in the wafer (12 inches) was measured to check the distribution condition of the film thickness. Specifically, the sheet resistance of 49 points on the wafer was measured to calculate the standard deviation (σ) thereof.

5 As the results similarly shown in Table 3, evidently, the fluctuation of the resistance distribution in the sheet is large (4.3 to 7.4%) from the initial stage to the end stage of sputtering in this Comparative Example; that is, the fluctuation of the film thickness distribution is large.

10 The electrical energy required up to the initial stabilization of sputtering was also measured and showed 150 kWh, and increased, as shown in Table 3. Thus, it was not possible to shorten the burn-in time, the evenness (uniformity) of the film was inferior, and it was not possible to improve the quality of the sputter deposition.

15 Similar testing was performed for a case of adding molybdenum in an amount equivalent to 0.5 mass ppm to tantalum having a purity of 99.999%, but the same tendency as this Comparative Example 4 was observed. It was obvious that this also affected the purity of tantalum.

20 INDUSTRIAL APPLICABILITY

[0084]

The present invention yields a superior effect of being able to provide a high purity tantalum sputtering target comprising a uniform and fine structure and which yields stable plasma and superior film evenness in other words, uniformity, by containing 1 mass ppm or more and 100 mass ppm or less of molybdenum as an essential component, and containing 0 to 100 mass ppm of niobium as needed, excluding 0 mass ppm thereof, and causing the total amount of molybdenum and niobium to be 1 mass ppm or more and 150 mass ppm or less, and having a purity of 99.998% or more excluding molybdenum and gas components. Moreover, since the plasma stabilization during sputtering can also be realized in the initial stage of sputtering, the present invention additionally yields the effect of being able to shorten the burn-in time. Thus, the target of the present invention is useful in the electronics field, particularly as a target suitable for forming films of complex shapes, forming circuits or forming barrier films.

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CLAIMS

1. A tantalum sputtering target containing 10 mass ppm or more and 100 mass ppm or less of molybdenum as an essential component, and having a purity of 99.998% or more excluding molybdenum and gas components.
2. A tantalum sputtering target containing 10 mass ppm or more and 50 mass ppm or less of molybdenum as an essential component, and having a purity of 99.998% or more excluding molybdenum and gas components.
3. The tantalum sputtering target according to claim 1 or claim 2, wherein variation of the molybdenum content in the target is $\pm 20\%$ or less.
4. The tantalum sputtering target according to any one of claims 1 to 3, wherein an average crystal grain size is 110 μm or less.
5. The tantalum sputtering target according to claim 4, wherein variation of the crystal grain size is $\pm 20\%$ or less.
6. The tantalum sputtering target according to claim 1 or claim 2, further containing 0 to 100 mass ppm of niobium, excluding 0 mass ppm thereof, wherein the total amount of molybdenum and niobium is 1 mass ppm or more and 150 mass ppm or less.
7. The tantalum sputtering target according to claim 6, further containing 10 mass ppm or more and 100 mass ppm or less of niobium.
8. The tantalum sputtering target according to claim 6, further containing 10 mass ppm or more and 50 mass ppm or less of niobium.
9. The tantalum sputtering target according to any one of claims 6 to 8, wherein variation of content of niobium and molybdenum in the target is $\pm 20\%$ or less.
10. The tantalum sputtering target according to any one of claims 6 to 9, wherein an average crystal grain size is 110 μm or less.

11. The tantalum sputtering target according to claim 10, wherein variation of the crystal grain size is $\pm 20\%$ or less.