Specification

[Title of the Invention] SPUTTERING TARGET, METHOD FOR MANUFACTURING THE SAME, AND FILM

[Technical Field]

[0001]

This disclosure relates to a sputtering target (hereinafter sometimes referred to simply as a “target”), a method for manufacturing the same, and a film.

[Background Art]

[0002]

Some semiconductor devices have a multilayer interconnect structure, which comprises conductive interconnects, insulating films, diffusion barrier layers, and the like. Conventionally, pure copper was often used for conductive interconnects; however, in recent years, as interconnects have become finer, new issues such as electrical resistance have emerged. Consequently, research is underway to develop a new material for conductive interconnects.

[0003]

Patent Document 1 discloses a Cu-Al binary alloy sputtering target and a method for manufacturing the same, which has a high Al content, and is capable of suppressing cracking of the sputtering target. Specifically, Patent Document 1 discloses the following sputtering target: a sputtering target comprised of a sintered body comprising a binary alloy of Cu and Al, with the balance consisting of unavoidable impurities, wherein the Cu and Al contents (at%) satisfy the relationship $0.48 \leq Al/(Cu+Al) \leq 0.70$, and the relative density is 95% or higher.

[Prior Art]

[Patent Documents]

[0004]

[Patent Document 1] Japanese Patent Application Publication No. 2023-124653

[Summary of Invention]

[Problems to be solved by Invention]

[0005]

Patent Document 1 discloses a Cu-Al binary alloy sputtering target with a high Al content, provided for the purpose of suppressing cracking during sputtering. However, the sputtering target disclosed in Patent Document 1 has room for further improvement from the perspective of suppressing sputtering-related problems. Therefore, an objective of the present disclosure is to provide a sputtering target and a method for manufacturing the same to suppress sputtering-related problems.

[Means for Solving the Problem]

[0006]

To achieve the above objective, the present disclosure, in one aspect, includes the following inventions.

(Invention 1)

A sputtering target comprising a binary alloy of Cu and Al, with the balance consisting of unavoidable impurities, wherein:

Cu and Al contents (at%) satisfy the following condition:

$0.48 \leq Al/(Cu+Al) \leq 0.70$, and

(1) When $0.48 \leq Al/(Cu+Al) < 0.55$,

a pore area fraction within a field of view observed by SEM is 2.0% or less, and

(2) When $0.55 \leq Al/(Cu+Al) \leq 0.70$,

the pore area fraction within the field of view observed by SEM is 1.0% or less.

(Invention 2)

The sputtering target according to Invention 1, wherein

the Cu and Al contents (at%) satisfy the following condition:

$0.48 \leq Al/(Cu+Al) \leq 0.52$, and

the pore area fraction within the field of view when observed by SEM is 2.0% or less.

(Invention 3)

The sputtering target according to Invention 1, wherein:

the Cu and Al contents (at%) satisfy the following condition:

$0.65 \leq Al/(Cu+Al) \leq 0.69$, and

the pore area fraction within the field of view when observed by SEM is 1.0% or less.

(Invention 4)

The sputtering target according to any one of Inventions 1 to 3, having flexural strength of 70 MPa or more.

(Invention 5)

The sputtering target according to any one of Inventions 1 to 4, wherein an oxygen content of the sputtering target is 1,000 ppm by mass or less.

(Invention 6)

A sputtering target comprising a binary alloy of Cu and Al, with the balance consisting of unavoidable impurities, wherein:

Cu and Al contents (at%) satisfy the following condition:

$0.48 \leq Al/(Cu+Al) \leq 0.70$,

an oxygen content of the sputtering target is 1,000 ppm by mass or less, and

flexural strength is 70 MPa or more.

(Invention 7)

The sputtering target according to Invention 6, wherein:

the Cu and Al contents (at%) satisfy the following condition:

$0.65 \leq Al/(Cu+Al) \leq 0.69$.

(Invention 8)

The sputtering target according to Invention 6, wherein:

the Cu and Al contents (at%) satisfy the following condition:

$0.48 \leq Al/(Cu+Al) \leq 0.52$,

and the flexural strength is 100 MPa or more.

(Invention 9)

A method for manufacturing the sputtering target according to any one of Inventions 1 to 8, wherein the method comprises:

・a step of providing an ingot;

・a step of producing powder from the ingot using a disk atomization method; and

・a step of producing a sintered body from said powder by hot pressing,

and

the method satisfies one or more of the following conditions:

・the step of producing the powder includes adjusting grain size distribution to satisfy the following conditions:

D50V 40.0–50.0 μm

D90V 65.0–100.0 μm

・the step of producing the sintered body includes hot pressing under the following conditions:

Temperature: 500–700°C

Pressure: 200–450 kgf/cm²

Holding time: 9 hours or more.

(Invention 10)

The method for manufacturing the sputtering target according to Invention 9, wherein

・the step of producing the powder includes adjusting the grain size distribution to satisfy the following condition:

((D90V–D10V)/D10V) ≥ 1.90.

(Invention 11)

The method for manufacturing the sputtering target according to Invention 9 or 10, wherein:

・the step of producing the powder includes adjusting the grain size distribution to satisfy the following condition:

((D90V–D10V)/D50V) ≥ 1.12.

(Invention 12)

A film manufactured using the sputtering target according to any one of Inventions 1 to 8.

[Effect of the Invention]

[0007]

In one aspect, the pore area fraction within the field of view when observed by SEM satisfies the following conditions.

(1) When 0.48 ≤ Al/(Cu+Al) < 0.55, the pore area fraction within the field of view when observed by SEM is 2.0% or less.

(2) When 0.55 ≤ Al/(Cu+Al) ≤ 0.70, the pore area fraction within the field of view when observed by SEM is 1.0% or less.

This provides a sputtering target with high Vickers hardness. Furthermore, the high Vickers hardness allows cracking to be suppressed.

[0008]

In one aspect, the target has flexural strength of 70 MPa or more and an oxygen content of 1,000 ppm by mass or less. Since the flexural strength is 70 MPa or higher, warping during

sputtering can be suppressed. As a result, a problem caused by warping during sputtering (for example, arcing) can be reduced. Furthermore, the low oxygen content contributes to reducing other problems during sputtering (for example, particles, etc.).

[Brief Description of the Drawings]

[0009]

[Fig. 1] Fig. 1 shows the measurement points on a sputtering target used to evaluate compositional uniformity.

[Fig. 2] Fig. 2 shows the settings screen of the image analysis software.

[Fig. 3] Fig. 3 shows a photograph of the SEM image from Test Example 1.

[Fig. 4] Fig. 4 shows a photograph of the SEM image from Test Example 3.

[DETAILED DESCRIPTION OF EMBODIMENTS]

[0010]

The following describes specific embodiments for carrying out the invention. The following description is intended to facilitate understanding of the invention. That is, it is not intended to limit the scope of the present invention.

[0011]

(1. Composition)

In one embodiment, the present disclosure relates to a sputtering target comprising a binary alloy of Cu and Al, with the balance consisting of unavoidable impurities. The sputtering target may include a backing plate and, in addition, may include a bonding layer.

[0012]

Although the shape of the sputtering target is not particularly limited, it may typically be planar (for example, circular, rectangular, etc.).

[0013]

In the sputtering target, the Cu and Al contents (at%) satisfy the condition: $0.48 \leq Al/(Cu+Al) \leq 0.70$.

[0014]

By setting the Al content to 48 at% or more and 70 at% or less relative to the total Cu and Al content, a conductor consisting of intermetallic compounds of Cu and Al can be preferably formed. This conductor is expected to exhibit excellent electrical conductivity and adhesion between the conductor and the insulator. From this perspective, the Al content relative to the total content of Cu and Al is preferably 50 at% or more, more preferably 55 at% or more, yet more preferably 62 at% or more, and even more preferably 66 at% or more.

[0015]

Furthermore, from a similar perspective, the Al content relative to the total content of Cu and Al is preferably 69 at% or less, and more preferably 68 at% or less. Furthermore, from another perspective (for example, from the perspective of the type of Cu-Al alloy), the Al content relative to the total content of Cu and Al is preferably less than 55 at%.

[0016]

The sputtering target preferably contains intermetallic compounds of $CuAl_2$ and/or CuAl, and more preferably, the sputtering target consists of intermetallic compounds of $CuAl_2$ and/or CuAl. That is, it is more preferred that the Cu and Al contents meet the relation of Al/(Cu+Al) = 0.67 ± 0.02 or Al/(Cu+Al) = 0.50 ± 0.02, and it is yet more preferred that the Cu and Al contents meet the relation of Al/(Cu+Al) = 0.67 ± 0.01 or Al/(Cu+Al) = 0.50 ± 0.01, and it is even more preferred that the Cu and Al contents meet the relation of Al/(Cu+Al) = 0.67, or Al/(Cu+Al) = 0.50.

[0017]

If a target material consisting of the intermetallic compound $CuAl_2$ or CuAl can be manufactured, there is no need to manufacture a pure copper metal target and a pure aluminum metal target individually to form $CuAl_2$ or CuAl interconnect materials, and the risk of impurity contamination during sputtering is reduced. Therefore, the purity of the sputtering target in one embodiment is preferably 4N (99.99% by mass) or

higher, more preferably 4N5 (99.995% by mass) or higher, and most preferably 5N (99.999% by mass) or higher.

[0018]

The purity of the sputtering target being 4N (99.99% by mass) or higher means that, when analyzed for composition using glow discharge mass spectrometry (GDMS), the total amount of Na, P, S, K, Ca, Cr, Fe, Ni, As, Ag, Sb, Bi, Th, and U contained in the sputtering target is less than 0.01 % by mass (100 ppm by mass).

[0019]

Incidentally, when the sputtering target is manufactured from an ingot, the Cu and Al contents in the sputtering target may be taken as the Cu and Al contents in the ingot consisting of Cu and Al intermetallic compounds as described below, and when measured from the sputtering target product, the composition of the sputtering target may be determined by inductively coupled plasma optical emission spectroscopy (ICP-OES).

[0020]

(2. Relative Density)

Although the relative density is not particularly limited, in a preferred embodiment, the relative density of the sputtering target of the present disclosure may be 95.0% or higher. A higher relative density of the target is preferable for stable sputtering with less arcing. The relative density is preferably 97% or more, more preferably 98.0% or more, and yet more preferably 99.0% or more. Although there is no specific upper limit on the relative density, it may be, for example, 100% or less, 99.9% or less, 99.5% or less, or 99.0% or less.

[0021]

The relative density is calculated using the formula: Relative density = Measured density ÷ Theoretical density × 100 (%). The measured density is the value obtained by dividing weight by volume, and the volume is measured using Archimedes' principle. The theoretical density is calculated by a weighted average, assuming that the entire sputtering target consists of $CuAl_2$(θ-phase) and CuAl(η-phase), with the theoretical density of $CuAl_2$(θ-phase) set at 4.35 g/cm^3 and the theoretical density of

$CuAl$(η-phase) set at 5.36 g/cm^3. Incidentally, the proportions of $CuAl_2$(θ-phase) and $CuAl$(η-phase) are calculated from the composition of the sputtering target. The relative density calculated using these theoretical densities may exceed 100%.

[0022]

(3. Compositional Uniformity)

In one embodiment, when the Al content is measured by ICP-OES at a total of five points located on two mutually perpendicular straight lines extending from the center of the sputtering surface of a flat sputtering target to its outer periphery, where the five points include the center of the sputtering surface, the outer periphery positions, and the intermediate positions between them, it is preferable that the difference between the maximum and minimum content values among the measured contents be 0.2 at% or less. Incidentally, the outer periphery positions are defined as points located 1/8 of a certain length from the outermost edge toward the center, where the certain length is the distance between the center and the outermost edge of the sputtering target. The intermediate positions, located between the center and the outer periphery positions, are defined as the midpoints along the straight lines connecting the center and the outer periphery positions. In this way, the small difference among Al contents at the measurement points and the high compositional uniformity ensure that the composition of the sputtering target is uniform at each point, which contributes to the formation of a uniform conductive layer.

[0023]

From this perspective, it is more preferable that the difference between the maximum and minimum Al content values measured based on the above method be 0.1 at% or less. While this compositional uniformity cannot be achieved, for example, with a sputtering target in which pure Cu and pure Al are alternately arranged or mixed, it is possible to achieve a high level of uniformity by preparing atomized powder, as described below.

[0024]

Referring to Fig. 1, when the sputtering surface of the sputtering target is circular, its center A is the center of the circle, and the five points, that is, the center position A, outer periphery positions E and C, and the intermediate positions B and D located between them, are arranged in an L-shape. The outer periphery positions E and C are defined as points located 1/8 of a certain length from the outermost edge toward the center position A, where the certain length is the distance between the center position A and the outermost edge of the sputtering target. When the sputtering surface of the sputtering target is rectangular, its center is the intersection of the diagonals. Further, when the sputtering surface of the sputtering target is rectangular, the outer periphery positions are defined as points located 1/8 of a certain length from the corner toward the center (the intersection of the diagonals), where the certain length is the distance between the center and the corner.

[0025]

(4. Crystal Structure)

The crystal structure of a sputtering target can be determined by analyzing the sputtering surface with an XRD (X-ray diffractometer). The mass ratio of each crystalline phase is obtained by quantitative analysis using the RIR (Reference Intensity Ratio) method based on the XRD analysis results. The RIR method is a technique for determining the mass ratio of each crystalline phase based on the ratio of the RIR value and the intensity of the strongest peak for each crystalline phase, as determined from the XRD results. If a sputtering target contains crystalline phases A, B, C, …, the mass fraction of crystalline phase A, X_A, is calculated using the following equation:

$$X_A = I_A k_A / (I_A k_A + I_B k_B + I_C k_C + \ldots),$$

where I represents the intensity of the strongest X-ray peak for each crystalline phase, and k represents the RIR value for each crystalline phase. As for the RIR values, those listed in the Powder Diffraction Files (PDF) database of the International

Center for Diffraction Data (ICSD Nos. 01-071-5027 and 03-065-1228) can be used.

By performing quantitative analysis using the RIR method, quantitative values for each phase of Cu, Al, $CuAl_2$, and CuAl can be obtained, and thus, the mass ratio of the total $CuAl_2$ + CuAl can also be obtained.

[0026]

The mass ratio of the total $CuAl_2$ + CuAl is preferably 95% or more, and more preferably 98% or more. This allows for the preferable formation of a conductive material consisting of intermetallic compounds of Cu and Al. Further, when $CuAl_2$ is the primary phase, the mass ratio of $CuAl_2$ is preferably 70% or more, more preferably 90% or more, and yet more preferably 95% or more. The “primary phase” as used herein refers to the most abundant crystalline phase among those contained in the sputtering target. When CuAl is the primary phase, the mass ratio of CuAl is preferably 70% or more, more preferably 90% or more, and yet more preferably 95% or more. This allows for the preferable formation of a conductive material consisting of an intermetallic compound of Cu and Al. Further, in a preferred embodiment of the present disclosure, the total mass ratio of $CuAl_2$ + CuAl is 100%, which means that neither a single Cu phase nor a single Al phase is contained.

[0027]

(5. Pore Area)

In the microstructure of a sputtering target according to one embodiment of the present disclosure, the pore area fraction within the field of view when observed by SEM is 2.0% or less, preferably 1.0% or less, more preferably 0.5% or less, and most preferably 0.1% or less. In another embodiment, the pore area fraction is 2.00% or less; preferably, 1.00% or less; more preferably, 0.50% or less; and most preferably, 0.10% or less.

[0028]

In one embodiment, the upper limit of the pore area may vary depending on the composition. In one example, when $0.48 \leq Al/(Cu+Al) < 0.55$, the pore area fraction is 2.0% or less (for

example, 2.00% or less). In another example, when $0.55 \leq Al/(Cu+Al) \leq 0.70$, the pore area fraction is 1.0% or less (for example, 1.00% or less). Although the tendency in pore area varies depending on the composition, in one embodiment, the sputtering target of the present disclosure enables the achievement of a pore area lower than that conventionally achieved when compared at the same composition.

[0029]

Although the lower limit is not particularly limited, it may, for example, be 0.01% or more. In one example, when $0.48 \leq Al/(Cu+Al) < 0.55$ (preferably, $0.48 \leq Al/(Cu+Al) \leq 0.52$), the lower limit of the pore area fraction may be 1.00% or more, and typically may be 1.50% or more. In another example, when $0.55 \leq Al/(Cu+Al) \leq 0.70$ (preferably, $0.65 \leq Al/(Cu+Al) \leq 0.69$), the lower limit of the pore area fraction may be 0.01% or more, and typically may be 0.80% or more. Incidentally, the measurement point is not particularly limited. For example, the measurement point may be at the outer periphery position of the sputtering target (for example, in the case of a circular sputtering target, a portion of the circumference (for example, the portions corresponding to C and E in Fig. 1), or, alternatively, 1/8 of a certain length from the corner toward the center (the intersection of the diagonals), where the certain length is the distance between the center and the corner). Furthermore, there may be multiple measurement points, and in such cases, the pore area fraction may be the average value of the individual measurement points.

[0030]

Because the pore area fraction is 2.0% or less (or, depending on the composition, 1.0% or less), the sputtering target has a Vickers hardness of a certain level or higher. Further, having a certain level of Vickers hardness or higher allows prevention of cracking.

[0031]

The pore area fraction can be measured according to the following method.

・Cut a sample out of the sputtering target (for example, at the outer periphery position) (for example, the sample size may be 10 mm × 10 mm × thickness: 3–20 mm).

・Before observation, polish the observation surface of the sample (the surface parallel to the sputtering surface) with #2000 sandpaper.

・Next, buff the sample’s observation surface using a polishing compound.

・Detect pores from secondary electron images obtained by observing the microstructure using an SEM (accelerating voltage: 15.0 kV; observation area: 350 μm × 500 μm; magnification: 250×).

・Perform image processing on the detected pores to calculate their area.

・Divide the total pore area by the area of the field of view in the SEM.

[0032]

When detecting pores, the contrast is adjusted to detect the pores. This is because, depending on the contrast, certain pores may be easier to visualize, while other specific pores may be harder to visualize. In one example, pore area is detected using a Hitachi High-Technologies Corporation Model SU3500 scanning electron microscope, with contrast adjusted via the instrument’s manual control panel. Then, practically, the conditions that yield the highest area fraction as a result of contrast adjustment are identified, and the pore area fraction is calculated under those conditions. In addition, the image analysis software Nikon NIS-Elements D is used for image processing. In Nikon NIS-Elements D, pores are detected using the Object Counting Tool. When doing this, the Threshold panel is used to set the brightness. Incidentally, although in this software the brightness value is automatically set within the range of 0–255, the upper limit of the brightness value is set to be 50 or less (see Fig. 2). Further, the measurement function implemented in this software is used to measure the area of the detected objects (pores) and the total area is calculated.

[0033]

(6. Flexural Strength)

In one embodiment, the flexural strength of the sputtering target of the present disclosure is 70 MPa or more, preferably 80 MPa or more, yet more preferably 100 MPa or more, and yet more preferably 110 MPa or more. High flexural strength suppresses warping during sputtering, resulting in the advantage of reducing problems (for example, arcing) during sputtering. Although the upper limit is not particularly limited, it may, for example, be 100 MPa or less, or 150 MPa or less. Although the tendency in flexural strength varies depending on the composition, in one embodiment relating to a specific composition (for example, when the Al content (at%) is greater than the Cu content, such as when $0.55 \leq Al/(Cu+Al) \leq 0.70$), the sputtering target of the present disclosure allows achieving flexural strength higher than that conventionally achieved.

[0034]

The flexural strength can be measured in accordance with JIS R 1601. In the JIS standard, the thickness of a sample is determined as 3 mm. To achieve this thickness, the same amount is ground off from both the front and back surfaces of the target. Then, a sample is cut from any portion to form a 4 × 40 mm rectangle. Specifically, the procedure is as follows:

(Test Conditions for Flexural Strength)

Test Method: Three-point bending test

Distance between supports: 30 mm

Sample size: 3 × 4 × 40 mm

Radius of curvature of the support: 5 mm

Head speed: 0.5 mm/min

[0035]

The measurement point for flexural strength is not particularly limited. For example, the measurement position for the flexural strength may be the same as the measurement points for pore area described above.

[0036]

(7. Vickers Hardness)

In one embodiment, the Vickers hardness of the sputtering target of the present disclosure is 460.0 or higher, preferably 470.0 or higher, and more preferably 700.0 or higher. A high Vickers hardness helps prevent cracking of the sputtering target. Although the upper limit is not particularly limited, it may, for example, be 550.0 or less, or 800.0 or less. Although the tendency in Vickers hardness varies depending on the composition, in one embodiment, the sputtering target of the present disclosure enables the achievement of a Vickers hardness higher than that conventionally achieved when compared at the same composition.

[0037]

Vickers hardness refers to the value measured based on the Vickers hardness test specified in JIS Z2244 (2009). Specifically, the conditions are as follows:

(Vickers Hardness Measurement Conditions)

- Test force: 2.0 N
- Indenter approach speed: 60 μm/sec
- Force application duration: 10 seconds
- Test temperature: Room temperature

[0038]

The measurement point for Vickers hardness is not particularly limited. For example, the measurement point for Vickers hardness may be the same as the measurement point for the pore area described above.

[0039]

(8. Oxygen Concentration)

In one embodiment, the oxygen concentration of the sputtering target of the present disclosure is 1,000 ppm by mass or less; preferably, 850 ppm by mass or less; more preferably, 300 ppm by mass or less; and most preferably, 200 ppm by mass or less. A sputtering target with low oxygen concentration tends to contain fewer impurities. Further, the low impurity content helps suppress adverse effects during sputtering (for example, the possibility of generation of particles during sputtering). Although the lower limit of the oxygen concentration is not

particularly limited, it may be 100 ppm by mass or more, or 150 ppm by mass or more.

[0040]

In the manufacturing method described below, there may be a need to adjust the grain size distribution of the raw material powder, and, as the grain size decreases, the surface area per unit volume increases. Thereby, the powder may react with more oxygen, which may result in an increase in the oxygen content of the sputtering target. However, the sputtering target of the present disclosure is characterized by suppressing the pore area while, at the same time, avoiding an increase in oxygen concentration.

[0041]

The oxygen content of the sputtering target can be measured using the inert gas fusion-infrared absorption method (for example, LECO TCH600). Furthermore, during measurement, either the entire sputtering target may be analyzed, or a sample portion of the target may be taken and analyzed. When analyzing the sample portions taken from the sputtering target, the sample portions may be collected from multiple positions, and an average value may be calculated. The measurement position for oxygen concentration is not specifically limited. For example, the measurement point for oxygen concentration may be the same as the measurement point for the pore area measurement described above.

[0042]

(9. Method for Manufacturing)

Although the method for manufacturing the sputtering target of the present disclosure is not particularly limited, the method for manufacturing in one embodiment includes at least the following steps.

・a step of providing an ingot

・a step of producing powder from the ingot using a disk atomization method; and

・a step of producing a sintered body from the powder by hot pressing.

[0043]

The above method has one or more of the following additional features.

[0044]

・The step of producing the powder includes adjusting the grain size distribution to satisfy the following conditions:

D50V 40.0–50.0 μm

D90V 65.0–100.0 μm

[0045]

・The step of producing the sintered body includes hot pressing under the following conditions:

Temperature: 500–700°C

Pressure: 200–450 kgf/cm^2

Holding time: 9 hours or more

[0046]

The following sections describe each process in detail.

[0047]

(9-1. The Step of Providing an Ingot)

In some embodiments of the present disclosure, the ingot provided may be an ingot in which the Cu and Al contents (at%) satisfy the relation $0.48 \leq Al/(Cu+Al) \leq 0.70$. In other embodiments of the present disclosure, the ingots provided may be an ingot consisting of Cu and an ingot consisting of Al, with respective amounts that satisfy the relation $0.48 \leq Al/(Cu+Al) \leq 0.70$. From the perspective of uniformity, the former embodiment is preferred.

[0048]

In the case of the former embodiment, it is preferable to melt the desired Cu and Al, or to melt the desired Cu-Al alloy, and produce an ingot such that the Cu and Al contents (at%) satisfy the relation $0.48 \leq Al/(Cu+Al) \leq 0.70$. In that case, the material to be melted can be selected based on the final composition of the target described above. For example, if the target composition is $CuAl_2$, either a $CuAl_2$ alloy may be melted, or Cu and Al may be introduced and melted such that their atomic ratio is 1:2. In another example, if the target composition is

CuAl, either a CuAl alloy may be melted, or Cu and Al may be introduced and melted such that their atomic ratio is 1:1. Producing an ingot via melting allows the raw materials to be stirred, thereby promoting uniformity.

[0049]

The melting temperature is not particularly limited, but 800–1000°C is preferred, and 850–950°C is more preferred.

[0050]

The molten metal can be poured into a mold to produce the desired ingot.

[0051]

(9-2. The Step of Producing Atomized Powder from Ingots)

The obtained ingot is subjected to an atomization method to produce atomized powder. Although it is preferable to use the ingot described above (i.e., the ingot that satisfies the relation $0.48 \leq Al/(Cu+Al) \leq 0.70$ in terms of Cu and Al content (at%)) as a raw material, there is no particular limitation as long as atomized powder with the desired atomic ratio of Cu and Al can be produced. For example, if the provided ingot contains a binary alloy of Cu and Al, with the balance consisting of unavoidable impurities (and if its composition is the same as that of the target to be produced), it may be fed into the atomization apparatus as is, and melted to produce atomized powder. In another example, the provided ingots may consist of two types: one consisting of Cu and the other consisting of Al. For example, if the target composition is $CuAl_2$, Cu and Al may be fed into the atomization apparatus such that the atomic ratio is 1:2 and Cu and Al may be melted to produce atomized powder. In another example, if the target composition is CuAl, Cu and Al may be fed into the atomization apparatus such that the atomic ratio is 1:1 and Cu and Al may be melted to produce atomized powder. By converting into powder through the atomization method, it can be subjected to the subsequent hot-pressing, enabling the manufacture of the target. Furthermore, producing atomized powder promotes the uniformity of the material.

[0052]

Although atomization methods include disk atomization, water atomization, and gas atomization, the target is manufactured using disk atomization. The conditions for disk atomization are not particularly limited. Manufacturing powder via disk atomization tends to result in a powder shape well-suited for packing (for example, high sphericity). This results in a higher filling rate, which leads to a sputtering target with a smaller pore area.

[0053]

(9-3. Treatment of Atomized Powder)

After obtaining atomized powder, the powder may be further ground, or no grinding may be performed. The latter is preferred. This is because the oxygen concentration may increase.

[0054]

The grain size distribution of the resulting atomized powder is not particularly limited. For example, the grain size distribution may satisfy the following conditions:

D50V: 40.0–80.0 μm (preferably 40.0–70.0 μm)

D90V: 65.0–125.0 μm (preferably 67.0–120.0 μm)

[0055]

In a preferred embodiment, the grain size of the resulting atomized powder may be adjusted. For example, the grain size may be adjusted to satisfy the following conditions.

D50V: 40.0–50.0 μm (preferably 40.0–45.0 μm)

D90V: 65.0–100.0 μm (preferably 67.0–72.0 μm)

[0056]

D50V is the median diameter (by volume) in the grain size distribution. On the other hand, D90V is the grain size at which the cumulative volume of the grains reaches 90% (by volume).

[0057]

The grain size distribution described above and related values (for example, D50V, D90V, etc.) can be measured using the laser diffraction (LD) method.

[0058]

Although the method for adjusting grain size is not particularly limited, typically, a sieve with a specific mesh size may be used. Although the sieve mesh size is not particularly limited, for example, it may be 70–170 μm. Preferably, the mesh size of the sieve may be 130–170 μm, or it may be 80–100 μm.

[0059]

Adjusting the grain size decreases the gaps when the powder is packed, leading to a decrease in pore area.

[0060]

In other preferred embodiments, the adjusted grain size distribution is broad. For example, it is preferable for the peak width, as represented in a grain size distribution graph, to be wide. The width of the grain size distribution is expressed by one of the following:

- ((D90V-D10V)/D10V) (Equation 1)
- ((D90V-D10V)/D50V) (Equation 2)

[0061]

When the width of the grain size distribution is expressed by Equation 1 above, the value is preferably 1.90 or more, and more preferably 2.00 or more. Although the upper limit is not particularly limited, it is typically 2.50 or less.

[0062]

When the width of the grain size distribution is expressed by Equation 2 above, the value is preferably 1.12 or more, and more preferably 1.13 or more. Although the upper limit is not particularly limited, it is typically 1.20 or less.

[0063]

The packing density tends to increase as the grains become finer. However, if the grain size distribution is too skewed toward extremely fine grains, the packing density may conversely become difficult to increase, and pores may form. As described above, maintaining a certain degree of width in the grain size distribution can reduce the possibility of pore formation. Further, while the flexural strength tends to increase as grains become finer, if they become too fine, the flexural strength

conversely decreases, and this also leads to the disadvantage of an increased oxygen content in the sintered body. From this perspective as well, as described above, it is preferable to adjust the grain size to an appropriate range.

[0064]

(9-4. The Step of Hot Pressing)

By packing the atomized powder described above, or powder obtained by grinding the atomized powder, into a hot pressing vessel and performing hot pressing, a sintered body can be obtained. The hot pressing is performed at a temperature of at least 500°C, and preferably at 550°C or higher. Performing the hot pressing at 500°C or higher improves processability (for example, it helps prevent cracking during manufacturing). In addition, performing the hot pressing at 500°C or higher improves the relative density. Although the upper limit for the temperature is not particularly limited, it is 700°C or less, and typically, 600°C or less. More preferably, the temperature is 560–580°C.

[0065]

Although the pressure is not particularly limited, it is preferably 200–450 kgf/cm^2, more preferably 250–350 kgf/cm^2, and most preferably 325 kgf/cm^2 or less. Furthermore, although the holding time is not particularly limited, it is preferably 3–20 hours and more preferably 9–11 hours. Setting the holding time within this more preferred range leads to a reduction in pore area. Further, setting the holding time within this more preferred range allows the oxygen content within the sintered body to be reduced.

[0066]

(9-5. Other Steps)

After the sintered body is obtained by hot pressing, other processing may be performed as appropriate. For example, hot isostatic pressing may be performed to further improve the relative density. Further, machining operations such as grinding and/or cutting may be performed as appropriate to finish the sintered body into the shape of a product for shipment.

Furthermore, the sintered body may be bonded to a backing plate to produce the final product. The conditions for these and other processes are not particularly limited and conditions well known in the art may be adopted as appropriate.

[0067]

Incidentally, as mentioned above, since the manufacturing method described above involves sintering powder, it need not include rolling or forging processes.

[0068]

The sputtering target according to an embodiment of the present invention has excellent machinability and has a low risk of cracking during processing steps in the manufacturing process (for example, grinding, cutting, etc.). Furthermore, because it has a relatively high relative density, wetting by grinding oil and the like can be avoided. Moreover, since it is manufactured as a sintered body, there is no need to perform rolling or forging processes, thereby eliminating the risk of cracking caused by these processes.

[0069]

In addition, the sputtering target according to one embodiment of the present invention exhibits excellent material uniformity, and for example, it has few visual irregularities (such as color irregularities). For example, when the microstructure is observed using methods such as SEM, there is little variation in brightness depending on the observation location.

[0070]

(10. Application)

The sputtering target described above can be used for the purpose of forming thin films by sputtering. Therefore, in one embodiment, the present disclosure relates to a film containing a binary alloy of Al and Cu manufactured using the sputtering target described above, or a film consisting of the binary alloy, and a method for manufacturing the film. Preferably, in one embodiment, the present disclosure relates to a semiconductor having a film of a binary alloy of Al and Cu

manufactured using the sputtering target described above, and a method for manufacturing the semiconductor.

[0071]

For example, the method for manufacturing may include steps such as arranging a substrate and a sputtering target opposite each other within a chamber, introducing an inert gas (for example, Ar), and applying a voltage to form a thin film.

[Examples]

[0072]

Although the present invention will be described in detail below with reference to examples, the descriptions herein are intended merely to illustrate the invention and are not intended to limit the scope of the invention.

[0073]

(Test Example 1)

An ingot was prepared by melting (at 900°C) a $CuAl_2$ intermetallic compound having a composition of 66.7 at% ± 0.5 at% Al, with the balance consisting of Cu and unavoidable impurities. Next, the ingot was subjected to an atomization method (disk atomization).

[0074]

The atomized powder was passed through a sieve with a mesh size of 150 μm, and the atomized powder that passed through the sieve was collected. The grain size of the collected atomized powder was measured using the method described above.

[0075]

Furthermore, hot pressing was performed on the collected atomized powder under the following conditions.

[0076]

Temperature: 570°C

Surface pressure: 350 kgf/cm^2

Holding time: 5 hours

[0077]

The resulting sintered body (which was disc-shaped) was machined to create a target from its central portion. The remaining portion, other than the target, was obtained as an

offcut. The Vickers hardness, flexural strength, pore area fraction, and oxygen content of the offcut were then measured using the methods described above. The distance between the offcut and the outer periphery position of the target after machining is only a few centimeters. Therefore, when using the target for measurement rather than the offcut, the measurement points may be set as follows:

Vickers hardness: 2 points on the outer periphery

Flexural strength: 5 points on the outer periphery

Pore area fraction: 1 point on the outer periphery

Oxygen content: 1 point on the outer periphery

[0078]

(Test Example 2)

The experiment was conducted under the same conditions as in Test Example 1 above. However, two conditions related to the hot pressing were changed as follows.

Surface pressure: 300 kgf/cm^2

Holding time: 10 hours

[0079]

(Test Example 3)

The experiment was conducted under the same conditions as in Test Example 1 above. However, one condition related to the hot pressing was changed as follows.

Surface pressure: 300 kgf/cm^2

[0080]

Furthermore, in Test Example 3, the collected atomized powder was passed through an additional sieve with a mesh size of 90 μm, and the atomized powder that passed through the sieve was collected. Hot pressing was then performed on the collected atomized powder.

[0081]

(Test Example 4)

The experiment was conducted under the same conditions as in Test Example 3. However, after passing the collected atomized powder through the sieve with a mesh size of 90 μm, it was passed through a further sieve with a mesh size of 63 μm, and

the atomized powder that passed through the sieve was collected. Hot pressing was then performed on the collected atomized powder.

[0082]

(Test Example 5)

The experiment was conducted under the same conditions as in Test Example 2. However, the composition was changed to a CuAl intermetallic compound consisting of 50.0 at% ± 0.5 at% Al, with the balance being Cu and unavoidable impurities.

[0083]

(Test Example 6)

The experiment was conducted under the same conditions as in Test Example 5. However, the hot press holding time was changed to 5 hours.

[0084]

The results are shown in Table 1. In addition, the SEM images for Test Examples 1 and 3 are shown in Figs. 3 and 4.

[Table 1]

	Sieve mesh size for passing the grains (μm)	D10V (μm)	D50V (μm)	D90V (μm)	(D90-D10) /D10	(D90-D10) /D50	Vickers hardness (HV)	Flexural strength (MPa)	Pore area fraction (%)	Oxygen content (ppm by weight)
Test Example 1	150	38.6	67.2	114.0	1.95	1.12	459.2	54.4	1.14	240
Test Example 2	150	38.6	67.2	114.0	1.95	1.12	471.1	71.4	0.05	180
Test Example 3	90	22.6	40.8	69.1	2.06	1.14	462.7	82.9	0.82	800
Test Example 4	63	24.1	39.7	63.3	1.63	0.99	426.7	78.1	1.48	3600
Test Example 5	150	36.5	58.3	92.6	1.54	0.96	754.0	115.8	1.80	180
Test Example 6	150	36.5	58.3	92.6	1.54	0.96	743.5	115.5	2.36	3200

[0085]

A comparison of Test Example 1 and Test Example 2 demonstrated that extending the holding time during hot pressing could reduce the pore area. It was also demonstrated that the Vickers hardness increased accordingly.

[0086]

A comparison of Test Examples 1, 3, and 4 demonstrated that the pore area could be reduced by appropriately adjusting the grain size distribution of the atomized powder. It was also demonstrated that the Vickers hardness increased accordingly.

[0087]

In particular, as indicated by the fact that Test Examples 1 and 4 had high pore area fractions, simply shifting the grain size distribution of the atomized powder toward finer grains does not necessarily result in a lower pore area fraction. In other words, it was demonstrated that the grain size distribution of the atomized powder needs to be appropriately adjusted.

[0088]

A comparison of Test Examples 5 and 6 demonstrated that extending the holding time during hot pressing could reduce the pore area. It was also demonstrated that the Vickers hardness increased accordingly.

[0089]

Further, similar effects were indicated in comparisons between Test Example 1 and Test Example 2, as well as between Test Example 5 and Test Example 6. This demonstrated that effects such as a reduction in pore area and an increase in the Vickers hardness could be achieved regardless of composition.

[0090]

The detailed embodiments of the present invention have been described. The above embodiments are merely an example of the present invention, and the present invention is not limited to the above embodiments. For example, a technical feature disclosed in one of the above embodiments may be applied to another embodiment. Furthermore, unless otherwise specified, for a particular method, it is possible to reorder a certain step relative to another step, and an additional step may be inserted between any two specific steps. The scope of the present invention is defined by the appended claims.

[0091]

Possibility of Contribution to the SDGs

According to one embodiment of the present disclosure, cracking during sputtering can be suppressed, which has the potential to improve product yield. Improved product yield leads to a stable supply of products and a reduction in waste of metal raw materials, which are limited resources. Therefore, an embodiment of the present disclosure has the potential to contribute to Goal 9, “Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation,” and Goal 12, “Ensure sustainable consumption and production patterns,” of the United Nations Sustainable Development Goals (SDGs).

What is claimed is:

[Claim 1]

A sputtering target comprising a binary alloy of Cu and Al, with the balance consisting of unavoidable impurities, wherein:

Cu and Al contents (at%) satisfy the following condition:

$0.48 \leq Al/(Cu+Al) \leq 0.70$, and

(1) When $0.48 \leq Al/(Cu+Al) < 0.55$,

a pore area fraction within a field of view observed by SEM is 2.0% or less, and

(2) When $0.55 \leq Al/(Cu+Al) \leq 0.70$,

the pore area fraction within the field of view observed by SEM is 1.0% or less.

[Claim 2]

The sputtering target according to claim 1, wherein

the Cu and Al contents (at%) satisfy the following condition:

$0.48 \leq Al/(Cu+Al) \leq 0.52$, and

the pore area fraction within the field of view when observed by SEM is 2.0% or less.

[Claim 3]

The sputtering target according to claim 1, wherein:

the Cu and Al contents (at%) satisfy the following condition:

$0.65 \leq Al/(Cu+Al) \leq 0.69$, and

the pore area fraction within the field of view when observed by SEM is 1.0% or less.

[Claim 4]

The sputtering target according to any one of claims 1 to 3, having flexural strength of 70 MPa or more.

[Claim 5]

The sputtering target according to any one of claims 1 to 4, wherein an oxygen content of the sputtering target is 1,000 ppm by mass or less.

[Claim 6]

A sputtering target comprising a binary alloy of Cu and Al, with the balance consisting of unavoidable impurities, wherein:

Cu and Al contents (at%) satisfy the following condition:

$0.48 \leq Al/(Cu+Al) \leq 0.70$,

an oxygen content of the sputtering target is 1,000 ppm by mass or less, and

flexural strength is 70 MPa or more.

[Claim 7]

The sputtering target according to claim 6, wherein:

the Cu and Al contents (at%) satisfy the following condition:

$0.65 \leq Al/(Cu+Al) \leq 0.69$.

[Claim 8]

The sputtering target according to claim 6, wherein:

the Cu and Al contents (at%) satisfy the following condition:

$0.48 \leq Al/(Cu+Al) \leq 0.52$,

and the flexural strength is 100 MPa or more.

[Claim 9]

A method for manufacturing the sputtering target according to any one of claims 1 to 8, wherein the method comprises:

・a step of providing an ingot;

・a step of producing powder from the ingot using a disk atomization method; and

・a step of producing a sintered body from the powder by hot pressing;

and

the method satisfies one or more of the following conditions:

・the step of producing the powder includes adjusting grain size distribution to satisfy the following conditions:

D50V 40.0–50.0 μm

D90V 65.0–100.0 μm

・the step of producing the sintered body includes hot pressing under the following conditions:

Temperature: 500–700°C

Pressure: 200–450 kgf/cm^2

Holding time: 9 hours or more.

[Claim 10]

The method for manufacturing the sputtering target according to claim 9, wherein

・the step of producing the powder includes adjusting the grain size distribution to satisfy the following condition:

((D90V - D10V) / D10V) ≥ 1.90.

[Claim 11]

The method for manufacturing the sputtering target according to claim 9 or 10, wherein:

・the step of producing the powder includes adjusting the grain size distribution to satisfy the following condition:

((D90V-D10V)/D50V) ≥ 1.12.

[Claim 12]

A film manufactured using the sputtering target according to any one of claims 1 to 8.