(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 January 2017 (12.01.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/006777 A1

(51) International Patent Classification:
C04B 35/5831 (2006.01) *C04B 35/645* (2006.01)
C01B 21/064 (2006.01) *C04B 35/63* (2006.01)
C04B 35/626 (2006.01)

(21) International Application Number:
PCT/JP2016/068743

(22) International Filing Date:
17 June 2016 (17.06.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2015-134262 3 July 2015 (03.07.2015) JP

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

WO 2017/006777 A1

(54) **Title**: CUBIC BORON NITRIDE SINTERED BODY, METHOD FOR PRODUCING CUBIC BORON NITRIDE SINTERED BODY, TOOL, AND CUTTING TOOL

(57) **Abstract**: The present invention provides a CBN sintered body excellent both in defect resistance and in abrasion resistance. The binder phase in the CBN sintered body contains at least titanium diboride, aluminum diboride, aluminum nitride, and MC_xN_y (M is a transition metal element of Group 4 to 6, $0 < x \leq 1$, $0 \leq y < 1$ and $0 < x + y \leq 1$, M may be composed of two kinds of metals A and B, and in the case, $M = A_iB_j$, and $i + j = 1$), wherein the content ratio of aluminum is 8 to 25% by mass relative to the total of the cubic boron nitride sintered body, the content ratio of MC_xN_y is 0.1 to 33% by mass relative to the total of the cubic boron nitride sintered body, in an X-ray diffractometry using a Cu-Kα line, I_{TiAlB2}/I_{CBN} is 0.60 to 1.20, the ratio of I_{AlN}/I_{CBN} is 0.20 to 0.40, and the half-value width of I_{TiAlB2} is 0.250° to 0.420°.

DESCRIPTION

Title of the Invention: CUBIC BORON NITRIDE SINTERED BODY, METHOD FOR PRODUCING CUBIC BORON NITRIDE SINTERED BODY, TOOL, AND CUTTING TOOL

Technical Field

[0001]

The present invention relates to a cubic boron nitride sintered body (hereinafter also referred to as a CBN sintered body), a method for producing a cubic boron nitride sintered body, a tool and a cutting tool.

Background Art

[0002]

A cubic boron nitride sintered body is known as a material excellent in both defect resistance and abrasion resistance.

[0003]

Accordingly, heretofore, a cubic boron nitride sintered body has been widely used for cutting tools for difficult-to-cut materials such as high-hardness steel, etc., and depending on the use thereof, various technique for further improving defect resistance and abrasion resistance have been disclosed (for example, PTLs 1 to 4).

[0004]

Of those, PTL 1 discloses a CBN sintered body containing a metal phase that contains alumina and at least one alloying element selected from the group consisting of nickel, cobalt, manganese, iron, vanadium and chromium, as a binder phase; PTL 2 discloses a CBN sintered body wherein the binder phase is composed of a first binder phase (a carbide, a nitride, a bride or a silicide of a transition element of Group 4 to 6, or a mixture or a reciprocal solid solution compound thereof) and a second binder phase (alumina, silicon, nickel, cobalt or iron, or an alloy or compound containing any of these); PTL 3 discloses a CBN sintered body containing a titanium carbonitride phase and a titanium diboride as a binder phase therein, and PTL 4 discloses a CBN sintered body wherein the binder phase contains a carbide solid solution containing titanium and a transition element of Group 4 to 6 (except titanium), and titanium carbide,

titanium diboride, aluminum nitride and inevitable impurities.

[0005]

However, with the recent tendency toward an increased cutting speed, high-speed cutting using a cutting tool formed according to the above-mentioned conventional technology has come to provide some problems that in any case, the cutting tool abrasion readily goes on and the cutting tool reaches its life within a relatively short period of time.

Citation List

Patent Literature

[0006]

PTL 1: JP-B 52-43846

PTL 2: JP-B 57-49621

PTL 3: Japanese Patent 5087748

PTL 4: Japanese Patent 3297535

Summary of Invention

Technical Problem

[0007]

The phenomenon that, in high-speed cutting, the abrasion of already-existing CBN sintered bodies is promoted is, according to the investigations made by the present inventors, presumed to be caused by the following factors.

[0008]

The phenomenon that the abrasion of the CBN sintered body of PTL 1 is promoted in high-speed cutting is presumed to be caused by the binder phase containing elements, such as Ni, Co, Fe, Mn, V and the like, which are rich in reactivity with carbon C and iron Fe contained in the material to be cut. Specifically, it is presumed that, owing to the cutting heat generated in high-speed cutting, the cutting edge may be heated to a high temperature, and the binder phase containing elements such as Ni, Co, Fe, Mn, V and the like rich in reactivity with carbon C and iron Fe contained in the material being cut would react with the material being cut to readily promote the abrasion.

[0009]

The phenomenon that the abrasion of the CBN sintered body of PTL 2 is

promoted in high-speed cutting is presumed to be caused by the binder phase formed of ceramics (titanium carbide, etc.) that are poorly reactive with CBN particles. In general, it is known that, in the CBN sintered body where the binder phase is formed of ceramics that are poorly reactive with CBN particles, the sintered body could hardly be densified and the force thereof to hold CBN particles is weak. Under a high-speed cutting condition where such CBN particles are exposed to a high-temperature environment, it is presumed that the abrasion owing to dropping off of the CBN particles would be promoted more.

[0010]

The phenomenon that the abrasion of the CBN sintered body of PTL 3 is promoted in high-speed cutting is presumed to be because the CBN particles and the binder phase could not be sufficiently reacted with each other in the sintering step and therefore the binding force between the CBN particles and the binder phase would be insufficient. In PTL 3, the amount of titanium diboride to be formed in the sintering step is reduced to try to improve the defect resistance but, as a result, there occurs a defect that the abrasion resistance lowers.

[0011]

The phenomenon that the abrasion of the CBN sintered body of PTL 4 is promoted in high-speed cutting is presumed to be because the main component of the binder phase contains a component (titanium carbide, etc.) poorly reactive with CBN particles, the amount of titanium diboride and aluminum nitride to be formed in the sintering step is insufficient and the crystallinity thereof is low, and therefore the force to hold CBN particles would be weak.

[0012]

An object of the present invention is to provide a technique capable of solving the problem that the abrasion of already-existing CBN sintered bodies is promoted in high-speed cutting, and capable of preventing progression of abrasion even under a condition of high-speed cutting and therefore capable of maintaining excellent defect resistance and abrasion resistance of a cubic boron nitride sintered body.

Technical Solution

[0013]

For solving the above-mentioned problems, the present inventors have made assiduous studies and, as a result, have found that when the component of

the binder phase is made to be a specific one and the content ratio of the product to be formed in the sintering step for the CBN sintered body and the crystallite size and the crystallinity thereof each are made to be in a specific condition, the holding force of the CBN particles can be greatly improved and the abrasion resistance of the CBN sintered body under a high-speed cutting condition can be thereby greatly improved. Specifically, the present inventors have found that a CBN sintered body whose peak intensity ratio of diffraction lines in X-ray diffractometry thereof shows a specific value can have extremely excellent abrasion resistance and defect resistance in continuous and intermittent cutting. In general, a crystallite means a maximum aggregate that can be considered as a single crystal, and the size of the crystallite is referred to as a crystallite size. The method for measuring the crystallite size includes a method of confirming the lattice fringe of a crystallite using an electronic microscope, and a method of calculating the crystallite size from the diffraction pattern in X-ray diffractometry and according to the following Scherrer formula.

Scherrer Formula:

$$\text{Crystallite Diameter } D = K\cdot\lambda/(\beta\cdot\cos\theta)$$

In this description, the crystallite size was calculated according to the latter method using an X-ray diffractometer. In the above-mentioned formula, K is a Scherrer constant, and $K = 0.9$. λ is a wavelength of the X-ray tube used, β is a half-value width, and θ is a diffraction angle.

[0014]

Based on the above-mentioned findings, the present invention is as follows.

[1] A cubic boron nitride sintered body which contains cubic boron nitride in an amount of 10 to 55% by volume and in which the voids in the cubic boron nitride are filled with a binder phase containing an aluminum compound and a titanium compound, wherein the binder phase contains at least titanium diboride, aluminum diboride, aluminum nitride, and MC_xN_y (M is a transition metal element of Group 4 to 6, $0 < x \leq 1$, $0 \leq y \leq 1$ and $0 < x + y \leq 1$, M may be composed of two kinds of metals A and B, and in the case, $M = A_iB_j$, and $i + j = 1$), the content ratio of aluminum that constitutes the aluminum compound is 8 to 25% by mass relative to the total of the cubic boron nitride sintered body, the content ratio of MC_xN_y is 0.1 to 33% by mass relative to the total of the cubic boron nitride sintered body, in an X-ray diffractometry using a Cu-Kα line, the ratio of the

peak intensity I_{TiAlB2} of the diffraction peak assigned to the (101) plane of titanium diboride and aluminum diboride to the peak intensity I_{CBN} of the diffraction peak assigned to the (111) plane of cubic boron nitride (I_{TiAlB2}/I_{CBN}) is 0.60 to 1.20, the ratio of the peak intensity I_{AlN} of the diffraction peak assigned to the (200) plane of aluminum nitride to the above-mentioned peak intensity I_{CBN} (I_{AlN}/I_{CBN}) is 0.20 to 0.40, and the half-value width of the diffraction peak assigned to the (101) plane of titanium diboride and aluminum diboride is 0.250° to 0.420°.

[2] The cubic boron nitride sintered body according to [1], wherein (I_{TiAlB2}/I_{CBN}) is 1.00 to 1.11 and (I_{AlN}/I_{CBN}) is 0.33 to 0.38.

[3] The cubic boron nitride sintered body according to [1] or [2], wherein the binder phase contains aluminum oxide having a number-average particle diameter of 1μm or less.

4] The cubic boron nitride sintered body according to any one of [1] to [3], wherein at least one M in MC_xN_y is tungsten.

[5] The cubic boron nitride sintered body according to any one of [1] to [4], wherein M in MC_xN_y is titanium and tungsten.

[6] The cubic boron nitride sintered body according to any one of [1] to [5], wherein the binder phase contains a reciprocal solid solution.

[7] A method for producing a cubic boron nitride sintered body as stated in any one of [1] to [6], which includes mixing raw materials containing cubic boron nitride, at least one of aluminum and an aluminum compound, a titanium compound and MC_xN_y (M is a transition metal element of Group 4 to 6, $0 < x \leq 1$, $0 \leq y \leq 1$ and $0 < x + y \leq 1$, M may be composed of two kinds of metals A and B, and in the case, $M = A_iB_j$, and $i + j = 1$) and sintering the resultant mixture under a pressure of 3 GPa or more and at 1,000 to 1,350°C.

[8] The method for producing a cubic boron nitride sintered body according to [7], wherein cubic boron nitride particles having a volume-average particle diameter of 0.3 to 10 μm are used as the cubic boron nitride.

[9] A tool containing a cubic boron nitride sintered body as stated in any one of [1] to [6], as a constituent material thereof.

[10] A cutting tool containing a cubic boron nitride sintered body as stated in any one of [1] to [6], as a constituent material thereof.

Advantageous Effects of Invention

[0015]

According to the present invention, there is provided a CBN sintered body capable of preventing progression of abrasion even under a high-speed cutting condition and capable of maintaining excellent defect resistance and abrasion resistance of the CBN sintered body.

Brief Description of Drawings

[0016]

Fig. 1 is a graph showing the result of X-ray diffractometry in Example 2.

Fig. 2 is a graph showing the result of X-ray diffractometry in Comparative Example 3.

Fig. 3 is a tissue-enlarged photograph (SEM image) in Example 2.

Description of Embodiments

[0017]

Preferred embodiments of the present invention are described below.

[0018]

<Cubic Boron Nitride Sintered Body>

The CBN sintered body of this embodiment is a sintered body which contains CBN particles in an amount of 10 to 55% by volume and in which voids between the CBN particles are filled with a binder phase containing an aluminum compound and a titanium compound, wherein the binder phase contains at least titanium diboride, aluminum diboride, aluminum nitride, and MC_xN_y (M is a transition metal element of Group 4 to 6, $0 < x \leq 1$, $0 \leq y \leq 1$ and $0 < x + y \leq 1$, M may be composed of two kinds of metals A and B, and in the case, $M = A_iB_j$, and $i + j = 1$), the content ratio of aluminum that constitutes the aluminum compound is 8 to 25% by mass relative to the total of the cubic boron nitride sintered body, the content ratio of MC_xN_y is 0.1 to 33% by mass relative to the total of the cubic boron nitride sintered body, and, in an X-ray diffractometry using a Cu-Kα line, the ratio of the peak intensity I_{TiAlB2} of the diffraction peak assigned to the (101) plane of titanium diboride and aluminum diboride to the peak intensity I_{CBN} of the diffraction peak assigned to the (111) plane of cubic boron nitride (I_{TiAlB2}/I_{CBN}) is 0.60 to 1.20; the ratio of the peak intensity I_{AlN} of the diffraction peak assigned to the (200) plane of aluminum nitride to the above-mentioned peak intensity I_{CBN} (I_{AlN}/I_{CBN}) is 0.20 to 0.40; and the half-value width of the diffraction peak assigned to the (101) plane of titanium diboride and aluminum diboride is 0.250° to 0.420°.

[0019]

The components constituting the CBN sintered body are described below.

[0020]

<CBN particles contained in CBN sintered body>

CBN particles are of a substance that is a second hardest substance behind synthetic diamond, and have both high heat resistance and chemical abrasion resistance. A CBN sintered body prepared by sintering CBN particles is extremely strong to high-temperature deformation and abrasion, and it is known that the physical data thereof are generally higher by 10 times than those of ceramic materials whose characteristics are most similar to those of the CBN sintered body. However, when the proportion of the CBN particles contained in the CBN sintered body is more than 55% by volume of the sintered body, the possibility that CBN particles aggregate increases and therefore the abrasion of the CBN sintered body may be promoted owing to dropping off of the CBN particles. On the other hand, when the proportion is less than 10% by volume, the CBN sintered body could not sufficiently exhibit the excellent characteristics thereof such as high hardness, high oxidation resistance and high thermal conductivity and, in addition, the abrasion is liable to progress easily and defects are liable to form easily. Accordingly, the content ratio of the CBN particles contained in the CBN sintered body of this embodiment is 10 to 55% by volume, preferably 20 to 45% by volume, more preferably 30 to 45% by volume. The method for measuring the content ratio of the CBN particles contained in a CBN sintered body is as described in the section of Examples.

[0021]

The number-average particle diameter of the CBN particles contained in the CBN sintered body is preferably 0.3 to 3.0 μm, more preferably 0.3 to 1.0 μm, even more preferably 0.4 to 0.9 μm, most preferably 0.7 to 0.8 μm. The method for measuring the number-average particle diameter of the CBN particles contained in a CBN sintered body is as described in the section of Examples.

[0022]

<Titanium diboride and aluminum diboride>

Titanium diboride and aluminum diboride are indispensable constituent components for the binder phase, and have characteristics of high hardness, high oxidation resistance and high thermal conductivity. These compounds are reaction compounds that are formed in the sintering step, and in the CBN

sintered body, these compounds act to enhance the holding force of the CBN particles and to prevent dropping off of the particles in cutting.

[0023]

The present inventors have found that, when the proportion of titanium diboride and aluminum diboride to be formed in the sintering step, and the crystallite size and the crystallinity of titanium diboride and aluminum diboride each are defined to fall within a specific rang, concretely, when in an X-ray diffractometry using a Cu-Kα line, the ratio of the peak intensity I_{TiAlB2} of the diffraction peak assigned to the (101) plane of titanium diboride and aluminum diboride to the peak intensity I_{CBN} of the diffraction peak assigned to the (111) plane of cubic boron nitride (I_{TiAlB2}/I_{CBN}) is defined to be 0.60 to 1.20, and the half-value width (FWHM) of the diffraction peak assigned to the (101) plane of titanium diboride and aluminum diboride is to be 0.250° to 0.420°, the holding force of the CBN particles can be increased.

[0024]

The X-ray diffraction patterns of titanium diboride and aluminum diboride overlap, and therefore, it is extremely difficult to differentiate these compounds. Consequently, in the present invention, the peak intensity of the peaks containing the both is used. The peak intensity obtainable from X-ray diffractometry is strongly influenced by not only the formation amount of the crystal phase but also the crystallinity and the orientation of the particles especially in the case of a sintered body, and therefore, the peak intensity ratio as referred to herein does not simply reflect the compositional amount ratio in the sintered body.

[0025]

In the case where the formation amount of titanium diboride and aluminum diboride are excessive relative to the CBN particles, both abrasion resistance and defect resistance may lower. Further, titanium diboride and aluminum diboride cause coarse growing of crystal particles during the process of producing the particles, which may causelowering of defect resistance.

[0026]

When (I_{TiAlB2}/I_{CBN}) is defined to be less than 1.20, lowering of defect resistance can be evaded. When (I_{TiAlB2}/I_{CBN}) is defined to be 0.60 or more, lowering of abrasion resistance can be evaded. From the viewpoint of maintaining excellent defect resistance and abrasion resistance of the CBN

sintered body, (I_{TiAlB2}/I_{CBN}) is preferably within a range of 0.65 to 1.155, more preferably within a range of 0.70 to 1.11, even more preferably within a range of 1.00 to 1.11.

[0027]

Titanium diboride and aluminum diboride are hexagonal compounds belonging to a space group P6/mmm, and therefore the mechanical and chemical characteristics have great anisotropy. When these compounds grow to coarse particles, in particular, the mechanical characteristics in the direction vertical to the C-axis significantly worsen. As a result, it is necessary that these compounds form in the vicinity of the CBN particles and are additionally fine particles that are fine in a crystallite size. When the half-value width (FWHM) of the diffraction peak assigned to the (101) plane of titanium diboride and aluminum diboride is specifically defined to fall within a range of 0.250° to 0.420°, these requirements can be satisfied.

[0028]

In the case where the half-value width (FWHM) of the diffraction peak is less than 0.250°, the formation amount of titanium diboride and aluminum diboride may increase and the crystals thereof may coarsely grow to lower defect resistance, and when more than 0.420°, the crystallinity of the crystals may lower and the desired abrasion resistance could not be realized. FWHM is preferably 0.300 to 0.400°, more preferably 0.320 to 0.390°.

[0029]

<Aluminum nitride>

Aluminum nitride is an indispensable constituent component for the binder phase, and has high thermal conductivity. The compound is also a reaction product to be formed in the sintering step, and in the CBN sintered body, the compound enhances the holding force of the CBN particles and acts to prevent the particles from dropping off in cutting.

[0030]

The present inventors have found that, when the ratio of aluminum nitride formed in the sintering step to the CBN particles, and the crystalline size of aluminum nitride and the crystallinity thereof each are controlled to fall within a specific range, concretely, when in X-ray diffractometry using a Cu-Kα ray, the ratio of the peak intensity I_{AlN} of the diffraction peak assigned to the (200) plane of aluminum nitride to the above-mentioned peak intensity I_{CBN} (I_{AlN}/I_{CBN}) is

controlled to fall within a range of 0.20 to 0.40, the holding force of the CBN particles can be increased.

[0031]

In the case where the formation amount of aluminum nitride is excessive relative to the CBN particles, both the abrasion resistance and the defect resistance lower. Further, aluminum nitride particles may undergo coarse growth and crystalline growth in the production step, which may cause lowering of defect resistance.

[0032]

In the range where (I_{AlN}/I_{CBN}) is more than 0.40, AlN particles may excessively form and grow to lower defect resistance. On the other hand, in the range where the ratio is less than 0.20, the holding force and the thermal conductivity of the CBN particles may lower, thereby lowering abrasion resistance.

[0033]

From the viewpoint of improving the abrasion resistance of the CBN sintered body, the combination of the "value (I_{TiAlB2}/I_{CBN})" and the "value (I_{AlN}/I_{CBN})" is preferably such that the "value (I_{TiAlB2}/I_{CBN})" falls within a range of 0.70 to 1.11 and the "value (I_{AlN}/I_{CBN})" falls within a range of 0.30 to 0.38, more preferably, the "value (I_{TiAlB2}/I_{CBN})" falls within a range of 1.00 to 1.11 and the "value (I_{AlN}/I_{CBN})" falls within a range of 0.33 to 0.38.

[0034]

<MC_xN_y>

MC_xN_y (M is a transition metal element of Group 4 to 6, $0 < x \leq 1$, $0 \leq y \leq 1$ and $0 < x + y \leq 1$, M may be composed of two kinds of metals A and B, and in the case, $M = A_iB_j$, and $i + j = 1$) is an indispensable constituent component for the binder phase. These compounds form a carbide solid solution or a carbonitride solid solution in the CBN sintered body to thereby strengthen the binder phase and enhance the abrasion resistance and the toughness of the CBN sintered body. M is preferably Ti, Zr, Hf, V, Nb, Ta, Cr, Mo or W, and for enhancing abrasion resistance and defect resistance, M is preferably Ti or W. Here, MC_xN_y means at least any of TiC_x ($0 < x \leq 1$) ; ZrC_x($0 < x \leq 1$) ; HfC_x($0 < x \leq 1$) ; VC_x ($0 < x \leq 1$) such as V_4C_3, V_8C_7, etc.; NbC_x ($0 < x \leq 1$) such as Nb_2C, Nb_6C_5, etc.; TaC_x ($0 < x \leq 1$) such as Ta_2C, etc.; CrC_x ($0 < x \leq 1$) such as Cr_2C, Cr_3C_2, $Cr_{23}C_6$, Cr_7C_3, etc.; MoC_x ($0 < x \leq 1$) such as Mo_2C, etc.; WC_x ($0 < x \leq 1$) such as W_2C, etc.; TiC_xN_y ($x+y=1$) ; ZrC_xN_y

(x+y=1) ; HfC_xN_y (x+y=1) ; VC_xN_y (x+y=1) ; NbC_xN_y (x+y=1) ; and TaC_xN_y (x+y=1). Among these, in particular, one or more components selected from TiC_x ($0 < x \leq 1$), TiC_xN_y (x+y=1) and WC are preferably contained.

[0035]

The present inventors have found that, when the content ratio of MC_xN_y is controlled to fall within a range of 0.1 to 33% by mass relative to the total of the cubic boron nitride sintered body, both defect resistance and abrasion resistance can be maintained favorably.

[0036]

In the case where the content ratio of MC_xN_y is more than 33% by mass relative to the total of the cubic boron nitride sintered body, defect resistance may degrade and in addition, since the reaction between the CBN particles and the binder phase could hardly proceed so that the reaction phase for holding the CBN particles could not almost be formed, abrasion resistance may also lower. On the other hand, in the range of less than 0.1% by mass (lower limit), the carbide amount to strengthen the binder phase may greatly lower and therefore abrasion resistance and defect resistance degrade. The content ratio of MC_xN_y is preferably 0.1 to 30% by mass, more preferably 0.5 to 28% by mass, most preferably 2 to 25% by mass. The method for measuring the content ratio of MC_xN_y is as described in the section of Examples.

[0037]

<Aluminum compound>

The aluminum compound is an indispensable constituent component for the binder phase. As the aluminum compound, aluminum oxide, aluminum carbide and the like may also be contained in addition to the above-mentioned aluminum diboride and aluminum nitride.

[0038]

The present inventors have found that when the content ratio of aluminum that constitutes the aluminum compound is controlled to fall within a range of 8 to 25% by mass relative to the total of the cubic boron nitride sintered body, the holding force of the CBN particles can be enhanced.

[0039]

In a condition where the content ratio of aluminum is more than 25% by mass relative to the total of the cubic boron nitride sintered body and where the formation amount of the aluminum compound is excessive, the defect resistance

worsens; but where the content ratio is lower than 8% by mass, the abrasion resistance lowers. The content ratio of aluminum relative to the total of the cubic boron nitride sintered body is more preferably 8 to 23% by mass, even more preferably 9 to 20% by mass, further more preferably 11 to 16% by mass. The method for measuring the content ratio of aluminum relative to the total of the cubic boron nitride sintered body is as described in the section of Examples.

[0040]

Aluminum oxide in the binder phase is a dispersion-forming phase in the binder phase and contributes toward improving the toughness of the sintered body. In addition, aluminum oxide in the binder phase is excellent in chemical reaction resistance and is therefore effective for exhibiting excellent abrasion resistance at a high temperature in cutting; however, when the number-average particle diameter thereof is 1 μm or more, the compound may be a starting point for crack progression in cutting. Accordingly, the number-average particle diameter of aluminum oxide in the binder phase is 1 μm or less, preferably 0.10 to 0.70 μm, more preferably 0.15 to 0.50 μm, further more preferably 0.18 to 0.30 μm, and most preferably 0.18 to 0.21 μm. The method for measuring the number-average particle diameter of aluminum oxide in the binder phase is as described in the section of Examples.

[0041]

<Titanium Compound>

The titanium compound is an indispensable constituent component for the binder phase. As the titanium compound, TiB_x ($0 < x < 2$) such as Ti_3B_4, Ti_2B_5, TiN_x ($0 < x \leq 1$), Ti_2N or the like may be contained in addition to the above-mentioned titanium diboride, TiC_x ($0 < x \leq 1$) and TiC_xN_y ($x+y=1$).

[0042]

Among the above-mentioned titanium compound, titanium nitride and titanium carbide are effective for enhancing the abrasion resistance and the defect resistance of cutting tools. In particular, titanium nitride is excellent in abrasion resistance, defect resistance, reaction resistance with materials to be cut, oxidation resistance in a high-temperature environment, sinterability, and reactivity with CBN. On the other hand, titanium carbide is excellent in abrasion resistance but is defective in point of defect resistance and sinterability. The content ratio of titanium to constitute the titanium compound is preferably 30 to 50% by mass relative to the total of the cubic boron nitride sintered body. In

such a condition where the content ratio of the titanium compound is more than 50% by mass relative to the total of the cubic boron nitride sintered body and the formation amount of the titanium compound is excessive, the defect resistance lowers. On the other hand, when it is less than 30% by mass, the abrasion resistance lowers. Thus, both cases are unfavorable. The content ratio of titanium relative to the total of the cubic boron nitride sintered body is more preferably 30 to 48% by mass, even more preferably 33 to 48% by mass, still more preferably 35 to 46% by mass, most preferably 40 to 46% by mass. The method for measuring the content ratio of titanium relative to the total of the cubic boron nitride sintered body is the same as the method for measuring the content ratio of aluminum.

[0043]

<Other Components in Binder Phase>

In addition to the above-mentioned components, the binder phase may contain any of borides of transition metal element of Group 4 to 6 (ZrB_2, ZrB_{12}, HfB_2, HfB, HfB_{12}, VB_2, V_3B_4, V_3B_{12}, VB, V_5B_6, V_2B_2, NbB_2, Nb_3B_2, NbB, TaB_2, Ta_2B, Ta_3B_2, TaB, Ta_3B_4, CrB, CrB_4, Cr_2B, Cr_2B_3, Cr_5B_3, CrB_2, MoB, Mo_2B_5, MoB_4, Mo_2B, MoB_2, WB, W_2B, WB_4), nitrides of transition metal compounds of Group 4 to 6 (ZrN_x ($0 < x \leq 1$), Hf_3N_2, HfN_x ($0 < x \leq 1$), Hf_4N_3, VN_x ($0 < x \leq 1$), V_2N, NbN, Nb_4N_3, Nb_2N, TaN_x ($0 < x \leq 1$), Ta_3N_5, Ta_4N, Ta_2N, Cr_2N, CrN_x ($0 < x \leq 1$), WN, W_2N), inevitable impurities that may be mixed in a production process, and reciprocal solution solids of these compounds.

[0044]

<Method for Producing CBN Sintered Body>

The CBN sintered body of this embodiment may be produced by mixing raw materials containing cubic boron nitride, at least one of aluminum and an aluminum compound, a titanium compound, and MC_xN_y (M is a transition metal element of Group 4 to 6, $0 < x \leq 1$, $0 \leq y \leq 1$ and $0 < x + y \leq 1$, M may be composed of two kinds of metals A and B, and in the case, $M = A_iB_j$, and $i + j = 1$) in a planetary ball mill formed of a cemented carbide or the like, and sintering the resultant mixture under a pressure of 3 GPa or more at 1,000 to 1,350°C. After mixing, if desired, the mixture may be heat-treated. The raw materials may further contain any other materials within a range where the sintered body after sintering can satisfy the conditions for constituting the present invention.

[0045]

The cubic boron nitride to be used as the raw material is preferably CBN particles prepared by finely grinding commercially-available CBN particles and then granulating them to have a volume-average particle diameter of 0.3 to 10 μm. When such CBN particles having a volume-average particle diameter of 10 μm or less are used, the number of the particles in the sintered body could be sufficiently secured to enhance abrasion resistance and defect resistance. In turn, when those having a volume-average particle diameter of 0.3 μm or more are used, any excessive reaction with a binder phase in the sintering process can be prevented, and therefore, the dispersion of particles can be improved to enhance abrasion resistance and defect resistance. For these reasons, the volume-average particle diameter of the CBN particles to be the raw material is preferably 0.3 to 10 μm, more preferably 0.3 to 3 μm. As the other raw materials, at least those to react with the CBN particles during sintering to form titanium diboride, aluminum diboride and aluminum nitride, and MC_xN_y (M is a transition metal element of Group 4 to 6, $0 < x \leq 1$, $0 \leq y \leq 1$ and $0 < x + y \leq 1$, M may be composed of two kinds of metals A and B, and in the case, $M = A_iB_j$, and $i + j = 1$) are used. As these "other raw materials", TiN, $TiAl_3$, Ti_2AlN, TiC, Al, WC and Ni are preferably used, for which commercially-available ones having a volume-average particle diameter of 1 μm or so may be used.

[0046]

The heat treatment in the sintered body production process is preferably carried out in vacuum or in a non-oxidizing atmosphere such as N_2, Ar or the like. For obtaining the products of the present invention, preferably, the pressure is 3.0 GPa or more and the temperature is 1,000°C or higher. The sintering conditions (temperature, pressure, atmosphere) must fall within a range where CBN is stable. The sintering device may be a general-purpose high-temperature high-pressure device (for example, a belt-type high-temperature high-pressure device). The upper limit of the pressure is not a factor that may have any influence on sintering, and may be suitably defined depending on the limitation on the production equipment. During sintering, a stable region for CBN must be secured. When the sintering temperature is lower than 1,000°C, much time may be taken for sintering and, in addition, the reaction phase during sintering may be insufficient to lower abrasion resistance. When the sintering temperature is higher than 1,350°C, the reaction between the binder phase and CBN may proceed too much, and if so, the reaction phase could not be controlled to be in a

desired formation state to lower defect resistance. From the viewpoint of maintaining excellent defect resistance and abrasion resistance of the CBN sintered body, the sintering temperature is 1,000 to 1,350°C, preferably 1,100 to 1,350°C, more preferably 1,150 to 1,350°C, even more preferably 1,200 to 1,350°C.

Examples

[0047]

Hereinunder the present invention is described more specifically with reference to Examples, but the present invention is not limited to these Examples.

[0048]

CBN sintered bodies of Examples 1 to 9 and Comparative Examples 1 to 2 were produced according to the formulations and at the temperatures shown in Table 1.

[0049]

Table 1

No.		Composition and Formulation Ratio (mass%)								Sintering Temperature (°C)
		CBN	TiN	$TiAl_3$	Ti_2AlN	TiC	Al	WC	Ni	
Example	1	26	57	-	-	-	15	2	-	1200
	2	35	50		-	-	13	2	-	1200
	3	27	50	20	-	-	-	3	-	1300
	4	35	50	13	-	-	-	2	-	1300
	5	35	-	-	63	-	-	2	-	1300
	6	35	43	-	-	10	10	2	-	1300
	7	35	-	-	45	18	-	2	-	1300
	8	45	41	-	-	-	11	3	-	1350
	9	45	41	-	-	-	8	3	3	1350
Comparative Example	1	26	57	-	-	-	15	2	-	1450
	2	35	50	-	-	-	13	2	-	1450
	3 (commercial product)	-	-	-	-	-	-	-	-	-
	4 (commercial product)	-	-	-	-	-	-	-	-	-
	5 (commercial product)	-	-	-	-	-	-	-	-	-

[0050]

<Examples 1 to 9>

The raw materials described in Table 1 were used, and metered according to each formulation as shown in Table 1. A solvent was added thereto, and using cemented carbide ball media, these were mixed for 2 hours to 20 hours according to a wet-process planetary ball mill process to prepare a uniform slurry. Acetone was used as the solvent for mixing. The mixed slurry was fully dried, and the resultant powder was layered on a cemented carbide-made support plate, inserted into a sintering device, and sintered for 1 hour in a non-oxidizing atmosphere

under a pressure of 3 GPa at the sintering temperature shown in Table 1 to give a sintered body. The upper and lower surfaces of the CBN sintered body were ground using a diamond grinding stone.

Regarding the above-mentioned raw materials, CBN is one prepared by finely grinding CBN particles manufactured by Showa Denko KK (trade name; BN) followed by steps of centrifugation and precipitating classification for granulation to give particles having a controlled volume-average particle diameter falling within a range of 0.3 to 3.0 μm. The other raw materials shown in Table 1 (TiN, $TiAl_3$, Ti_2AlN, TiC, Al, WC, Ni) are raw materials for forming the binder phase, for which commercial products having a volume-average particle diameter of about 1 μm or so were used. The particle size distribution of the raw material powder was measured using a particle sizer Microtrack HRA (manufactured by Nikkiso Co., Ltd.), and the volume-average particle diameter was determined also using the same device.

[0051]

<Comparative Examples 1 and 2>

The CBN sintered bodies of Comparative Examples 1 and 2 were produced according to the same method as in Examples 1 to 9 except for varying the raw material formulation ratio and the sintering temperature, thereby preparing samples of Comparative Examples 1 and 2.

[0052]

<Comparative Examples 3, 4 and 5>

As Comparative Examples 3 to 5, commercially-available, CBN sintered body-made tools were purchased, and used for comparison under the same condition as in Examples.

[0053]

<Evaluation of CBN Sintered Body>

Next, the resultant sintered body was subjected to X-ray diffractometry (XRD) with a Cu-Kα ray under the condition of an output of 40 kV and 40 mA, a sampling width of 0.0167°, a scan speed of 0.4178°/s, and a 2θ measurement range of 10 to 80°C, using a powdery X-ray diffractometer manufactured by PANalytical B.V., thereby providing an XRD pattern. The resultant XRD pattern was processed for background deletion and removal of two Cu-Kα lines.

[0054]

Fig. 1 shows an XRD pattern of "Example 2" as a typical case of an XRD

pattern in Examples. In Fig. 1, the peak at around 2θ of 42.4° is a diffraction peak assigned to the (200) plane of titanium nitride, the peak at around 43.2° is a diffraction peak assigned to the (111) plane of cubic boron nitride, and the peak at around 44.3° is a diffraction peak assigned to the (101) plane of titanium diboride and aluminum diboride. The width between the two arrows shown in Fig. 1 is a half-value width (FWHM) of the diffraction peak assigned to the (101) plane of titanium diboride and aluminum diboride. The diffraction peak assigned to the (200) plane of aluminum nitride is detected on the lower angle side than 41°, and is therefore not shown in Fig. 1. Fig. 2 shows an XRD pattern of "Comparative Example 3". In Fig. 2, the peak at around 2θ of 41.8° is a diffraction peak assigned to the (200) plane of titanium carbide, and the peak at around 43.2° is a diffraction peak assigned to the (111) plane of cubic boron nitride.

[0055]

Table 2 shows calculated results of the intensity ratio of each peak confirmed in the XRD pattern, specifically, the ratio of the peak intensity I_{TiAlB2} of the diffraction peak assigned to the (101) plane of titanium diboride and aluminum diboride to the peak intensity I_{CBN} of the diffraction peak assigned to the (111) plane of cubic boron nitride (I_{TiAlB2}/I_{CBN}), and the ratio of the peak intensity I_{AlN} of the diffraction peak assigned to the (200) plane of aluminum nitride to the above-mentioned peak intensity I_{CBN} (I_{AlN}/I_{CBN}). In the case where titanium diboride and aluminum diboride, or aluminum nitride was not formed or was formed little in the sintered body composition, the peak intensity ratio and the half-value width were not very reliable and were therefore omitted.

[0056]

Table 2

	No.	Peak Intensity Ratio ITiAlB$_2$/ICBN	Peak Intensity Ratio IAlN/ICBN	FWHM(°) at TiB$_2$(101)
Example	1	0.64	0.32	0.374
	2	0.73	0.33	0.364
	3	0.96	0.32	0.366
	4	1.10	0.34	0.355
	5	1.07	0.37	0.349
	6	0.80	0.34	0.376
	7	1.07	0.38	0.351
	8	0.76	0.26	0.349
	9	0.80	0.23	0.349
Comparative Example	1	1.73	0.70	0.357
	2	1.18	0.45	0.340
	3	0.07	-	-
	4	0.53	0.26	0.431
	5	0.32	0.13	-

[0057]

The content ratio of CBN particles contained in the CBN sintered body of the present invention means the ratio by volume of the CBN particles contained in the CBN sintered body, and is calculated as follows. The produced CBN sintered body is mirror-polished, and using a scanning electron microscope (referred to as SEM) (in this Example, "Model Number S-5500, manufactured by Hitachi-High Technologies Corporation) at a magnification of 3,500 to 10,000 times, a reflection electron microscopic image thereof is taken. In the taken image, a black part, a white part and a gray part are confirmed, and among these, the black part corresponds to CBN particles. Using an image processing software application, the total area occupied by the black part (CBN particles) is calculated and the results are shown in Table 3. In Table 3, the areal ratio of the black part to the entire SEM image is expressed as % by volume.

[0058]

Table 3

	No.	Cubic Boron Nitride Sintered Body		
		CBN Content Ratio (% by volume)	Binder Phase	
			Constituent Compounds	Content Ratio (% by volume)
Example	1	29	TiN, TiB_2, AlB_2, AlN, Al_2O_3, WC	71
	2	39	TiN, TiB_2, AlB_2, AlN, Al_2O_3, WC	61
	3	28	TiN, TiB_2, AlB_2, AlN, Al_2O_3, WC	72
	4	40	TiN, TiB_2, AlB_2, AlN, Al_2O_3, WC	60
	5	38	TiN, TiB_2, AlB_2, AlN, Al_2O_3, WC	62
	6	39	TiC, TiCN, TiN, TiB_2, AlB_2, AlN, Al_2O_3, WC	61
	7	38	TiC, TiCN, TiN, TiB_2, AlB_2, AlN, Al_2O_3, WC	62
	8	49	TiN, TiB_2, AlB_2, AlN, Al_2O_3, WC	51
	9	48	TiN, TiB_2, AlB_2, AlN, Al_2O_3, (TiW)C, Ni	52
Comparative Example	1	28	TiN, TiB_2, AlB_2, AlN, Al_2O_3, WC	72
	2	43	TiN, TiB_2, AlB_2, AlN, Al_2O_3, WC	57
	3	48	TiC, TiB_2, AlB_2, Al_2O_3, WC	52
	4	52	TiN, TiB_2, AlB_2, AlN, Al_2O_3, WC	48
	5	65	TiC, TiCN, TiN, TiB_2, AlB_2, AlN, Al_2O_3, WC	35

[0059]

The number-average particle diameter of each substance in the sintered body of the present invention was calculated as follows. The produced CBN sintered body is mirror-polished, and using SEM at a magnification of 10,000 to 30,000 times, a reflection electron microscopic image thereof was taken. In the taken image, a black part, a white part and a gray part are confirmed. At that time, each element component was specified using the attached energy dispersion-type X-ray spectrometer (EDX). The black part was CBN, the white part was TiN or TiC or AlN, and the gray part was Al_2O_3. On the SEM image, the major axis diameter of the Al_2O_3 particles was measured in at least 100 points of the gray part, and the total value was divided by 100 to obtain a number-average particle diameter thereof. The data are shown in Table 4. The number-average particle diameter of the CBN particles is calculated in the same manner. Fig. 3 shows an example of the SEM image at that time.

[0060]

Table 4

	No.	Al_2O_3 Particle Diameter (μm)	CBN Particle Diameter (μm)
Example	1	0.19	0.57
	2	0.20	0.73
	3	0.19	0.63
	4	0.19	0.76
	5	0.21	0.71
	6	0.23	0.70
	7	0.20	0.66
	8	0.26	0.63
	9	0.26	0.61
Comparative Example	1	0.31	0.74
	2	0.24	0.69
	3	0.19	0.87
	4	0.20	0.96
	5	0.38	2.32

[0061]

Table 5 shows the content ratio of MC_xN_y (M is a transition metal element of Group 4 to 6, $0 < x \leq 1$, $0 \leq y \leq 1$ and $0 < x + y \leq 1$, M may be composed of two kinds of metals A and B, and in the case, $M = A_iB_j$, and $i + j = 1$) relative to the total of the cubic boron nitride sintered body, the content ratio of aluminum relative to the total of the cubic boron nitride sintered body, and the content ratio of titanium relative to the total of the cubic boron nitride sintered body. Regarding the content ratio of MC_xN_y, the composition and the amount thereof were estimated from XRD, and the content ratio was determined from the formulation ratio and SEM-EDX. The content ratios of aluminum and titanium each was calculated by quantification through high-frequency induction plasma emission analysis (ICP method).

[0062]

Table 5

	No.	MC_xN_y in Sintered Body		Mass ratio (%) of Al Element in Sintered Body	Mass ratio (%) of Ti Element in Sintered Body
		Compound	Content Ratio (% by mass)		
Example	1	WC	2.7	15.4	45.4
	2	WC	3.1	13.5	40.1
	3	WC	2.8	15.2	44.8
	4	WC	3.3	14.1	40.4
	5	WC	3.1	15.0	45.1
	6	TiC, TiCN, WC	18.5	10.3	43.0
	7	TiC, TiCN, WC	30.8	11.1	42.6
	8	WC	5.5	11.7	34.3
	9	(TiW)C	5.5	8.6	33.8
Comparative Example	1	WC	2.7	15.6	46.2
	2	WC	3.1	13.3	39.5
	3	TiC, WC	87.3	5.4	36.6
	4	WC	3.2	11.5	35.0
	5	TiC, TiCN, WC	44.4	13.3	25.1

[0063]

<Cutting Test>

Using an arc-discharge wire cutter, the CBN sintered body was cut into a tip of 13 mm × 13 mm, and then worked into a cutting tool having a shape defined in ISO Standards: SNGA 120408. Next, the CBN sintered body obtained as the result was tested for a dry-process continuous high-speed cutting test with a hardened steel under the following conditions:

Work material: round bar of carburized and hardened steel: SCM415 (HRC64) Cutting speed: 150 m/min

Incision: 0.2 mm

Feeding: 0.1 mm/rev

Time: 20 min

After 20 minutes, the flank wear of the cutting blade was observed and measured. The results are shown in Table 6.

[0064]

Table 6

	No.	Tool Flank Wear Amount (mm)
Example	1	0.135
	2	0.120
	3	0.140
	4	0.122
	5	0.116
	6	0.130
	7	0.144
	8	0.158
	9	0.151
Comparative Example	1	defect
	2	defect
	3	0.163
	4	0.172
	5	0.178

[0065]

In the samples of Examples 1 to 9, (I_{TiAlB2}/I_{CBN}) is within a range of 0.60 to 1.20, (I_{AlN}/I_{CBN}) is within a range of 0.20 to 0.40 and FWHM of I_{TiAlB2} (101) is within a range of 0.250 to 0.420°, and it is presumed that the CBN particles react with TiN, Al and the like in the binder phase to form an ultrafine hard phase compound TiB2 and a high-thermal conductivity compound AlN, thereby enhancing the holding force of the CBN particles therein. As a result, in the high-speed cutting test, dropped off of the CBN particles is reduced and the high abrasion resistance performance is realized.

[0066]

The samples of Comparative Examples 1 to 5 are those where cubic boron nitride reacted excessively with the binder phase therein, or the reaction was insufficient and therefore the peak intensity ratio in X-ray diffraction could not satisfy the claimed range.

[0067]

In Comparative Example 1, cubic boron nitride reacted excessively with the binder phase and, as a result, (I_{TiAlB2}/I_{CBN}) was more than 1.20 and (I_{AlN}/I_{CBN}) was more than 0.40, and in the cutting test, defect was recognized. It is presumed that the compounds of TiB_2, AlB_2, AlN and the like formed and grown excessively as a result of reaction between the CBN particles and the binder phase and therefore the defect resistance lowered.

[0068]

In Comparative Example 2, (I_{AlN}/I_{CBN}) was more than 0.40, like in

Comparative Example 1, and in the cutting test, defect was recognized. It is presumed that a large amount of a brittle compound AlN formed and, as a result, the defect resistance lowered.

[0069]

In Comparative Examples 3, 4 and 5, (I_{TiAlB2}/I_{CBN}) was less than 0.60. In addition, in Comparative Example 4, FWHM of I_{TiAlB2} (101) was more than 0.420, in Comparative Example 5, (I_{AlN}/I_{CBN}) was less than 0.20, and in these, abrasion tended to readily go on in the cutting test. In these Comparative Examples 3, 4 and 5, it is presumed that the reaction between the CBN particles and the binder phase was insufficient and, as a result, the holding force of the CBN particles was weak and the CBN particles readily dropped off.

[0070]

Regarding already-existing CBN sintered bodies, there are known CBN sintered bodies containing TiB_2 and AlN formed therein, but the intensity ratio of the X-ray diffraction pattern thereof was extremely low. This may be presumed because not only the amount of the compounds formed as reaction products is small but also the crystallinity of the particles is poor. In the case where such particles are formed, the particles provide a factor of lowering the hardness and the holding force of the particles, thereby lowering the abrasion resistance and the defect resistance of the sintered bodies. In addition, in the case where the sintering time is prolonged or the sintering temperature is elevated for increasing the crystallinity of the particles, growth of abnormal crystals readily occurs and, as a result, large and coarse particles may form though the crystallinity is increased, thereby lowering the abrasion resistance and the defect resistance. As opposed to this, in the present invention, the components of the binder phase are specifically defined, and the content ratio of the products formed in the sintering step for the CBN sintered body, and the crystal size and the crystallinity thereof each is controlled to be in a specific state, thereby resulting in success in satisfying both excellent abrasion resistance and excellent defect resistance.

[0071]

The CBN sintered body of the present invention can maintain excellent abrasion resistance and defect resistance even in severe service environments. In particular, in the case where the CBN sintered body is used as a cutting tip, it can reduce flak wear and can realize excellent cutting performance, as compared with already-existing CBN sintered body tips. Accordingly, in cutting/turning

operation, the frequency of tip exchange can be reduced and the productivity can be increased.

CLAIMS

[Claim 1]

A cubic boron nitride sintered body which contains cubic boron nitride in an amount of 10 to 55% by volume and in which the voids in the cubic boron nitride are filled with a binder phase containing an aluminum compound and a titanium compound, wherein:

the binder phase contains at least titanium diboride, aluminum diboride, aluminum nitride, and MC_xN_y (M is a transition metal element of Group 4 to 6, $0 < x \leq 1$, $0 \leq y \leq 1$ and $0 < x + y \leq 1$, M may be composed of two kinds of metals A and B, and in the case, $M = A_iB_j$, and $i + j = 1$),

the content ratio of aluminum that constitutes the aluminum compound is 8 to 25% by mass relative to the total of the cubic boron nitride sintered body,

the content ratio of MC_xN_y is 0.1 to 33% by mass relative to the total of the cubic boron nitride sintered body,

in an X-ray diffractometry using a Cu-Kα line,

the ratio of the peak intensity I_{TiAlB2} of the diffraction peak assigned to the (101) plane of titanium diboride and aluminum diboride to the peak intensity I_{CBN} of the diffraction peak assigned to the (111) plane of cubic boron nitride (I_{TiAlB2}/I_{CBN}) is 0.60 to 1.20,

the ratio of the peak intensity I_{AlN} of the diffraction peak assigned to the (200) plane of aluminum nitride to the above-mentioned peak intensity I_{CBN} (I_{AlN}/I_{CBN}) is 0.20 to 0.40,

and the half-value width of the diffraction peak assigned to the (101) plane of titanium diboride and aluminum diboride is 0.250° to 0.420°.

[Claim 2]

The cubic boron nitride sintered body according to claim 1, wherein (I_{TiAlB2}/I_{CBN}) is 1.00 to 1.11 and (I_{AlN}/I_{CBN}) is 0.33 to 0.38.

[Claim 3]

The cubic boron nitride sintered body according to claim 1 or 2, wherein the binder phase contains aluminum oxide having a number-average particle diameter of 1μm or less.

[Claim 4]

The cubic boron nitride sintered body according to any one of claims 1 to 3, wherein at least one M in MC_xN_y is tungsten.

[Claim 5]

The cubic boron nitride sintered body according to any one of claims 1 to 4, wherein M in MC_xN_y is titanium and tungsten.

[Claim 6]

The cubic boron nitride sintered body according to any one of claims 1 to 5, wherein the binder phase contains a reciprocal solid solution.

[Claim 7]

A method for producing a cubic boron nitride sintered body as stated in any one of claims 1 to 6, which comprises mixing raw materials containing cubic boron nitride, at least one of aluminum and an aluminum compound, a titanium compound and MC_xN_y (M is a transition metal element of Group 4 to 6, $0 < x \leq 1$, $0 \leq y \leq 1$ and $0 < x + y \leq 1$, M may be composed of two kinds of metals A and B, and in the case, $M = A_iB_j$, and $i + j = 1$) and sintering the resultant mixture under a pressure of 3 GPa or more and at 1000 to 1350°C.

[Claim 8]

The method for producing a cubic boron nitride sintered body according to claim 7, wherein cubic boron nitride particles having a volume-average particle diameter of 0.3 to 10 μm are used as the cubic boron nitride.

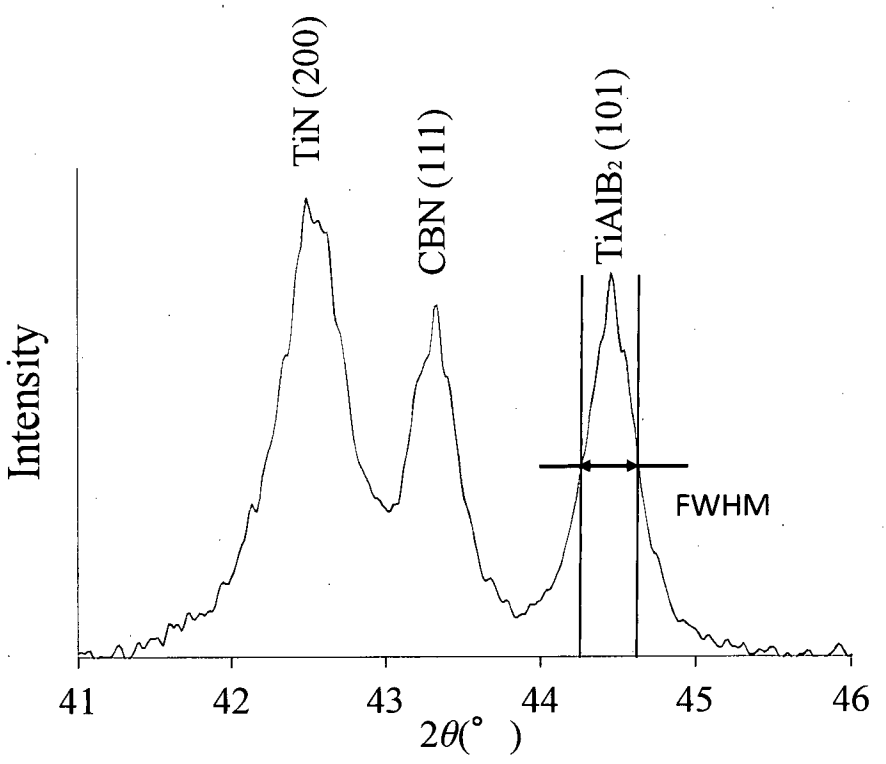
[Claim 9]

A tool comprising a cubic boron nitride sintered body as stated in any one of claims 1 to 6, as a constituent material thereof.

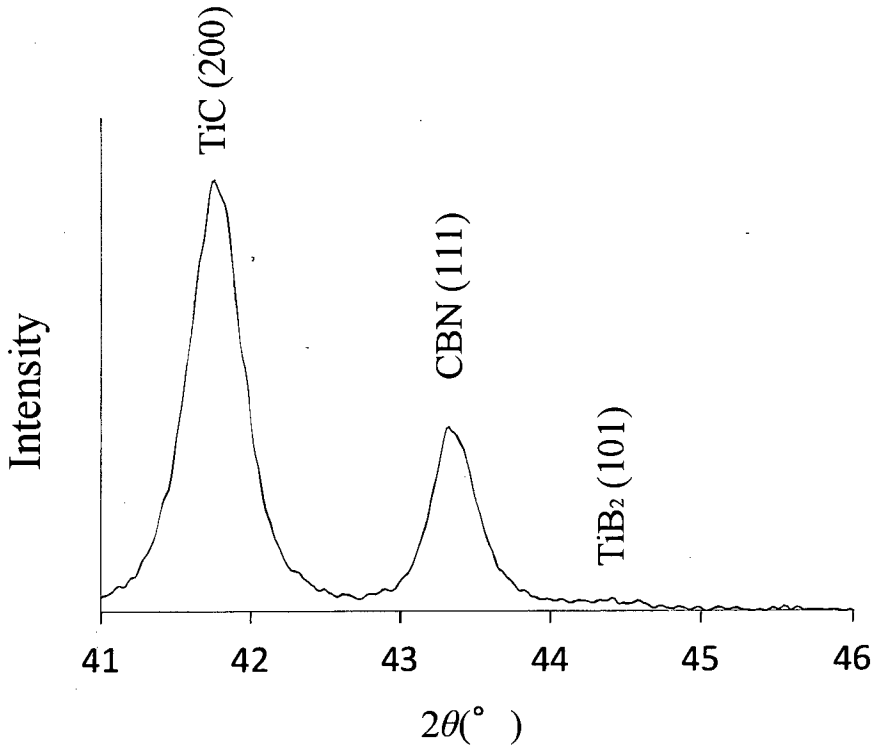
[Claim 10]

A cutting tool comprising a cubic boron nitride sintered body as stated in any one of claims 1 to 6, as a constituent material thereof.

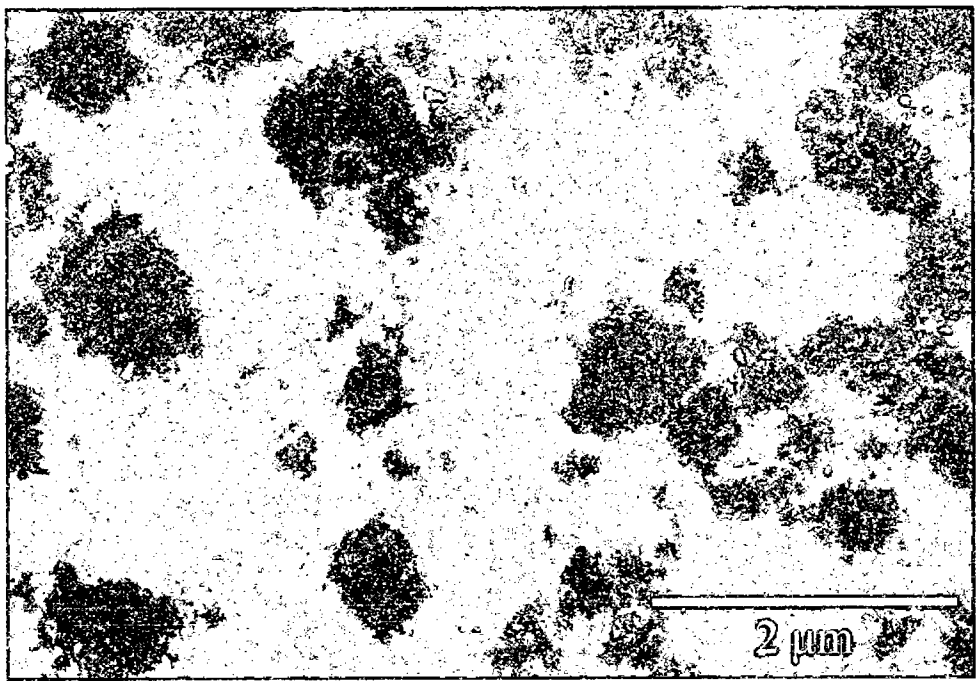
[Fig. 1]


TiN (200)
CBN (111)
TiAlB2 (101)
FWHM
Intensity
41
42
43
44
45
46
2θ(°)

[Fig. 2]


TiC (200)
CBN (111)
TiB2 (101)
Intensity
41
42
43
44
45
46
2θ(°)

[Fig. 3]



INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2016/068743

A. CLASSIFICATION OF SUBJECT MATTER
INV. C04B35/5831 C01B21/064 C04B35/626 C04B35/645 C04B35/63
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C04B C01B B23B C22C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 834 486 A2 (SUMITOMO ELECTRIC INDUSTRIES [JP]) 8 April 1998 (1998-04-08) claims 1-10; figure 1; examples 1-3; tables 1-3	1-10
X	US 2014/165474 A1 (YEE NELSON [US]) 19 June 2014 (2014-06-19)	1,2,7,9, 10
A	claims 1-32; figure 1; examples 1-3	3-6,8
A	EP 2 420 483 A1 (TUNGALOY CORP [JP]) 22 February 2012 (2012-02-22) claims 1-5; figure 1; examples 1, 2; tables 1-6	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 October 2016	17/10/2016

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/JP2016/068743

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0834486 A2	08-04-1998	CA 2217175 A1	04-04-1998
		DE 69714170 D1	29-08-2002
		DE 69714170 T2	16-01-2003
		EP 0834486 A2	08-04-1998
		JP H10114575 A	06-05-1998
		US 6001757 A	14-12-1999
US 2014165474 A1	19-06-2014	CN 104684670 A	03-06-2015
		EP 2890511 A1	08-07-2015
		KR 20150048117 A	06-05-2015
		US 2014165474 A1	19-06-2014
		WO 2014035821 A1	06-03-2014
EP 2420483 A1	22-02-2012	EP 2420483 A1	22-02-2012
		JP 5660034 B2	28-01-2015
		US 2012035045 A1	09-02-2012
		WO 2010119962 A1	21-10-2010