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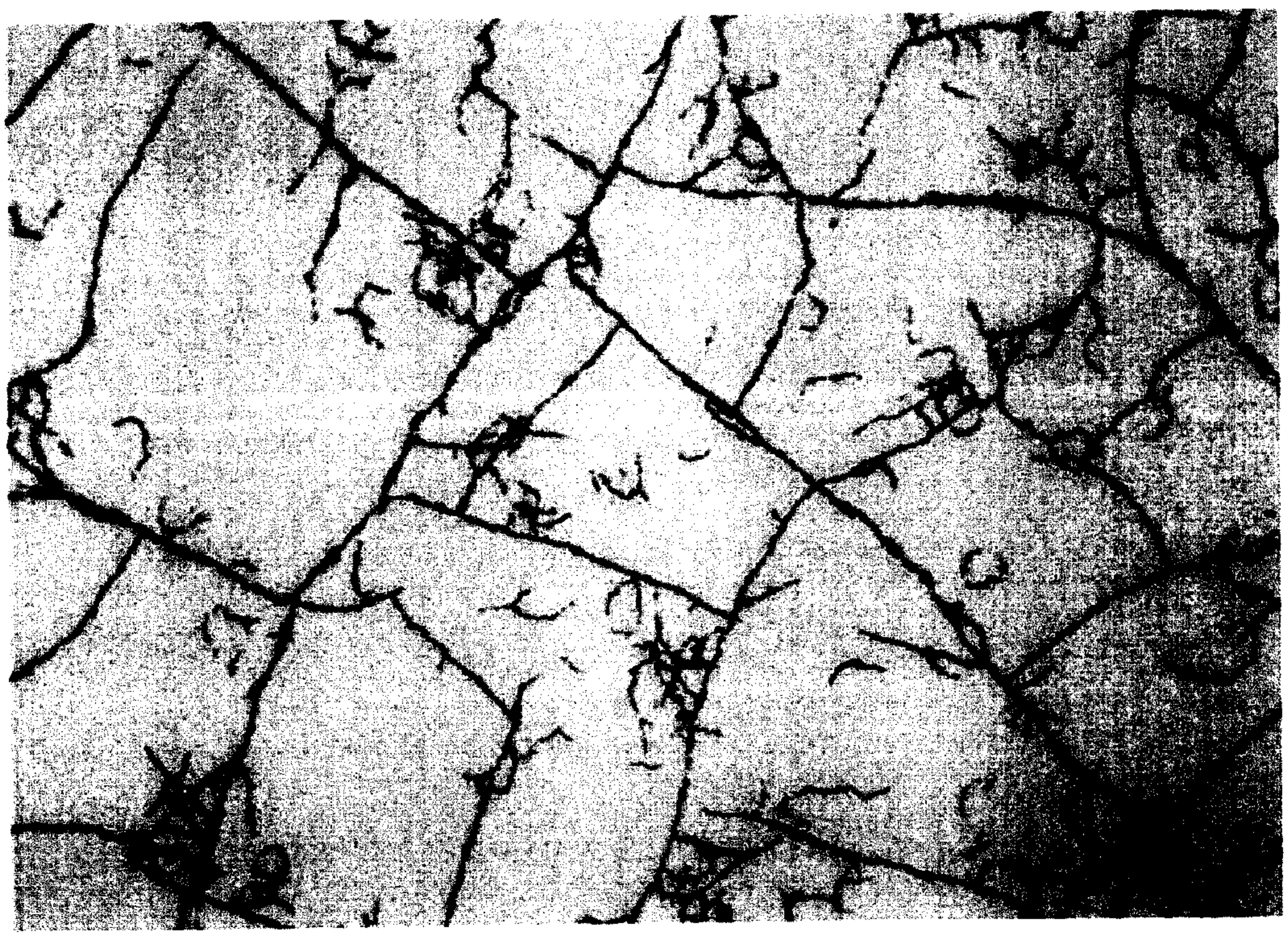

(57) Abrégé/Abstract:
To obtain a coated cutting tool that has excellent chipping resistance, wear resistance, and fracture resistance and long tool life, a coated cutting tool, includes: a substrate; and a coating layer formed on a surface of the substrate, wherein the coating layer includes at least one layer of a Ti compound layer, the Ti compound layer is a compound containing a Ti element and at least one of element selected from the group consisting of C, N, 0, and B, the Ti compound layer has a region surrounded by cracks when a polished surface approximately parallel to the surface of the substrate in the Ti compound layer is viewed from an upper surface, inside the region has an intermittent crack, one end or both ends of the crack not making contact with the cracks constituting the region, and relationship between an average number density A of the region and an average number density B of the intermittent crack satisfies 0.7 < B/A <2.

ABSTRACT

To obtain a coated cutting tool that has excellent chipping resistance, wear resistance, and fracture resistance and long tool life, a coated cutting tool, includes: a substrate; and a coating layer formed on a surface of the substrate, wherein the coating layer includes at least one layer of a Ti compound layer, the Ti compound layer is a compound containing a Ti element and at least one of element selected from the group consisting of C, N, O, and B, the Ti compound layer has a region surrounded by cracks when a polished surface approximately parallel to the surface of the substrate in the Ti compound layer is viewed from an upper surface, inside the region has an intermittent crack, one end or both ends of the crack not making contact with the cracks constituting the region, and relationship between an average number density A of the region and an average number density B of the intermittent crack satisfies $0.7 < B/A < 2$.

DESCRIPTION

COATED CUTTING TOOL

TECHNICAL FIELD

[0001] The present invention relates to a coated cutting tool.

BACKGROUND ART

[0002] It is conventionally known to use a coated cutting tool in which a coating layer, including a single layer of one member or multilayers of two or more members of, for example, a carbide, a nitride, a carbonitride, a carboxide, and a carboxynitride of Ti, and aluminum oxide, with a total film thickness from 3 to 20 μm is formed on a surface of a substrate made of cemented carbide by chemical vapor deposition, for cutting of steel, cast iron, and the like.

[0003] When a coating film is formed on a surface of tungsten carbide-based cemented carbide, tensile stress remains in the coating film and thus coated cutting tools are generally considered to have reduced breaking strength and be prone to break. It has been proposed to release the tensile residual stress by generating cracks with, for example, shot peening after formation of a coating film and the proposal has been quite effective (for example, see Patent Literature 1).

[0004] Further, a cutting tool that has high density cracks in a coating film in a lower portion on a substrate side and has low density cracks in the coating film in an upper portion on a surface side, is known (for example, see Patent Literature 2).

PRIOR ART DOCUMENTS

Patent Literature

[0005] Patent Literature 1: JP H05-116003 A
Patent Literature 2: JP H06-246512 A

DISCLOSURE OF THE INVENTION

[0006] In cutting process in recent years, higher speed, higher feed, and deeper cut became notable and the tool life has tended to be reduced more than conventional ones. Because of such background, when cracks are simply increased in the coating film, the fracture resistance of the tool as disclosed in Patent Literature 1 is improved. However, the tool as disclosed in Patent Literature 1 has a problem of reduction in separation resistance, chipping resistance, and wear resistance of the coating film from the cracks. The tool disclosed in Patent Literature 2 has improved wear resistance in the upper portion while it has a problem of insufficient wear resistance in the lower portion. Addition to it, it has a further problem of possibly separation in the coating film from the high density cracks in the lower portion. An object of the present invention is to provide a coated cutting tool that shows good chipping resistance, wear resistance, and fracture resistance and has long tool life by improving the mode of crack generation in the coated cutting tool.

[0007] From the above perspective, the present inventor made intensive research on extension of tool life coated cutting tools and has found that, in some embodiments of the present invention, it is possible to improve fracture resistance without impairing chipping resistance and wear resistance, and as a result, it is possible to extend the tool life.

[0008] That is, the summary of the present invention is as follows.

(1) A coated cutting tool includes: a substrate; and a coating layer formed on a surface of the substrate, wherein

the coating layer includes at least one layer of a Ti compound layer,

the Ti compound layer is a compound containing a Ti element and at least one of element selected from the group consisting of C, N, O, and B,

the Ti compound layer has a region surrounded by cracks when a polished surface approximately parallel to the surface of the substrate in the Ti compound layer is viewed from an upper surface,

inside the region has an intermittent crack, one end or both ends of the intermittent crack not making contact with the cracks constituting the region, and

relationship between an average number density A of the region and an average number density B of the intermittent crack satisfies $0.7 < B/A < 2$.

(2) The coated cutting tool according to (1), wherein the Ti compound layer is formed on the surface of the substrate and has an average layer thickness from 2 to 20 μm.

(3) The coated cutting tool according to any of (1) or (2), wherein the coating layer has an aluminum oxide layer with an average layer thickness from 1 to 15 μm on a surface of the Ti compound layer.

(4) The coated cutting tool according to any of (1) through (3), wherein the Ti compound layer is a compound further containing at least one of element selected from

the group consisting of Zr, Hf, V, Nb, Ta, Cr, Mo, W, Al, and Si.

(5) The coated cutting tool according to any of (1) through (4), wherein the aluminum oxide layer is a compound further containing at least one of element selected from the group consisting of Zr, Hf, V, Nb, Ta, Cr, Mo, W, and Si.

(6) The coated cutting tool according to any of (1) through (5), wherein the coating layer includes an outermost layer made of at least one of element selected from the group consisting of Zr, Hf, V, Nb, Ta, Cr, Mo, W, and Si and at least one member selected from the group consisting of C, N, O, and B on a surface of the aluminum oxide layer.

(7) The coated cutting tool according to any of (1) through (6), wherein the entire coating layer has a total layer thickness from 3 to 30 μm as an average layer thickness.

(8) The coated cutting tool according to any of (1) through (7), wherein the substrate is any of cemented carbide, cermet, ceramic, or sintered cubic boron nitride.

According to an aspect of the present invention, there is provided a coated cutting tool, comprising: a substrate; and a coating layer formed on a surface of the substrate, wherein

the coating layer includes at least one layer of a Ti compound layer,

the Ti compound layer is a compound containing a Ti element and an element comprising carbon, nitrogen, oxygen, or boron or any combination thereof,

the Ti compound layer has a region surrounded by cracks when a polished surface approximately parallel to the surface of the substrate in the Ti compound layer is viewed from an upper surface,

inside the region has an intermittent crack, one end or both ends of the intermittent crack not making contact with the cracks constituting the region, and

relationship between an average number density A of the region and an average number density B of the intermittent crack satisfies $0.7 < B/A < 2$.

[0009] <Coated Cutting Tool>

The coated cutting tool of the present invention includes a substrate and a coating layer formed on a surface of the substrate. Specifically, examples of a type of coated cutting tool may include an indexable cutting inserts for milling or turning, drills, and end mills.

[0010] <Substrate>

Examples of the substrate of the present invention may include, for example, cemented carbide, cermet, ceramics, sintered cubic boron nitride, sintered diamond, and high speed steel. Among them, the substrate is even more preferably any of cemented carbide, cermet, ceramics, or sintered cubic boron nitride for excellent wear resistance and fracture resistance.

[0011] Such substrate may have a modified surface. The effects of the present invention are exhibited even when the surface is modified in such a manner that, for example, a β-free layer is formed on the surface for cemented carbide and a surface hardened layer may be formed for cermet.

[0012] <Coating Layer>

The entire coating layer of the present invention has a total layer thickness preferably from 3 to 30 μm as an average layer thickness. The wear resistance may be poor in the case of less than 3 μm, and the adhesion to the substrate and the fracture resistance may be reduced in the case of more than 30 μm. In the range, from 3 to 20 μm is even more preferred.

[0013] <Ti Compound Layer>

The coating layer of the present invention includes at least one layer of a Ti compound layer. The Ti compound layer means a compound layer containing a Ti element as an essential component and further containing at least one of element selected from the group consisting of C, N, O, and B. The Ti compound layer may contain at least one of element selected from the group consisting of Zr, Hf, V, Nb, Ta, Cr, Mo, W, Al, and Si as an optional component.

[0014] The Ti compound layer of the present invention is preferably formed on the surface of the substrate because the adhesion between the substrate and the coating layer is improved. The Ti compound layer of the present invention has an average layer thickness preferably from 2 to 20 μm. This is because the wear resistance tends to be reduced when the Ti compound layer has an average layer thickness of less than 2 μm while the fracture resistance tends to be reduced when the Ti compound layer has an average layer thickness of more than 20 μm.

[0015] In the Ti compound layer of the present invention, when a polished surface approximately parallel to the surface of the substrate is viewed from an upper surface, the Ti compound layer has a region surrounded by cracks and inside the region has an intermittent crack, one end or both ends of the intermittent crack not making contact with the cracks constituting the region. Here, "viewed from an upper surface" means to view the polished surface from the approximately normal direction of the surface. In other words, it means to view from the front surface side of the coating layer, although not existing because of being polished, that is, to view from opposite side from the substrate. In addition, relationship between an average number density A of the region and an average number density B of the intermittent crack satisfies $0.7 < B/A < 2$, thereby obtaining an effect of stopping cracks generated in the coating layer during cutting by the intermittent crack, so that the chipping resistance and the fracture resistance are excellent. In addition, particles in the coating layer falling during cutting are suppressed to the minimum by having the intermittent crack, and thus it is possible to maintain the wear resistance. When relationship B/A between the average number density A of the region and the average number density B of the intermittent crack is 0.7 or less, the distribution of the intermittent crack is insufficient, and thus it is not possible to obtain the effect of stopping development of cracks generated in the coating layer during cutting by the intermittent crack, so that the chipping resistance and the fracture resistance are reduced. On the other hand, when the relationship B/A between the average number density A of the region and the average number density B of the intermittent crack is 2 or more, the intermittent crack is distributed in many spots, so that the cracks constituting the region and the intermittent crack are linked easily and the fracture resistance is reduced.

[0016] The polished surface of the Ti compound layer is a surface of the Ti compound layer that is obtained by polishing the coated cutting tool approximately parallel to the surface of the substrate until the Ti compound layer is exposed. At this point, it is preferred to obtain the polished surface at a position of a layer thickness of 50% or more of the average layer thickness of the Ti compound layer. For the coated cutting tool formed with Ti compound layers of a plurality of compositions, it is preferred to measure a region of a layer of the composition with the thickest average layer thickness and the intermittent crack.

[0017] The region observed on the polished surface of the Ti compound layer of the present invention is an area surrounded by cracks generated in the coating layer during cooling after the coating layer is formed and cracks produced in the coating layer by processing, such as dry blasting and shot peening. The number of regions is defined in such a manner that the smallest area surrounded by the cracks is one region. When there is an even smaller region in a region, they are defined as two regions.

[0018] It is possible to obtain the average number density of the region of the present invention by the following method. The number of regions observed on the polished surface of the Ti compound layer is measured. It is possible to obtain the number density of regions by dividing the number of regions by the area of the measured Ti compound layer. It is possible to obtain the average number density by dividing the number density by the number of measured fields of view.

[0019] The intermittent crack of the present invention is a crack having one end or both ends of the crack not making contact with the cracks constituting the region. Examples of the mode of intermittent crack may include, for example, a mode of not making contact with any crack in the region and a mode of developing cracks from the cracks constituting the region toward inside the region while the development is stopped without crossing the region.

[0020] It is possible to obtain the average number density of the intermittent crack of the present invention by the following method. The number of intermittent crack segments observed in the polished surface of the Ti compound layer is measured. It is possible to obtain the number density of the intermittent crack by dividing the number of intermittent crack segments by the area of the measured Ti compound layer. It is possible to obtain the average number density by summing each number density of the measured fields of view and dividing the total of number densities by the number of measured fields of view.

[0021] The coating layer of the present invention preferably includes an aluminum oxide layer (hereinafter, an Al_2O_3 layer) on the surface of the Ti compound layer because it is possible to suppress progress of wear due to reaction with the work piece material. The crystal system of Al_2O_3 layer is not particularly limited, and examples thereof may include α form, β form, δ form, γ form, κ form, χ form, pseudo-τ form, η form, and ρ form. Among them, the crystal system of Al_2O_3 layer is preferably α form that is stable at high temperatures or κ form that is excellent in the adhesion between the Ti compound layer and the Al_2O_3 layer. Particularly in the case that the region involved in cutting becomes high in temperature such as in high speed cutting, the Al_2O_3 layer is not easily fracture or chipping when using an α-Al_2O_3 layer. The Al_2O_3 layer preferably has an average layer thickness from 1 to 15 μm. The crater wear resistance on the rake face may be reduced when the Al_2O_3 layer has an average layer thickness of less than 1 μm, and separation easily occurs and the fracture resistance may be reduced when it has more than 15 μm.

[0022] Here, Fig. 1 illustrates an example of a photograph of a polished surface in the Ti compound layer of the present invention approximately parallel to the surface of the substrate viewed from an upper surface, and Fig. 2 illustrates an example of a photograph of a polished surface in a conventional Ti compound layer approximately parallel to the surface of the substrate viewed from an upper surface.

[0023] [Method of forming coating layer]

Examples of a method of forming each layer constituting the coating layer in the coated cutting tool of the present invention may include, for example, the following method.

[0024] For example, it is possible to form a TiN layer by chemical vapor deposition in which the raw material gas composition is $TiCl_4$: from 5.0 to 10.0 mol%, N_2: from 20 to 60 mol%, and H_2: residual, the temperature: from 850 to 920°C, and the pressure: from 100 to 350 hPa.

[0025] It is possible to form a TiCN layer by chemical vapor deposition in which the raw material gas composition is $TiCl_4$: from 10 to 15 mol%, CH_3CN: from 1 to 3 mol%, N_2: from 0 to 20 mol%, and H_2: residual, the temperature: from 850 to 920°C, and the pressure: from 60 to 80 hPa.

[0026] It is possible to form a TiC layer by chemical vapor deposition in which the raw material gas composition is $TiCl_4$: from 1.0 to 3.0 mol%, CH_4: from 4.0 to 6.0 mol%, and H_2: residual, the temperature: from 990 to 1030°C, and the pressure: from 50 to 100 hPa.

[0027] It is possible to form an α-Al_2O_3 layer by chemical vapor deposition in which the raw material gas composition is $AlCl_3$: from 2.1 to 5.0 mol%, CO_2: from 2.5 to 4.0

mol%, HCl: from 2.0 to 3.0 mol%, H_2S: from 0.28 to 0.45 mol%, and H_2: residual, the temperature: from 900 to 1000°C, and the pressure: from 60 to 80 hPa.

[0028] It is possible to form a κ-Al_2O_3 layer by chemical vapor deposition in which the raw material gas composition is $AlCl_3$: from 2.1 to 5.0 mol%, CO_2: from 3.0 to 6.0 mol%, CO: from 3.0 to 5.5 mol%, HCl: from 3.0 to 5.0 mol%, H_2S: from 0.3 to 0.5 mol%, and H_2: residual, the temperature: from 900 to 1000°C, and the pressure: from 60 to 80 hPa.

[0029] It is possible to form a TiAlCNO layer by chemical vapor deposition in which the raw material gas composition is $TiCl_4$: from 3.0 to 5.0 mol%, $AlCl_3$: from 1.0 to 2.0 mol%, CO: from 0.4 to 1.0 mol%, N_2: from 30 to 40mol%, and H_2: residual, the temperature: from 975 to 1025°C, and the pressure: from 90 to 110 hPa.

[0030] It is possible to form a TiAlCO layer by chemical vapor deposition in which the raw material gas composition is $TiCl_4$: from 0.5 to 1.5 mol%, $AlCl_3$: from 3.0 to 5.0 mol%, CO: from 2.0 to 4.0 mol%, and H_2: residual, the temperature: from 975 to 1025°C, and the pressure: from 60 to 100 hPa.

[0031] It is possible to form a TiCNO layer by chemical vapor deposition in which the raw material gas composition is $TiCl_4$: from 3.0 to 5.0 mol%, CO: from 0.4 to 1.0 mol%, N_2: from 30 to 40 mol%, and H_2: residual, the temperature: from 975 to 1025°C, and the pressure: from 90 to 110 hPa.

[0032] It is possible to form a TiCO layer by chemical vapor deposition in which the raw material gas composition is $TiCl_4$: from 0.5 to 1.5 mol%, CO: from 2.0 to 4.0 mol%, and H_2: residual, the temperature: from 975 to 1025°C, and the pressure: from 60 to 100 hPa.

[0033] The coated cutting tool having an average number density A of the region and an average number density B of the intermittent crack satisfying $0.7 < B/A < 2$ in the Ti compound layer is obtained by, for example, the following method.

[0034] It is possible to easily control the average number density B of the intermittent crack in the Ti compound layer by dry shot blasting using projectiles having a shape with an aspect ratio greater than conventional ones after the coating layer is formed. The shape of the projectiles even more preferably has a sharp convex. As the conditions of dry shot blasting, for example, the projectiles may be projected at a projection speed from 80 to 100 m/sec for a projection time from 0.5 to 1 minute to have a projection angle to the surface of the coating layer from 30 to 90°. The projectiles for dry shot blasting are preferably a material, such as Al_2O_3 and ZrO_2, having an average particle diameter from 160 to 200 μm.

[0035] It is possible to measure the layer thickness of each layer using an optical microscope, a scanning electron microscope (SEM), a field emission scanning electron microscope (FE-SEM), and the like from the sectional structure of the coated cutting tool. The layer thickness of the coated cutting tool may be obtained by measuring the layer thickness of each layer at three or more points at the positions near 50 μm from the edge toward the rake face of the coated cutting tool and obtaining an average of them. It is possible to measure the composition of each layer using an energy dispersive X-ray spectrometer (EDS), a wavelength dispersive X-ray spectrometer (WDS), and the like from the sectional structure of the coated cutting tool of the present invention.

[0036] Examples of the method of measuring the region and the intermittent crack in the Ti compound layer may include, for example, the following method. The coated cutting tool is polished in a direction approximately parallel to the surface of the substrate until the Ti compound layer is exposed to obtain a polished surface of the Ti compound layer. It is possible to easily observe cracks by etching the polished surface with fluonitric acid. The polished surface is observed at magnifications from 300 to 750 using an optical microscope to take a photograph of the polished surface. Using the photograph of the polished surface, the number of regions and the number of intermittent crack segments in the Ti compound layer are measured. It is possible to obtain the number densities of the region and the intermittent crack by dividing the measured numbers of regions and intermittent crack segments respectively by the measured area. It is possible to obtain the average number density A and the average number density B of the intermittent crack by summing the respective measured number densities of the region and the intermittent crack of each field of view and dividing them respectively by the measured number of fields of view. It is preferred to measure an area of 0.2 mm^2 or more using the photograph of the polished surface. When the number of regions is measured using a photograph of the polished surface, an area where it is not possible to confirm formation of a region because a crack abuts against an end of the photograph is defined as a region of 0.5.

Effects of the Invention

[0037] The coated cutting tool of the present invention maintains the wear resistance and is excellent in the chipping resistance and the fracture resistance, and thus exhibits an effect of extending the tool life more than conventional ones.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] Fig. 1 is an example of a photograph of a polished surface approximately parallel to the surface of the substrate viewed from an upper surface in a Ti compound layer of the present invention.

Fig. 2 is an example of a photograph a polished surface approximately parallel to the surface of the substrate viewed from an upper surface in a conventional Ti compound layer.

EXAMPLES

[0039] The present invention is described below with reference to Examples while the present invention is not limited to them.

[0040] As a substrate, a cutting insert made of cemented carbide having a shape of CNMG120412 according to JIS and composition of 86.0WC-1.0TiCN-1.3TaC-0.2NbC-0.5ZrC-11.0Co (hereinbefore, mass%) was prepared. After a cutting edge ridge of the substrate was subjected to circular honing with an SiC brush, the surface of the substrate was washed. Then, the substrate was charged into an external heating chemical vapor deposition apparatus, and a coating layer was formed on the substrate surface to have the configuration of the coating layer and the average layer thickness shown in Table 1. Ten samples were prepared for each. In Table 1, α in the crystal system of the aluminum oxide layer (Al_2O_3 layer) represents an α-Al_2O_3 layer and κ represents a κ-Al_2O_3 layer.

[0041] After the coating layer was formed, the samples thus obtained were subjected to dry shot blasting. As the conditions for dry shot blasting of Present Products 1 through 10, projectiles were projected at a projection speed of 90 m/sec for a projection time from 0.5 to 1 minute to have a projection angle to the surface of the coating layer of 45°. For the projectiles of dry shot blasting, Al_2O_3 with an average aspect ratio from 2 to 4 and an average particle diameter of 50 μm when measured at the positions of the smallest a projectile diameter was used.

[0042] Comparative Products 1 and 2 were subjected to neither dry shot blasting nor wet shot blasting.

[0043] Comparative Product 3 was subjected to dry shot blasting using steel ball projectiles having an average particle diameter of 150 μm. As the conditions for dry shot blasting, the projectiles were projected at a projection speed of 120 m/sec for a projection time of one minute to have a projection angle to the surface of the coating layer of 45°.

[0044] As the conditions for dry shot blasting of Comparative Products 4, 5, 7, and 8, projectiles were projected at a projection speed of 90 m/sec for a projection time from 0.5 to 1 minute to have a projection angle to the surface of the coating layer of 45°.

For the projectiles of dry shot blasting, Al_2O_3 with an average particle diameter of 150 μm was used.

[0045] Comparative Product 6 was subjected to wet shot blasting. Projectiles were projected at a projection speed of 120 m/sec for a projection time of one minute to have a projection angle to the surface of the coating layer of 45°. For the projectiles of wet shot blasting, Al_2O_3 with an average particle diameter of 30 μm was used.

[0046] [Table 1]

Sample No.	Coating Layer								
	Ti Compound Layer						Aluminum Oxide Layer		Total Layer Thickness (μm)
	First Layer		Second Layer		Third Layer				
	Composition	Average Layer Thickness (μm)	Composition	Average Layer Thickness (μm)	Composition	Average Layer Thickness (μm)	Crystal System	Average Layer Thickness (μm)	
Present Product 1	TiN	0.3	TiCN	7.0	TiCNO	1.0	α	5.0	13.3
Present Product 2	TiN	0.2	TiCN	1.5	TiCNO	0.3	α	1.0	3.0
Present Product 3	TiN	1.0	TiCN	18.0	TiCNO	1.0	α	5.0	25.0
Present Product 4	TiN	1.0	TiCN	13.0	TiCNO	1.0	α	15.0	30.0
Present Product 5	TiN	0.3	TiCN	3.0	TiCNO	1.0	α	5.0	9.3
Present Product 6	TiN	0.3	TiCN	10.0	TiCNO	1.0	α	5.0	16.3
Present Product 7	TiN	0.3	TiCN	7.0	TiAlCNO	1.0	α	5.0	13.3
Present Product 8	TiN	0.3	TiCN	7.0	TiCNO	1.0	κ	5.0	13.3
Present Product 9	TiC	0.3	TiCN	7.0	TiCO	1.0	α	5.0	13.3
Present Product 10	TiN	0.3	TiCN	7.0	TiAlCO	1.0	α	5.0	13.3
Comparative Product 1	TiN	0.3	TiCN	7.0	TiCNO	1.0	α	5.0	13.3
Comparative Product 2	TiN	0.3	TiCN	7.0	TiCNO	1.0	α	5.0	13.3
Comparative Product 3	TiN	0.3	TiCN	7.0	TiCNO	1.0	α	5.0	13.3
Comparative Product 4	TiN	0.3	TiCN	7.0	TiCNO	1.0	α	5.0	13.3
Comparative Product 5	TiN	0.3	TiCN	7.0	TiCNO	1.0	α	5.0	13.3
Comparative Product 6	TiN	0.3	TiCN	7.0	TiCNO	1.0	α	5.0	13.3
Comparative Product 7	TiN	0.2	TiCN	1.0	TiCNO	0.3	α	1.0	2.5
Comparative Product 8	TiN	0.3	TiCN	20.0	TiCNO	0.7	α	10.0	31.0

[0047] The layer thickness of each layer of the samples thus obtained was obtained by measuring cross sections near the positions 50 μm from the edge of the coated cutting tool toward the central portion of the rake face at three points with an SEM and obtaining an average of them.

[0048] To measure a region and an intermittent crack in the Ti compound layer, the samples thus obtained were polished until the Ti compound layer was exposed in the direction approximately parallel to the surface of the substrate. The polished surface of the Ti compound layer was prepared to have an average layer thickness at a position 70% of the layer thickness, and the polished surface of the Ti compound was etched with fluonitric acid. The polished surface of the Ti compound layer was observed at magnifications of 300 using an optical microscope to take a photograph of the polished surface in an area of 0.33 mm^2. Three inserts were prepared for each sample, the number of regions and the number of intermittent crack segments in the Ti compound layer were obtained using the respective photographs of the polished surface to obtain an average number density A of the region and an average number density B of the intermittent crack in the Ti compound layer from these values. Table 2 shows the average number density A of the region and the average number density B of the intermittent crack in the Ti compound layer.

[0049] [Table 2]

Sample No.	Average Number Density A in Region Surrounded by Cracks (number/mm^2)	Average Number Density B of Intermittent Crack (number/mm^2)	Average Number Density B of Intermittent Crack / Average Number Density A in Region Surrounded by Cracks
Present Product 1	917	1052	1.15
Present Product 2	429	409	0.95
Present Product 3	1005	1052	1.05
Present Product 4	917	1052	1.15
Present Product 5	520	393	0.76
Present Product 6	610	1209	1.98
Present Product 7	864	991	1.15
Present Product 8	766	853	1.11
Present Product 9	808	796	0.99
Present Product 10	784	934	1.19
Comparative Product 1	155	32	0.21
Comparative Product 2	320	54	0.17
Comparative Product 3	972	375	0.39
Comparative Product 4	446	268	0.60
Comparative Product 5	671	1399	2.08
Comparative Product 6	336	78	0.23
Comparative Product 7	415	264	0.64
Comparative Product 8	792	1647	2.08

[0050] Using the samples thus obtained, First Cutting Test and Second Cutting Test were performed. Processing distances until tool life are shown in Table 3. First Cutting Test is a test to evaluate the wear resistance and Second Cutting Test is one to evaluate the fracture resistance.

[0051] [First Cutting Test]

Work piece material: S45C round bar,

Cutting speed: 250 m/min,

Feed: 0.30 mm/rev,

Depth of cut: 2.0 mm,

Coolant: Used,

Point of evaluation: Processing time until tool life was measured where the tool life was defined as the time when the sample was fracture or had a maximum width of flank wear reaching 0.2 mm.

[0052] [Second Cutting Test]

Work piece material: S45C round bar with two longitudinal grooves at equal interval,

Cutting speed: 200 m/min,

Feed: 0.40 mm/rev,

Depth of cut: 1.5 mm,

Coolant: Used,

Point of evaluation: The number of impacts until tool life was measured where the tool life was defined as the time when the sample was fracture. The number of impacts was defined as the number that the work piece material made contact with the sample, and the test was terminated when the number of contact reached 20000 times at maximum. Five inserts were prepared for each sample, and the respective number of impacts was measured to obtain an average from the values of these numbers of impacts to define as the tool life.

[0053] [Table 3]

Sample No.	First Cutting Test		Second Cutting Test	
	Wear Test		Breaking Test	
	Tool Life (min)	Mode of Damage	Tool Life (times)	Mode of Damage
Present Product 1	42	Normal Wear	20000	Normal Wear
Present Product 2	26	Normal Wear	16200	Fracture
Present Product 3	38	Normal Wear	18900	Fracture
Present Product 4	35	Normal Wear	18000	Fracture
Present Product 5	25	Normal Wear	16500	Fracture
Present Product 6	29	Normal Wear	16900	Fracture
Present Product 7	41	Normal Wear	20000	Normal Wear
Present Product 8	39	Normal Wear	20000	Normal Wear
Present Product 9	34	Normal Wear	17800	Fracture
Present Product 10	40	Normal Wear	18200	Fracture
Comparative Product 1	20	Fracture	3600	Fracture
Comparative Product 2	18	Fracture	3200	Fracture
Comparative Product 3	32	Normal Wear	8900	Fracture
Comparative Product 4	21	Chipping	5600	Fracture
Comparative Product 5	22	Chipping	6000	Fracture
Comparative Product 6	26	Normal Wear	4300	Fracture
Comparative Product 7	15	Chipping	5100	Fracture
Comparative Product 8	18	Chipping	5400	Fracture

[0054] As shown in Table 3, it was found that the wear resistance, the chipping resistance, and the fracture resistance were improved, thereby the processing time until tool life was longer and the number of impacts was more in Present Products than in Comparative Products, so that the tool life was significantly longer.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A coated cutting tool, comprising: a substrate; and a coating layer formed on a surface of the substrate, wherein

the coating layer includes at least one layer of a Ti compound layer,

the Ti compound layer is a compound containing a Ti element and an element comprising carbon, nitrogen, oxygen, or boron or any combination thereof,

the Ti compound layer has a region surrounded by cracks when a polished surface approximately parallel to the surface of the substrate in the Ti compound layer is viewed from an upper surface,

inside the region has an intermittent crack, one end or both ends of the intermittent crack not making contact with the cracks constituting the region, and

relationship between an average number density A of the region and an average number density B of the intermittent crack satisfies $0.7 < B/A < 2$.

2. The coated cutting tool according to claim 1, wherein the Ti compound layer is formed on the surface of the substrate and has an average layer thickness from 2 to 20 μm.

3. The coated cutting tool according to claim 1 or 2, wherein the Ti compound layer is a compound further comprising Zr, Hf, V, Nb, Ta, Cr, Mo, W, Al, or Si, or any combination thereof.

4. The coated cutting tool according to any one of claims 1 to 3, wherein the coating layer has an aluminum oxide layer with an average layer thickness from 1 to 15 μm on a surface of the Ti compound layer.

5. The coated cutting tool according to claim 4, wherein the aluminum oxide layer is a compound further comprising Zr, Hf, V, Nb, Ta, Cr, Mo, W, or Si, or any combination thereof.

6. The coated cutting tool according to any one of claims 1 to 3, wherein the coating layer includes an aluminum oxide layer and an outermost layer made of Zr, Hf, V, Nb, Ta, Cr, Mo, W, or Si, or any combination thereof, and a member comprising C, N, O, or B, or any combination thereof, on a surface of the aluminum oxide layer.

7. The coated cutting tool according to claim 4 or 5, wherein the coating layer includes an outermost layer made of Zr, Hf, V, Nb, Ta, Cr, Mo, W or Si, or any combination thereof, and a member comprising C, N, O or B, or any combination thereof, on a surface of the aluminum oxide layer.

8. The coated cutting tool according to any one of claims 1 to 7, wherein the entire coating layer has a total layer thickness from 3 to 30 μm as an average layer thickness.

9. The coated cutting tool according to any one of claims 1 to 8, wherein the substrate is any one of cemented carbide, cermet, ceramic, or sintered cubic boron nitride.

Fig. 1

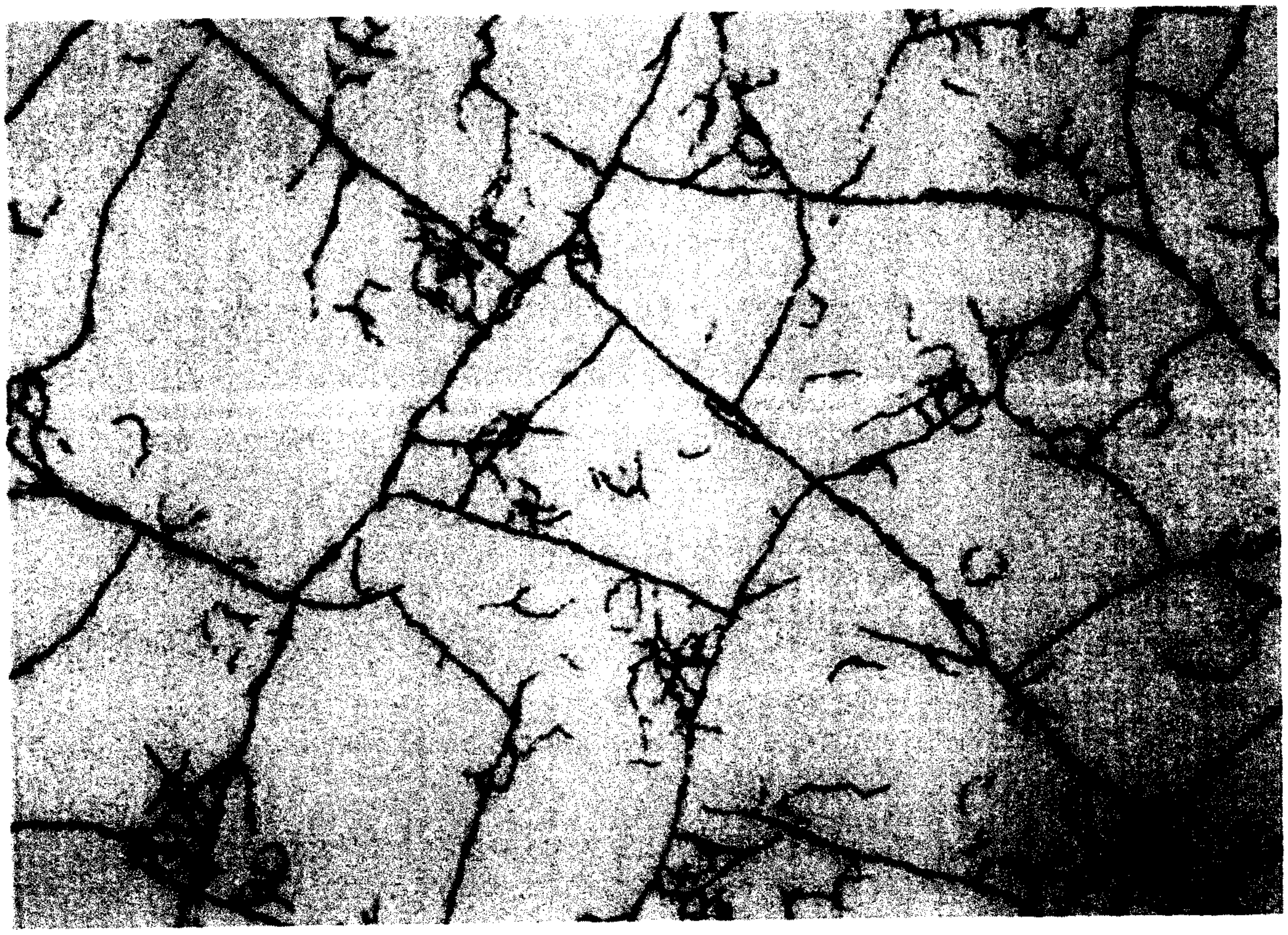

Fig. 2