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(54) **Hard covering film for cutting tool**

(57) It is an object of the present invention to provide a hard covering film for a cutting tool which can improve the wear resistance beyond that of a conventional AlCrN film. According to the present invention, there is provided a hard covering film for a cutting tool formed on a cutting tool substrate, characterized in that: the hard covering film comprises a first multi-layer covering film layer formed by alternatingly layering two or more layers each of a first covering film layer and a second covering film layer; the first covering film layers have metal and semi-metal components that are expressed (in terms of at%) by $Al_{(100-x-y-z)}Cr_{(x)}V_{(y)}B_{(z)}$ (where $20 \leq x \leq 40$, $2 \leq y \leq 15$, and $5 \leq z \leq 15$), have N as a non-metallic element, and have unavoidable impurities; the second covering film layers have metal and semi-metal components that are expressed (in terms of at%) by $Al_{(100-u-v-w)}Cr_{(u)}V_{(v)}B_{(w)}$ (where $20 \leq u \leq 40$, $0 \leq v \leq 5$, $0 \leq w \leq 5$), have N as a non-metallic element, and have unavoidable impurities; the relationship between y and v such that $y \geq v$ is satisfied; and the relationship between z and w such that $z - 5 \geq w$ is satisfied.

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Description

TECHNICAL FIELD

[0001] The present invention relates to a hard covering film for a cutting tool which covers cutting tools such as endmills, drills, or the like, and is used to improve the wear resistance.

BACKGROUND ART

[0002] Conventionally, TiN, TiCN, and TiAlN have been used as hard covering films for covering metal cutting tools. In particular, the TiAlN covering films represented by Patent Documents 1 and 2 improve hardness and heat resistance by adding Al to TiN; because of good wear resistance, these alloys are widely used as hard covering films for cutting tools used to work iron and steel materials including tempered steel.

[0003] In recent years, however, there has been a demand for the further improvement of wear resistance against iron and steel materials in tools, and AlCrN covering films in which the heat resistance is improved beyond that of TiAlN covering films by using CrN as a base instead of TiN have been proposed in Patent Document 3.

[Patent Document 1] Japanese Laid-Open Patent Publication No. 62-56565
[Patent Document 2] Japanese Laid-Open Patent Publication No. 2-194159
[Patent Document 3] Japanese Patent No. 3039381

[0004] However, although AlCrN covering films have a better heat resistance than TiAlN covering films, the hardness is somewhat smaller; accordingly, the wear resistance against iron and steel materials is not regarded to be sufficient.

DISCLOSURE OF THE INVENTION

[0005] The present invention was devised in light of such conditions; as a result of research on covering film compositions and covering film constructions, the present inventors discovered that the abovementioned problems can be solved by improving the hardness and lubricating properties of the hard covering film. The inventors thereby perfected the present invention. By forming the hard covering film with a specified composition and layer structure, the present invention provides a hard covering film for a cutting tool which is extremely superior in terms of practicality, and which makes it possible to improve the hardness and lubricating properties of the hard covering film, and to make a great improvement in wear resistance over that of a conventional AlCrN film.

[0006] The main points of the present invention will be described below.

[0007] A first aspect of the present invention relates to a hard covering film for a cutting tool formed on a cutting tool substrate, characterized in that: the hard covering film comprises a first multi-layer covering film layer formed by alternatingly layering two or more layers each of a first covering film layer and a second covering film layer; the first covering film layers have metal and semi-metal components that are expressed (in terms of at%) by $Al_{(100-x-y-z)}Cr_{(x)}V_{(y)}B_{(z)}$ (where $20 \leq x \leq 40$, $2 \leq y \leq 15$, and $5 \leq z \leq 15$), have N as a non-metallic element, and have unavoidable impurities; the second covering film layers have metal and semi-metal components that are expressed (in terms of at%) by $Al_{(100-u-v-w)}Cr_{(u)}V_{(v)}B_{(w)}$ (where $20 \leq u \leq 40$, $0 \leq v \leq 5$, $0 \leq w \leq 5$), have N as a non-metallic element, and have unavoidable impurities; the V content proportion y of the first covering film layer and the V content proportion v of the second covering film layer satisfy the relationship $y \geq v$; and the B content proportion z of the first covering film layer and the B content proportion w of the second covering film layer satisfy the relationship $z - 5 \geq w$.

[0008] A second aspect of the present invention relates to the first aspect of the hard covering film for a cutting tool, and is characterized in that a third covering film layer is disposed between the first multi-layer covering film layer and the substrate; and the metallic elements and semi-metallic elements of the third covering film layer are the same as the metallic elements and semi-metallic elements of the second covering film layer.

[0009] A third aspect of the present invention relates to the first aspect of the hard covering film for a cutting tool, and is characterized in that a fourth covering film layer is disposed directly above the substrate; the fourth covering film layer is a nitride or carbide having Ti as a main component; and the fourth covering film layer has a thickness set at 0.01 μm to 0.5 μm.

[0010] A fourth aspect of the present invention relates to the second aspect of the hard covering film for a cutting tool, and is characterized in that a fourth covering film layer is disposed directly above the substrate; the fourth covering film layer is a nitride or carbide having Ti as a main component; and the fourth covering film layer has a thickness set at 0.01 μm to 0.5 μm.

[0011] A fifth aspect of the present invention relates to the first aspect of the hard covering film for a cutting tool, and is characterized in that a fourth covering film layer is disposed directly above the substrate; the fourth covering film layer is a nitride or carbide having Cr as a main component; and the fourth covering film layer has a thickness set at 0.01 μm to 0.5 μm.

[0012] A sixth aspect of the present invention relates to the second aspect of the hard covering film for a cutting tool, characterized in that a fourth covering film layer is disposed directly above the substrate; the fourth covering film layer having Cr as a main component; and the fourth covering film layer has a thickness set at 0.01 μm to 0.5 μm.

[0013] A seventh aspect of the present invention relates to any of the first through sixth aspects of the hard covering film for a cutting tool, and is characterized in that a second multi-layer covering film layer formed by alternatingly layering two or more layers each of a fifth covering film layer and a sixth covering film layer is disposed on a surface layer side of the first multi-layer covering film layer; metallic elements, semi-metallic elements, and non-metallic elements of the fifth covering film layer are the same as metallic elements, semi-metallic elements, and non-metallic elements of the first covering film layer; the sixth covering film layer has metallic elements and semi-metallic elements expressed (in terms of at%) by $Si_{(100-t)}M_{(t)}$ (where $0 \le t \le 30$, and M indicates one or more elements of group 4a, 5a, 6a, or 3b of the periodic table), has N as a non-metallic element, and has unavoidable impurities; the fifth covering film layer has a thickness set at 40 nm or less; the sixth covering film layer has a thickness set at 0.2 to 4 nm; and the thicknesses of the fifth covering film layer and sixth covering film layer are set so that the fifth covering film layer is four or more times thicker than the sixth covering film layer.

[0014] An eighth aspect of the present invention relates to the seventh aspect of the hard covering film for a cutting tool, and is characterized in that the first multi-layer covering film layer has an NaCl crystal structure.

[0015] A ninth aspect of the present invention relates to the eighth aspect of the hard covering film for a cutting tool, and is characterized in that the substrate is made of a super-hard metal alloy composed of hard particles having WC as a main component, and a binder having Co as a main component, the mean particle size of the WC particles is set at 0.1 μm to 2 μm, and the Co content is set at 5 to 15% in terms of percentage by weight.

[0016] Since the present invention is constructed as described above, a hard covering film for a cutting tool which is extremely superior in terms of practicality is obtained, in which the hardness and lubricating properties of the hard covering film are improved, and the wear resistance is improved far beyond that of a conventional AlCrN film.

BEST MODE FOR CARRYING OUT THE INVENTION

[0017] Preferred embodiments (the manner in which the present invention is implemented) of the present invention will be briefly described below while indicating the effects of the present invention.

[0018] The lubricating properties are improved by adding V, and the hardness is improved by adding B. Accordingly, the lubricating properties and hardness are improved far beyond those of a conventional AlCrN covering film.

[0019] Here, while the hardness of the covering film is increased by adding B, the toughness drops slightly. In the present invention, however, both hardness and toughness are obtained by alternatingly layering first covering film layers with second covering film layers having a B content that is at least 5 at% (at%) less than that of the first covering film layers, thereby minimizing the drop in toughness. Specifically, the first covering film layers which have a high B content act mainly to improve the hardness, and the second covering film layers which have a low B content between these first covering film layers act mainly to improve the toughness. Thus, a hard and tough covering film is obtained, and a covering film superior in terms of wear resistance, which is correspondingly resistant to chipping is formed.

[0020] The V content of the second covering film layers may be the same as that of the first covering film layers; however, since the B content is smaller and the hardness is slightly lower, it is desirable that the V content be lower than that of the first covering film layers, so that the hardness will not become excessively low.

[Examples]

[0021] Concrete examples of the present invention will be described below.

[0022] The present example is a hard covering film for a cutting tool formed on a cutting tool substrate, characterized in that: the hard covering film comprises a first multi-layer covering film layer formed by alternatingly layering two or more layers each of a first covering film layer and a second covering film layer; the first covering film layers have metal and semi-metal components that are expressed (in terms of at%) by $Al_{(100-x-y-z)}Cr_{(x)}V_{(y)}B_{(z)}$ (where $20 \le x \le 40$, $2 \le y \le 15$, and $5 \le z \le 15$), have N as a non-metallic element, and have unavoidable impurities; the second covering film layers have metal and semi-metal components that are expressed (in terms of at%) by $Al_{(100-u-v-w)}Cr_{(u)}V_{(v)}B_{(w)}$ (where $20 \le u \le 40$, $0 \le v \le 5$, $0 \le w \le 5$), have N as a non-metallic element, and have unavoidable impurities; the V content proportion y of the first covering film layer and the V content proportion v of the second covering film layer satisfy the relationship $y \ge v$; and the B content proportion z of the first covering film layer and the B content proportion w of the second covering film layer satisfy the relationship $z - 5 \ge w$.

[0023] The respective parts will be described in concrete terms.

[0024] The substrate used is made of a super-hard metal alloy composed of hard particles whose main component is WC (tungsten carbide) and a binder whose main component is Co (cobalt). In concrete terms, the mean particle size of the WC particles is set at 0.1 μm to 2 μm, and the Co content is set at 5 to 15% in terms of percentage by weight.

[0025] A fourth covering film layer comprising a nitride or carbide whose main component is Ti (titanium) is disposed directly on top of this substrate. The film thickness of this fourth covering film layer is set at 0.01 μm to 0.5 μm. A nitride or carbide whose main component is Cr (chromium) may also be used as the fourth covering film layer. In this case as well, it is advisable that the film thickness be set at 0.01 μm to 0.5 μm.

[0026] A third covering film layer is disposed on top of this fourth covering film layer. The metallic elements and semi-metallic elements of this third covering film layer are the same as the metallic elements and semi-metallic elements of the second covering film layer.

[0027] In the present example, a first multi-layer covering film layer formed by alternatingly layering the first and second covering film layers is disposed on top of this third covering film layer. The first multi-layer covering film layer has a construction which has an NaCl crystal structure.

[0028] A second multi-layer covering film layer formed by layering two or more layers each of a fifth covering film layer and a sixth covering film layer is disposed on the surface layer side of this first multi-layer covering film layer. The metallic elements, semi-metallic elements, and non-metallic elements of the fifth covering film layer are the same as the metallic elements, semi-metallic elements, and non-metallic elements of the first covering film layer. The metallic elements and semi-metallic elements in the sixth covering film layer are expressed (in terms of at%) by

$$Si_{(100-t)}M_{(t)}$$

(where $0 \leq t \leq 30$, and M indicates one or more elements of group 4a, 5a, 6a, or 3b of the periodic table), N is included as a non-metallic element, and unavoidable impurities are included. The film thickness of the fifth covering film layer is set at 0.8 nm to 40 nm, the film thickness of the sixth covering film layer is set at 0.2 nm to 4 nm, and the film thicknesses of the fifth covering film layer and sixth covering film layer are set so that the fifth covering film layer is four times thicker than the sixth covering film layer or greater.

[0029] The reason for using the abovementioned construction and the action and effect obtained as a result of the abovementioned construction will be described below.

[0030] First, in regard to the first multi-layer covering film layer, the reason for setting the covering film construction as described above will be described. First of all, the composition of the first covering film layer will be described. The present inventors studied covering films in which various third elements were added to AlCrN, and discovered that the wear resistance with respect to iron and steel materials can be improved by adding specified amounts of V (vanadium) and B (boron). It appears that this is due to the fact that the hardness and lubricating properties of the covering film are improved.

[0031] In concrete terms, in cases where the amount of B is less than 5% in terms of the at% of metals and semi-metals alone, the effect is small; however, in amounts equal to or greater than 5%, a hardness improving effect appears; furthermore, it was confirmed that in cases where the B content exceed 15%, there is no great change in the hardness value. Furthermore, B is a more expensive element than Al (aluminum) and Cr; accordingly, considering the covering film hardness and cost, the amount of B was set at 5% to 15% in terms of the at% of metals and semi-metals only as the composition range of the first covering film layer.

[0032] When the content of V is increased, the lubricating properties of the covering film are improved. In concrete terms, in cases where the amount of V is less than 2% in terms of the at% of metals and semi-metals alone, the effect is small; however, at 2% or greater, a lubrication improving effect appears, and it was confirmed that the wear resistance with respect to iron and steel materials of tools covered by the covering film is improved. On the other hand, it was also confirmed that if the V content is increased to an excessive amount, the hardness of the covering film drops, and the wear resistance with respect to iron and steel materials drops. Furthermore, V is a much more expensive element than Al and Cr; accordingly, considering the lubricating properties and hardness of the covering film, and the cost, the amount of V was set at 2% to 15% in terms of the at% of the metals and semi-metals alone as the composition range of the first covering film layer.

[0033] When a first covering film layer was formed directly above the substrate and a cutting tool was manufactured, and a cutting test was then performed on iron and steel materials, better cutting performance with less wear compared to the case of an AlCrN covering film was obtained under finishing conditions with a small feeding speed and shallow cutting depth; however, in the case of rough working conditions with a large feeding speed and deep cutting depth, it was ascertained that there were also cases in which microscopic chipping occurred in the cutting blade. It is thought that this resulted from the fact that although the hardness of the covering film increased as a result of the inclusion of B, the toughness of the covering film dropped slightly.

[0034] Accordingly, a second covering film layer was provided in which the drop in toughness was suppressed by reducing the B content by 5 at% or greater compared to the first covering film layer, and a method was devised in which both hardness and toughness were obtained by alternatingly layering two or more layers each of a first covering film layer and a second covering film layer (in a first multi-layer covering film layer). The V content of the second covering film layer may be the same as that of the first covering film layer; however, since the B content is small and the hardness is somewhat low, it is desirable to reduce the V content to a value less than that of the first covering film layer so that the hardness is prevented from becoming too low.

[0035] Next, the crystal structure of the first multi-layer covering film layer will be described. The crystal structure and hardness were examined by forming films under various film forming conditions, which showed that there are cases in which an NaCl crystal structure and cases in which a wurtzite crystal structure is adopted depending on the film formation conditions together with the first covering film layer and second covering film layer. When the hardness values are compared, the hardness of the latter is much lower than the hardness of the former. Accordingly, it is desirable that the crystal structure of the first multi-layer covering film layer be formed as an NaCl crystal structure.

[0036] In a cutting tool that is prepared by forming a first covering film layer directly on top of a substrate, it was also ascertained that there are cases in which microscopic peeling of the covering film occurs during cutting. Accordingly, a third covering film layer constructed from the same element components as the second covering film layer was formed directly on top of the substrate, and a cutting tool was prepared by forming a first multi-layer covering film layer on top of this. When a cutting test was performed, microscopic peeling of the covering film during cutting was reduced, and more stable cutting was possible. It is thought that the reason that film peeling was reduced by the formation of a third covering film layer between the first multi-layer covering film layer and the substrate can be explained as follows: specifically, it is known that the film stress in the area directly above the substrate tends to be greatest in the direction of thickness of the covering film; if the toughness of the covering film in this area is low, microscopic failure of the covering film layer tends to occur, and it is thought that this leads to film peeling. Accordingly, if a third covering film layer with a high toughness is formed directly above the substrate, microscopic failure of the covering film tends not to occur, and it is thought that this leads to a reduction in film peeling.

[0037] As a separate approach for reducing film peeling and microscopic failure of the covering film, it is also possible to form a Ti or Cr nitride or carbide (fourth covering film layer) which is superior in terms of adhesion to the substrate directly on top of the substrate. Even if a fourth covering film layer is formed directly on top of the substrate, and a first multi-layer covering film layer is formed on top of this, film peeling and microscopic failure of the covering film are greatly reduced. In an even more preferable covering film construction, it is preferable to form a fourth covering film layer directly on top of the substrate, to form a third covering film layer on top of this, and to form a first multi-layer covering film layer on top of this. In cases where a third covering film layer is formed on top, an effect in improving the adhesion to the substrate appears even in cases where the thickness of the fourth covering film layer is relatively thin; however, in this case as well, it is desirable that the thickness be 0.01 μm or greater. Furthermore, since the object of the fourth covering film layer is to obtain an effect that improves the adhesion to the substrate, there is no need to make the film thickness too thick; it is desirable that the film thickness be set at 0.5 μm or less.

[0038] Next, the second multi-layer covering film layer will be described. The present inventors studied the structure of AlCrVBN, and discovered that layering an extremely thin covering film (sixth covering film layer) of an Si (silicon) nitride with an AlCrVBN covering film (fifth covering film layer) causes the structure of the AlCrVBN covering film to change from a columnar structure to a so-called nano-composite structure in which very fine crystals of 50 nm or less (NaCl crystal structure) are mixed with amorphous parts. The reason for this change from a columnar structure to a nano-composite structure will have to be clarified by future research; however, it is thought that since an Si nitride covering film comprises a substance that is readily converted into an amorphous substance, the BN inside the AlCrVBN film is converted into an amorphous substance by layering so that a thin AlCrVBN film (fifth covering film layer) is sandwiched between extremely thin amorphous covering films (sixth covering film layers), thus forming a nano-composite structure. These sixth covering film layers may also be SiN films; in cases where an SiN film is formed by DC type arc ion plating or sputtering, an Si target is used as an evaporation source. However, since the conductivity of an Si target is low, the stable continuation of film formation is relatively difficult. Accordingly, a small amount of a metallic element M may be added in order to raise the conductivity of the target material, and facilitate the stabilization of film formation. In the sixth covering film layers, SiN is easily converted into an amorphous substance. Accordingly, in order to ensure a large amorphous region, it is desirable that the proportion of M in the metallic elements and semi-metallic elements of the sixth covering film layers be lowered to 30% or less in terms of at%. There are no particular restrictions on the types of elements M used; these elements are one or more types from groups 4a, 5a, 6a, or 3b of the periodic table. One element or two or more elements among the Al, Cr, V and B included in the fifth covering film layer may be used as elements M.

[0039] Furthermore, it is known that the hardness increases as the size of the covering film crystals is reduced. Even in covering films of the same components, a covering film having a nano-composite structure has a higher hardness than a covering film having a columnar structure. If the fifth covering film layer is too thick, conversion to a nano-composite structure becomes difficult; accordingly, it is desirable that the thickness be set at 40 nm or less. Furthermore, if the sixth covering film layer is too thin, it becomes difficult to change the fifth covering film layer to a nano-composite layer, and if this layer is too thick, the second multi-layer covering film layer becomes brittle; accordingly, it is desirable to set the thickness of this layer at 0.2 nm to 4 nm. Furthermore, the object of forming the second multi-layer covering film layer with a layered structure is to convert the AlCrVBN covering film into a nano-composite structure; accordingly, it is desirable to set the thickness of the fifth covering film layer at a thickness that is four times the thickness of the sixth covering film layer or greater so that the volumetric proportion of the fifth covering film layer in the second multi-layer covering film layer is 80% or greater.

[0040] The hard covering film of the present example was invented for cutting tools used for iron and steel materials. In regard to the substrate, it is desirable that the super-hard alloy composed of hard particles whose main component is WC and the binder whose main component is Co be a material in which hardness and toughness are balanced as a cutting tool for iron and steel materials. If the mean particle size of the WC particles is set at too small a value, it becomes difficult to uniformly disperse the WC particles in the binder, and this tends to cause a drop in the bending resistance of the super-hard alloy. On the other hand, if the WC particles are too large, the hardness of the super-hard alloy drops. Furthermore, if the Co content is too small, the bending resistance of the super-hard alloy drops; conversely, if the Co content is too large, the hardness of the super-hard alloy drops. Accordingly, it is desirable that a super-hard alloy in which the mean particle size of the WC particles is 0.1 μm to 2 μm, and the Co content is 5 to 15% in terms of wt%, be used for the substrate.

[0041] Since the present example is constructed as described above, the lubricating properties are improved by the addition of V; furthermore, the hardness is improved by the addition of B. Accordingly, the lubricating properties and hardness can be improved beyond those of a conventional AlCrN covering film.

[0042] Here, when B is added, the hardness of the covering film is increased, but the toughness drops slightly. In the present invention, however, both hardness and toughness are obtained by alternatingly layering the first covering film layers with second covering film layers having a B content that is at least 5 at% less than that of the first covering film layers, thereby minimizing the drop in toughness. Specifically, a hard covering film with a strong viscosity is obtained by causing the first covering film layer which has a large B content to have mainly an effect in improving the hardness, and causing the second covering film layer which has a smaller B content than this first covering film layer to have mainly an effect in improving toughness. Thus, a covering film with a superior wear resistance which tends not to show any chipping is obtained.

[0043] Furthermore, the V content of the second covering film layer may be the same as that of the first covering film layer; however, since the B content is small, and the hardness drops somewhat, it is desirable that the V content be set at a value that is smaller than that of the first covering film layer, so that the hardness is not too low.

[0044] In particular, in the present example, a fourth covering film layer, third covering film layer, first multi-layer covering film layer, and second multi-layer covering film layer are successively layered on top of the substrate, and covering film layers having specified characteristics are further respectively disposed on the substrate side and surface layer side of the first multi-layer covering film layer. Specifically, a covering film layer which is superior in terms of toughness is disposed on the substrate side of a covering film with a large film stress, and a covering film layer which is superior in terms of hardness is disposed on the surface layer side contacting the object that is being cut, so that the covering film tends not to peel from the substrate, the surface layer tends not to wear, and chipping is very unlikely to occur.

[0045] Accordingly, in the present example, the hardness and lubricating properties of the covering film are improved by adding V and B to an AlCrN covering film, and the manner of layering is devised so that a high toughness can be ensured while a high hardness and lubricating properties are maintained, thus producing a hard covering film for a cutting tool which demonstrates exceptional performance showing improved wear resistance with respect to iron and steel materials.

[0046] Experimental examples supporting the effect of the present example will be described below.

[0047] In the experiments, a composite film forming apparatus respectively having two arc discharge ion plating evaporation sources and sputtering evaporation sources was used as a film forming apparatus. The four evaporation sources were disposed inside the apparatus at 90-degree intervals in the following order: arc discharge ion plating evaporation source (evaporation source A), sputtering evaporation source (evaporation source B), arc discharge ion plating evaporation source (evaporation source C), and sputtering evaporation source (evaporation source D). A rotary stage was disposed in the central part inside the apparatus; a film forming substrate was set on this stage, and this stage was caused to rotate while a bias voltage was applied. Targets of various compositions were attached inside the film forming apparatus as evaporation sources of metal and semi-metal components; furthermore, at least one gas selected from a group consisting of N_2 gas, CH_4 gas, and Ar gas was introduced into the film forming apparatus as a reaction gas, and a specified covering film was formed using a two-blade ball endmill (external diameter 2 mm) formed from an ultrahard alloy as a film forming substrate. The evaporation source D (sputtering evaporation source) was used to form the fourth covering film layer, the evaporation source A and evaporation source C (arc discharge ion plating evaporation sources) were used to form the third covering film layer and first multi-layer covering film layer, and the evaporation source A (arc discharge ion plating evaporation source) and evaporation source B (sputtering evaporation source) were used to form the second multi-layer covering film layer. During the formation of the fourth covering film layer and second multi-layer covering film layer, Ar gas was introduced into the film forming apparatus in the proportion of 1/2 of the total gas flow rate; during the formation of the third covering film layer and first multi-layer covering film layer, no Ar gas was introduced. Furthermore, film formation was performed with the arc discharge current set at 100 A, and the sputtering power set at 1.5 kW. The super-hard alloy of the substrate comprised hard particles whose main component was WC, and a binder whose main component was Co. The mean particle size of the WC particles was 1 μm, and the Co content was 8 wt%. In film formation, films were formed on the substrate endmill in the order fourth covering film layer, third covering film layer, first multi-layer covering film layer, and second multi-layer covering film layer so that the overall covering film thickness was 2.0 to 2.8 μm. A cutting experiment was performed under the following cutting conditions using an endmill covered with a specified covering film, and the wear width of the endmill relief surface was measured.

[0048] In the cutting experiment, the material that was cut was an SKD61 tempered material (52 HRC), and cutting was performed under wet conditions. An endmill with an external diameter of 2 mm was caused to rotate at a speed of 24600 min^{-1}; the feeding speed was set at 1480 mm/min, the cutting depth Ad was set at 0.16 mm, Pf was set at 0.7 mm, and the experiment was performed using a water-soluble cutting oil as a coolant. The results of the cutting experiment are shown in Table 1.

[Table 1]

No	Fourth Covering film layer		Third covering film layer		First multi-layer covering film layer		Second multi-layer covering film layer		Relief surface wear surface width (μm)	Remarks
	Composition	Thickness (μm)	Composition	Thickness (μm)	Composition	Thickness (μm)	Composition	Thickness (μm)		
1	TiCN	0.5	---	---	$[(Al_{65}Cr_{35})N+(Al_{58}Cr_{27}V_5B_{10})N]$ Mixture	1.5	---	---	126.8	Example
2	---	---	$(Al_{65}Cr_{35})N$	0.5	$[(Al_{65}Cr_{35})N+(Al_{58}Cr_{27}V_5B_{10})N]$ Mixture	1.5	$[Al_{58}Cr_{27}V_5B_{10})N+SiN]$ Mixture	0.4	123.2	Example
3	TiN	0.2	$(Al_{65}Cr_{35})N$	0.5	$[(Al_{65}Cr_{35})N+(Al_{58}Cr_{27}V_5B_{10})N]$ Mixture	1.5	$[(Al_{58}Cr_{27}V_5B_{10})N+SiN]$ Mixture	0.4	119.6	Example
4	TiN	0.2	---	---	$[(Al_{65}Cr_{35})N+(Al_{58}Cr_{27}V_5B_{10})N]$ Mixture	1.5	$[(Al_{57}Cr_{27}V_5B_{10})N+(Si_{80}Al_{20})N]$ Mixture	0.6	118.6	Example
5	---	---	$(Al_{61}Cr_{35}V_2B_2)N$	0.5	$[(Al_{61}Cr_{35}V_2B_2)N+(Al_{60}Cr_{26}V_2B_{12})N]$ Mixture	2.0	---	---	133.6	Example
6	TiN	0.2	---		$[(Al_{61}Cr_{35}V_2B_2)N+Cr_{26}V_2B_{12})N]$ Mixture	2.0	$[(Al_{60}Cr_{26}V_2B_{12})N+(Si_{90}Cr_{10})N]$ Mixture	0.6	120.4	Example
7	TiN	0.2	$(Al_{61}Cr_{35}V_2B_2)N$	$(Al_{61}Cr_{35}V_2B_2)N+(Al_{60}$ 0.5	$Cr_{26}V_2B_{12})N]$ Mixture	1.5	$[(Al_{60}Cr_{26}V_2B_{12})N+(Si_{90})Cr_{10})N]$ Mixture	0.4	117.4	Example

(continued)

No	Fourth Covering film layer		Third covering film layer		First multi-layer covering film layer		Second multi-layer covering film layer		Relief surface wear surface width (μm)	Remarks
	Composition	Thickness (μm)	Composition	Thickness (μm)	Composition	Thickness (μm)	Composition	Thickness (μm)		
8	CrN	0.2	---	---	$[(Al_{60}Cr_{38}B_2)N+(Al_{60}Cr_{25}V_7B_8)N]$ Mixture	2.0	---	---	130.4	Example
9	CrN	0.2	$(Al_{60}Cr_{38}B_2)N$	0.5	$[(Al_{60}Co_{38}B_2)N+(Al_{60}Cr_{25}V_7B_8)N]$ Mixture	1.5	$[(Al_{60}Cr_{25}V_7B_8)N+(Si_{90}A\ l_{10})N]$ Mixture	0.5	122.6	Example
10	---	---	$(Al_{70}Cr_{30})N$	0.5	$[(Al_{70}Cr_{30})N+(Al_{55}Cr_{25}V_{10}B_{10})N]$ Mixture	1.5	---	---	134.2	Example
11	CrCN	0.4	$(Al_{70}Cr_{30})N$	0.5	$[(Al_{70}Cr_{30})N+(Al_{55}Cr_{25}V_{10}B_{10})N]$ Mixture	1.5	$[(Al_{55}Cr_{25}V_{10}H_{10})N+SiN]$ Mixture	0.4	126.6	Example
12	TiN	0.2	---	---	$[(Al_{70}Cr30)N+(Al_{55}Cr_{25}V_{10}B_{10})N]$ Mixture	1.5	$[(Al_{55}Cr_{25}V_{10}B_{10})N+SiN]$ $[(Al_{55}Cr_{25}V_{10}B_{10})N+SiN]$ $[(Al_{55}Cr_{25}V_{10}B_{10})N+SiN]$ Mixture	0.4	124.8	Example
13	TiN	0.2	$(Al_{70}Cr_{30})N$	0.5	$[(Al_{70}Cr_{30})N+(Al_{55}Cr_{25}V_{10}B_{10})N]$ Mixture	1.5	$[(Al_{55}Cr_{25}V_{10}B_{10})N+SiN]$ Mixture	0.4	122.2	Example

(continued)

No	Fourth Covering film layer		Third covering film layer		First multi-layer covering film layer		Second multi-layer covering film layer		Relief surface wear surface width (μm)	Remarks
	Composition	Thickness (μm)	Composition	Thickness (μm)	Composition	Thickness (μm)	Composition	Thickness (μm)		
14	TiN	0.2	$(Al_{70}Cr_{30})N$	0.5	$[(Al_{70}Cr_{30})N+(Al_{55}Cr_{25}V_{10}B_{10})N]$ Mixture	1.5	$[(Al_{55}Cr_{25}V_{10}B_{10})N+(Si_{80}$ Mixture	0.4	124.2	Example
15	TiN	0.2	$(Al_{70}Cr_{30})N$	0.5	$[(Al_{70}Cr_{30})N+(Al_{58}Cr_{27}V_5B_{10})N]$ Mixture	1.5	$[(Al_{58}Cr_{27}V_5B_{10})N+(Si_{80}Al_{20})N]$ Mixture	0.4	118.4	Example
16	TiN	0.3	$(Al_{58}Cr_{27}V_5B_{10})N$	2.0	---	---	---	---	142.4	Comparative example
17	---	---	$(Al_{58}Cr_{27}V_5B_{10})CN$	2.5	---	---	---	---	149.6	Comparative example
18	---	---	$(Al_{57}Cr_{30}V_3B_{10})N$	2.5	---	---	---	---	146.8	Comparative example
19	---	---	$(Al_{65}Cr_{35})N$	2.5	---	---	---	---	158.4	Comparative example
20	---	---	TiCN	2.5	---	---	---	---	184.2	Comparative example

[0049] Furthermore, in the fourth covering film layer (TiCN) of No. 1 and in the third covering film layer (TiCN) of No. 20, the amount of C in the part directly above the substrate was set at 0, i.e., the composition of this part was set as TiN, and film formation was performed while gradually increasing the amount of C toward the surface layer part. Furthermore, in the fourth covering film layer (CrCN) of No. 11, the amount of C in the part directly above the substrate was set at 0, i.e., the composition of this part was set as CrN, and film formation was performed while gradually increasing the amount of C toward the surface layer part.
[0050] In Table 1, together with the present example, the results obtained when cutting experiments were performed using an endmill covered with a conventional hard covering film or a hard covering film outside the range of the preset invention by means similar to those used in the present example are shown as comparative examples.
[0051] It is seen from Table 1 that the endmill relief surface wear width is reduced, i.e., the wear resistance is better in the present example than in the comparative examples.
[0052] It is explicitly stated that all features disclosed in the description and/or the claims are intended to be disclosed separately and independently from each other for the purpose of original disclosure as well as for the purpose of restricting the claimed invention independent of the composition of the features in the embodiments and/or the claims. It is explicitly stated that all value ranges or indications of groups of entities disclose every possible intermediate value or intermediate entity for the purpose of original disclosure as well as for the purpose of restricting the claimed invention, in particular as limits of value ranges.

Claims

1. A hard covering film for a cutting tool formed on a cutting tool substrate, **characterized in that:**

   the hard covering film comprises a first multi-layer covering film layer formed by alternatingly layering two or more layers each of a first covering film layer and a second covering film layer;
   the first covering film layers have metal and semi-metal components that are expressed (in terms of at%) by

$$Al_{(100-x-y-z)}Cr_{(x)}V_{(y)}B_{(z)}$$

   (where $20 \le x \le 40$, $2 \le y \le 15$, and $5 \le z \le 15$), have N as a non-metallic element, and have unavoidable impurities;
   the second covering film layers have metal and semi-metal components that are expressed (in terms of at%) by

$$Al_{(100-u-v-w)}Cr_{(u)}V_{(v)}B_{(w)}$$

   (where $20 \le u \le 40$, $0 \le v \le 5$, $0 \le w \le 5$), have N as a non-metallic element, and have unavoidable impurities;
   the V content proportion y of the first covering film layer and the V content proportion v of the second covering film layer satisfy the relationship $y \ge v$; and
   the B content proportion z of the first covering film layer and the B content proportion w of the second covering film layer satisfy the relationship $z - 5 \ge w$.

2. The hard covering film for a cutting tool according to claim 1, **characterized in that:**

   a third covering film layer is disposed between the first multi-layer covering film layer and the substrate; and
   the metallic elements and semi-metallic elements of the third covering film layer are the same as the metallic elements and semi-metallic elements of the second covering film layer.

3. The hard covering film for a cutting tool according to claim 1, **characterized in that:**

   a fourth covering film layer is disposed directly above the substrate;
   the fourth covering film layer is a nitride or carbide having Ti as a main component; and
   the fourth covering film layer has a thickness set at 0.01 μm to 0.5 μm.

4. The hard covering film for a cutting tool according to claim 2, **characterized in that:**

a fourth covering film layer is disposed directly above the substrate;
the fourth covering film layer is a nitride or carbide having Ti as a main component; and
the fourth covering film layer has a thickness set at 0.01 μm to 0.5 μm.

5. The hard covering film for a cutting tool according to claim 1, **characterized in that:**

a fourth covering film layer is disposed directly above the substrate;
the fourth covering film layer is a nitride or carbide having Cr as a main component; and
the fourth covering film layer has a thickness set at 0.01 μm to 0.5 μm.

6. The hard covering film for a cutting tool according to claim 2, **characterized in that:**

a fourth covering film layer is disposed directly above the substrate;
the fourth covering film layer having Cr as a main component; and
the fourth covering film layer has a thickness set at 0.01 μm to 0.5 μm.

7. The hard covering film for a cutting tool according to any of claims 1 through 6, **characterized in that:**

a second multi-layer covering film layer formed by alternatingly layering two or more layers each of a fifth covering film layer and a sixth covering film layer is disposed on a surface layer side of the first multi-layer covering film layer;
metallic elements, semi-metallic elements, and non-metallic elements of the fifth covering film layer are the same as metallic elements, semi-metallic elements, and non-metallic elements of the first covering film layer;
the sixth covering film layer has metallic elements and semi-metallic elements expressed (in terms of at%) by

$$Si_{(100-t)}M_{(t)}$$

(where $0 \leq t \leq 30$, and M indicates one or more elements of group 4a, 5a, 6a, or 3b of the periodic table), has N as a non-metallic element, and has unavoidable impurities;
the fifth covering film layer has a thickness set at 40 nm or less;
the sixth covering film layer has a thickness set at 0.2 to 4 nm; and
the thicknesses of the fifth covering film layer and sixth covering film layer are set so that the fifth covering film layer is four or more times thicker than the sixth covering film layer.

8. The hard covering film for a cutting tool according to claim 7, **characterized in that** the first multi-layer covering film layer has an NaCl crystal structure.

9. The hard covering film for a cutting tool according to claim 8, **characterized in that:**

the substrate is made of a super-hard metal alloy composed of hard particles having WC as a main component, and a binder having Co as a main component;
the mean particle size of the WC particles is set at 0.1 μm to 2 μm; and
the Co content is set at 5 to 15% in terms of percentage by weight.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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