

CERMET FOR TOOL

The present invention relates to cermets for use in tools such as coating tools, spike pins, scrapers, hobs, reamers and screw drivers.

5 Conventionally, TiC base and Ti(C, N) base cermets have been paid attention because a) the raw materials are inexpensive, b) the cermets have strong oxidation-resistance so that tools made of such materials are less subject to oxidation during high-speed cutting in which the
10 tools are exposed to high temperature, c) such cermets offer strong adhesion-resistance at high temperature, and d) such cermets are chemically stable. So the tools made of these materials are less liable to wear which occurs due to their affinity to the material to be cut than WC base
15 alloys (cemented carbide).

This type of cermet, however, has a limited scope of application because 1) its mechanical breaking-resistance (referred to as breaking-resistance hereafter), 2) crack extension-resistance due to thermal shock or uneven
20 distribution of heat (referred to as thermal shock resistance hereinafter), and 3) plastic deformation resistance at high temperature or under high pressure (referred to as plastic deformation-resistance hereinafter) are not quite satisfactory.

25 Lately, sintered bodies having a hard dispersed phase (carbonitride phase) made of carbide, nitride and carbonitride of transition metals in Groups IVa, Va and VIa

have been proposed to overcome the problems described above. Further, various proposals have been made on the structure and composition of such sintered bodies with the aim of improving the properties of cermets (see Japan
5 Published Examined Patent Application No. S 63-3017).

For instance, a proposed cermet containing N has WC and carbide, nitride and carbonitride of transition metals in Group Va. Structurally, such a cermet contains a hard dispersed phase comprising TiN single phase particles
10 (single structural particles) and dual phase particles in which the cores are rich in Groups IVa transition metal and the outer layers are rich in Groups Va and VIa transition metals.

However, a sintered body having such a hard dispersed
15 phase has not successfully enhanced such performance characteristics as breaking-resistance, thermal shock-resistance, and plastic deformation-resistance without impairing the cermet's inherent properties.

More particularly, if substances such as WC and
20 carbide, nitride, and carbonitride of Group Va transitional metals are added to a cermet to improve breaking-resistance, thermal shock-resistance, and plastic deformation-resistance, dual phase particles grow in number, which reduces mechanical wear-resistance (referred
25 to as wear-resistance hereinafter), and adhesion-resistance at high temperature (referred to as temperature adhesion-resistance hereinafter).

According to the invention there is provided a cermet for use in tools comprising:

- 70 to 95 volume percent of a hard dispersed phase comprising 5 to 50 volume percent of Type-I particles, 5 which are single phase particles; and 95 to 50 volume percent of Type-II particles, which are dual phase particles, said hard dispersed phase containing at least one Group IVa transition metal, at least one Group Va transition metal, tungsten, carbon and nitrogen, wherein 10 (a) the mole ratio of the total amount of Group IVa transition metal, Group Va transition metal and tungsten to the total amount of carbon and nitrogen is 1.0 : 0.85-1.0, (b) the mole ratio of Group IVa transition metal to Group Va transition metal to tungsten is 0.50-0.85 : 0.05-0.30 : 15 0.05-0.30, (c) titanium is used as a Group IVa transition metal and tantalum is used as a Group Va transition metal, the mole ratio of titanium to Group IVa transition metal(s) is 0.8-1 : 1 and the mole ratio of tantalum to Group Va transition metal(s) is 0.30 -1.0 : 1.0, (d) the mole ratio 20 of carbon to nitrogen is 0.40-0.90 : 0.10-0.60 and (e) the mole ratio of nitrogen to carbon and nitrogen in the Type-I particles is 0.25-1.0 : 1; and 30 to 5 volume percent of a binder phase composed of at least one Group VIII metal.

The cermet of the invention has superior breaking- 25 resistance, thermal shock-resistance, and plastic deformation-resistance without impairment of wear-resistance and temperature adhesion-resistance.

(a) The Type-I particles account for 5-50 volume percentage of the hard dispersed phase and are

single phase particles comprising at least one nitride or carbonitride of a Group IVA transition metal, wherein the ratio of N to C and N is 0.25-1 to 1.

(b) The Type-II particles preferably contain more
5 Group IVA transition metal in the outer layer than in the core while said particles contain more Group Va transition metal and W in the core than in the outer layer, and the ratio of Group IVA transition metal to Group Va transition metal to W changes gradually and sequentially from the core
10 to the outer layer.

The present invention has been made upon the following background.

i) Background on Type-I particles

If a sintered body containing N for use in cermet
15 contains Type-I particles whose cores are rich in carbide, nitride and carbonitride of Group IVA transition metal and whose outer layers are rich in solid solutions of carbonitride of Groups IVA, Va and VIA transition metals the cermet develops increasingly poorer wear-resistance and
20 breaking-resistance as the outer layers become thicker.

It is, therefore, important to keep the formation of solid solutions thin in the outer layers and disperse particles rich in Group IVA transition metal throughout a cermet. This way the cermet is provided with high wear-
25 resistance, adhesion-resistance and breaking-resistance.

ii) Background on Type-II particle

Carbide, nitride and carbonitride of Group IVA

transition metal and WC are commonly added to a sintered body containing N for use in cermet to increase thermal shock-resistance, breaking-resistance and plastic deformation-resistance, which produces, as a component of a hard dispersed phase, dual phase particles wherein WC abound in the cores while Group IVa and Va transition metals abound in the outer layers. Although the dual phase particles improve thermal shock-resistance, breaking-resistance and plastic deformation-resistance to a certain extent, wear-resistance and adhesion-resistance which are inherent properties of a cermet decrease as the amount of Type-II particles increases in a sintered body. In other words, it is essential to restrain the development of the dual phases in Type-II particles when carbide, nitride and carbonitride of a Group Va transition metal and WC are added.

Based on the background described above, we have discovered that Type-II particles having the structure and the components shown in Fig. 1(a) significantly improve the above-described performance characteristics of a cermet.

In Fig. 1(a), the core and the outer layer of a Type-II particle are compared in terms of the amount of each component therein. Likewise, Fig. 1(b) compares the core and outer layer of a conventional particle. The curved lines of Fig. 1 schematically indicate the amount of each component in the core and the outer layer and do not reflect the actual ratio therein.

As Fig. 1(a) shows, a Type-II particle present in the cermet of the present invention has a weakly developed dual phase structure without a clearly defined line distinguishing the core and the outer layer. The core is rich in Group Va transition metal, W and C, while the outer layer is rich in Group IVa transition metal and N. The content ratio of these components gradually and sequentially changes from the core to the surface: the amount of Group Va transition metal and W increases from the surface to the core, while Group IVa transition metal, conversely, increases from the core to the surface. On the other hand, the prior-art particle shown in Fig. 1(b) has a well-developed dual phase structure, wherein the core is rich in W and C while the outer layer is rich in Group IVa and Va transition metals and N. A Type-II particle present in the cermet of the present invention distinctively differs from the prior-art particle in that the core abounds in Group Va transition metal.

Due to the above-described structure and composition, there is contained a larger amount of solid solutions of carbide and carbonitride of Group Va transition metal and WC in Type-II particles in the cermet of the present invention than in the conventional particles, which allows performance characteristics of carbide and carbonitride of Group Va transition metal and WC such as thermal shock-resistance to be fully developed, while breaking-resistance, a performance characteristic of WC, is also

improved. Furthermore, the reduction of temperature adhesion-resistance, which is caused by addition of WC, is minimized. Since a large amount of solid solutions of carbide, nitride and carbonitride of Group Va transition metal are contained in the core, thermal shock-resistance is enhanced. Further, the reduction of wear-resistance caused by addition of Group Va transition metal is minimized because the content ratio of solid solutions of Group Va transitional metal is low in the outer layer.

10 We have performed experiments on the content ratio of Type-I and Type-II essentially constituting a hard dispersed phase. The content ratio of Type-I particles to Type-II particles was gradually changed until the ratio which maximizes the performance characteristics was
15 discovered.

W alone, excluding Mo, of the Group VIa transition metal is used for this invention because solid solutions made of Mo and Group IVa and Va transition metal are easily formed in Type-I particles if Mo is added, which renders
20 the structure in the outer layers of Type-I particles fragile. Therefore, breaking-resistance is impaired. Moreover, addition of Mo would reduce thermal shock-resistance and breaking-resistance because the formation of solid solution of W and a binder phase is limited due to
25 the fact that Mo more easily forms a solid solution with a binder phase than W does.

The following are the reasons that the structure and

components for the present invention have been determined as described above:

1) The volume percentages of the hard dispersed phase and of the binder phase (70 to 95% and 5 to 30%, respectively) in the cermet of the present invention have been determined for the following reasons.

If a cermet contains less than 70% by volume of a hard dispersed phase or more than 30% by volume of a binder phase, wear-resistance, temperature adhesion-resistance and plastic deformation-resistance are adversely affected. On the other hand, if the volume percentage of a hard dispersed phase is over 95% or the volume percentage of a binder phase is below 5%, breaking-resistance and thermal shock-resistance are adversely affected.

So, these performance characteristics are fully developed if the volume percentages of a hard dispersed phase and that of a binder phase is set in the range from 70 to 95% and from 5 to 30%, respectively.

2) The mole ratio of Group IVa transition metal to Group Va transition metal to W (0.5 - 0.85 to 0.05 - 0.30 to 0.05 - 0.30) has been determined for the following reasons.

If the amount of Group IVa transition metal in the above ratio is below 0.5, the content ratio of single phase particles (Type-I particles) is too low, which results in a reduction in wear-resistance and temperature adhesion-resistance. Further, such a low amount of Group IVa

transition metal reduces the formation of a solid solution of Group IVa transition metal in the outer layers of Type-II particles, hence making the content ratio of Group Va transition metal and W in the outer layer too high.

5 Consequently, wear-resistance and temperature adhesion-resistance are impaired.

If the amount Group IVa transition metal in the above ratio exceeds 0.85, thermal shock-resistance and breaking-resistance are impaired because the content ratio of Type-
10 II particles becomes too low. Excessive solid solution easily forms in the outer layers of Type-I particles to affect wear-resistance and breaking-resistance.

Furthermore, because the content ratio of solid solutions of Group IVa transition metal becomes too high in the cores
15 of Type-II particles, properties of Group Va transition metal and W such as thermal shock-resistance and breaking-resistance are reduced.

Therefore, if the amount of Group IVa transition metal in the above ratio is set between 0.5 and 0.85, the
20 above-identified characteristics are maximized.

(3) The mole ratio of Group Va transition metal to Group IVa transition metal to W (0.05 - 0.30 to 0.5 - 0.85 to 0.05 - 0.30) has been determined for the following reasons.

25 If the amount of Group Va transition metal is below 0.05, the content ratio of the components (especially W and Group IVa transition metal) does not change gradually and

sequentially and particles similar to the conventional dual phase particles having cores rich in W and outer layers rich in Group IVa transition metal are easily formed to reduce thermal shock-resistance and plastic deformation-
5 resistance.

If the amount is over 0.3, the outer layers of Type-II particles contain too much Group Va transition metal, resulting in reduction of wear-resistance. Further, excessive solid solutions are apt to form in the outer
10 layers of Type-I particles to reduce wear-resistance and breaking-resistance.

On the other hand, if the amount of Group Va transition metal is set in the range from 0.05 to 0.3, the above-identified performance characteristics are maximized.

15 (4) The mole ratio of W to Group IVa transition metal to Group Va transition metal (0.05 - 0.30 to 0.5 - 0.85 to 0.05 - 0.30) has been determined for the following reasons.

If the amount of W is below 0.05 in the above ratio,
20 growth of Type-II particles is checked and wettability of Type-II particles by a binder phase is decreased. Therefore, Type-II particles become fragile and impair thermal shock-resistance and breaking-resistance.

If the amount of W is over 0.3, Type-BI solid
25 solution of W and Group IVa and Va transition metals (especially those in Group Va) does not form and solid solution rich in WC deposits. Then, the content ratio of

the components does not change gradually and sequentially from the cores to the outer layers to reduce wear-resistance and temperature adhesion-resistance. Moreover, since W does not easily combine with N, decomposition of N is apt to occur, producing pores and blowholes. Consequently, wear-resistance and breaking-resistance decrease.

Therefore, if the amount of W in the above ratio is set between 0.05 and 0.3, superior performance characteristics can be obtained.

(5) The mole ratio of C to N (0.4 - 0.9 to 0.1 - 0.6) has been determined for the following reasons.

If the amount of C is more than 0.9 and the amount of N is less than 0.1 in the above ratio, growth of Type-I and Type-II particles becomes excessive so that the diameter of the particles become too large. Excessive solid solutions easily form in the outer layers of Type-I particles so that fewer Type-I particles (single phase particles) form. Further, because solid solutions of Group IVa transition metal form at too high a rate, performance characteristics obtained by addition of W and Group Va transition metal are reduced, the reduced characteristics being wear-resistance, breaking-resistance, thermal shock-resistance and plastic deformation-resistance.

If the amount of C in the above-described ratio is less than 0.4 and the amount of N in the above-described ratio is more than 0.6, decomposition of N easily occurs to

produce pores and blowholes. The content ratio of Type-II particles becomes too low. Further, Type-BI solid solution of W and Group IVa and Va transition metals (especially those in Group Va) does not form and solid solution rich in WC deposits. Consequently, the content ratio of the components does not change gradually and sequentially from the cores to the outer layers. If too much N is contained in the cermet, the range of sintering temperature becomes too high. As a result, excessive solid solutions are easily formed in the outer layers of Type-II particles. For these reasons, wear-resistance, breaking-resistance, and temperature adhesion-resistance decrease.

If the mole ratio of C to N is in the range of 0.4-0.9 to 0.1-0.6, the performance characteristics are superior.

(6) The mole ratio of Group IVa transitional metal, Group Va transition metal, and W to C and N (1 to 0.85 - 1.0) has been determined for the following reasons (IVa+Va+W/C+N ratio).

If the amount of C and N in the above-described ratio is less than 0.85, a harmful chemical substance materializes to impair breaking-resistance.

If the amount of C and N in the above-described ratio is more than 1.0, a graphite phase easily deposits and the stoichiometric composition of a sintered body becomes imperfect to reduce breaking-resistance.

If the ratio is 1 to 0.85-1.0, a superior

characteristic mentioned above is obtained. A proper mole ratio is determined by the ratio of N to C and N; the greater the N/C+N ratio is, the smaller the Group IVa metal + Group Va metal + W/C+N ratio is.

- 5 (7) The mole ratio of Ti to all the Group IVa transition metals (0.8-1 to 1) has been determined for the following reasons.

As the amount of Zr and Hf in the Group IVa transition metal increases, wear-resistance, thermal shock-
10 resistance, and plastic deformation-resistance can be expected to improve. Also, if the amount of Zr and Hf is more than 0.2, the degree of sintering lowers, hence reducing wear-resistance and breaking-resistance.

If the mole ratio of Ti to all the Group IVa
15 transition metals is 0.8-1 to 1, superior performance characteristics are obtained.

- (8) The mole ratio of Ta to Group Va transition metals (0.3-1 to 1) has been determined for the following reasons.

20 Ta and Nb, which are Group Va transition metals, are added to improve thermal shock-resistance and plastic deformation-resistance. It is common to use Nb in part in the place of expensive Ta. However, if the amount of Ta in the above-shown ratio is less than 0.3, restraint on
25 particle growth in a hard dispersed phase becomes extremely weak and wear-resistance, breaking-resistance and thermal shock resistance deteriorate.

If the mole ratio of Ta to all the Group Va transition metals is 0.3-1 to 1, the above-mentioned performance characteristics become superior.

(9) The mole ratio of N to C and N in Type-I particles (0.25-1 to 1) has been determined for the following reasons.

Type-I particles, if they are made small in size, large in number, and evenly distributed throughout a sintered body, improve wear-resistance, breaking-resistance, and plastic deformation-resistance. If the mole ratio of N to C and N is less than 0.25, excessive solid solution easily forms in the outer layers of Type-I particles and particle growth becomes excessive, which deteriorates the above-described performance characteristics.

If the ratio of N to C and N is 0.25-1 to 1, these performance characteristics become superior.

(10) Type-I particles account for 5-50 volume percentage of a hard dispersed phase. This percentage has been determined by the following reasons.

Generally, the outer layer of a dual phase particle comprises solid solutions of Group IVa, Va, and VIa transition metals. It is known that the thicker the layer is, the poorer wear-resistance and breaking-resistance are. Therefore, it is important to secure a predetermined percentage (5 - 50 volume percentage in this invention) of the single phase particles in a hard dispersed phase by

making the outer layers thin. Thus, superior wear-resistance and breaking-resistance of Type-I particles are guaranteed. It is also important to disperse Group IVa transition metals evenly throughout Type-I particles

- 5 (single phase particles) to obtain high wear-resistance and temperature adhesion-resistance. Type-I particles (single phase particles) are small in size so that they easily disperse to improve plastic deformation-resistance.

Therefore, if a hard dispersed phase contains less
10 than 5% by volume of Type-I particles, high wear-resistance and plastic deformation-resistance can not be obtained. Further, an excessive amount of Group IVa transition metal is contained in the form of solid solution in Type-II
15 Type-I particles in a hard dispersed phase. Consequently, performance characteristics of Type-II particles such as breaking-resistance and temperature adhesion-resistance deteriorate.

On the other hand, if a hard dispersed phase contains
20 more than 50 volume percentage of Type-I particles, there is contained too small an amount of Type-II particles, which causes deterioration of wear-resistance and thermal shock-resistance. Moreover, since much of Group IVa transition metal is used to form Type-I particles, there is
25 not enough solid solution of Group IVa transition metal in the outer layer of Type-II particles. Thus, wear-resistance decreases.

If a hard dispersed phase contains in the range from
5 to 50 volume percentage of Type-I particles, the above-
30 identified performance characteristics improve.

The embodiments of the present invention will be explained hereinafter.

A cermet for tools for the present invention is manufactured in the following method.

First, solid solutions used as materials for cermet are manufactured.

Powdered materials shown in Table 1 which are commercially available powder metallurgical materials, are mixed in a ratio shown in Table 2 in a stainless-steel ball mill. Solid solutions not containing nitrogen, (Ta, W, Mo) C and (Ta, Nb, W) C, are manufactured by means of heating in vacuum at a temperature ranging from 1500 to 1800 degree centigrade for one to five hours while solid solutions containing carbonitride, (Ti, Ta, W) (C, N), are manufactured under the same conditions except that heating is performed in an air stream under nitrogen partial pressure of 50 to 650 torr. Then, the manufactured solid solutions were milled to obtain solid solution particles having mean particle diameter ranging from 1.0 to 1.7 micrometer.

The mole ratio of the components contained in the obtained solid solution powder was measured by chemical analysis. The results are shown in Table 2. X-ray diffraction was performed to confirm that the mole ratio of the components such as carbide, nitride, and carbonitride of Ta, Nb, W, and Mo contained in the solid solution powder does not change throughout the powder; that is to say, the solid solutions have a uniform composition.

Second, a predetermined proportion of the above-mentioned materials shown in Table 1 and the above-described solid solution shown in Table 2 are mixed by the combinations specified in Table 3. Secondly, acetone is added to this mixture to be milled and mixed for 50 to 120 hours. Further, drying was performed and paraffin totaling 1.0% by weight of the mixture is mixed into the mixture. Then, pressure of 1.5 kg per square millimeter is applied to the mixture. After the pressed mixture was degreased, it is heated for about three hours until the mixture reaches a temperature ranging from 1,000 to 1,200 degrees centigrade in a vacuum furnace. The mixture is now held in an Ar gas atmosphere under a pressure ranging from -60 to -25 centimeter Hg at a temperature ranging from 1,400 to 1,550 degrees centigrade for one hour. Furthermore, the mixture is cooled down to 1,000 degrees centigrade at a rate of 5 to 30 degrees centigrade per minute to obtain Sample Sintered Bodies from No. 1 to No. 60 shown in Table 4.

Chemical analysis was performed on the sample sintered bodies (referred to as samples hereinafter) comprising a hard dispersed phase to determine the components of said hard dispersed phase, the components being Groups IVa, Va and VIa transition metals, C and N. The mole and volume percentages of the transition metals contained in the hard dispersed phase were determined by using a transmission electron microscope. The results of the chemical analysis and the microscopic measurement are shown in Table 4. The ratio of N to C and N in Type-I particles of each sample was

also determined by Auger analysis; the ratios of Samples No. 1 to 24 which are the embodiments of the present invention were 0.25 or more. Harmful substances such as graphite or a decarbonized phase were observed in none of the samples from No.1 to 60.

The capitalized alphabets of the left column of Table 3 denote the combinations of the compositions of the samples, of which E, F, G, I, and J are the combinations of the samples for the present invention and A, B, C, D, H, K, and L are the combination of the samples provided for the purpose of comparison and are not combinations according to the present invention. Likewise, Samples No.1 to 24 of the Table 4 are the sintered bodies for the present invention while Samples No. 25 to 60 are sintered bodies provided for the purpose of comparison. Table 4 shows the mole percentage of each element of each hard dispersed phase, the volume percentage of the hard dispersed phase and the binder phase in each sample, and the sintering temperature at which sintering was conducted for each sample.

The structure and composition of the particles contained in Samples No. 1 to 60 were studied to identify the following five types of particles: Type-I, II, III, IV, and V particles. The samples for the present invention (Samples No. 1 to 24) uniquely consist of Type-I and Type-II particles, whose structure and composition have already been described in detail above. Therefore, no further description of the two types of particles is provided.

Type-III particles are dual phase particles having cores

rich in Group IVa transition metal and devoid of Group Va and VIa transition metals and outer layers rich in Group Va and VIa transition metals.

Type-IV particles are dual phase particles whose
5 cores are rich in Group VIa transition metal and devoid of Group IVa and Va transition metals and whose outer layers are rich in Group IVa and Va transition metals.

Type-V particles, formed only in the hard dispersed phase manufactured by the combination denoted by K of Table
10 3, are single phase particles without cores and have solid solutions of Group IVa, Va and VIa transition metals uniformly distributed throughout therein so that the mole ratio of the components thereof does not change distinctively from the core to the surface.

15 Table 5 indicates the types of particles included in the hard dispersed phase of each Sample.

The operational lives of Samples No. 1 to 60 were estimated by the following four cutting tests.

Test 1 (turning)

20 Tip shape: Japan Industrial Standard SNP432

Work material: Japan Industrial Standard SNCM8

(Brinell hardness: BH300)

Cutting speed: 200 meter per minute

Feed rate: 0.2 millimeter per revolution

25 Depth of cut: 1.5 millimeter

Estimation of life: Time (minutes) required for flank wear (VB) to reach 0.2 millimeter (under a dry condition where

coolant was not used)

Test 2 (milling)

Tip shape: Japan Industrial Standard SPP422

Work material: Japan Industrial Standard SCM440H

(Brinell hardness: BH240)

Cutting speed: 244 meter per minute

Feed rate: 0.12 millimeter per revolution

Depth of cut: 3 millimeter

Estimation of life: Time (minutes) required for flank wear (VB) to reach 0.2 millimeter (under a dry condition where coolant was not used)

Test 3 (milling)

Tip shape: Japan Industrial Standard SPP422

Work material: Japan Industrial Standard SCM440H

(Brinell hardness: BH240)

Cutting speed: 150 meter per minute

Feed rate: 0.25 millimeter per revolution

Depth of cut: 1.5 millimeter

Estimation of life: Number of impact frequencies until broken (under a dry condition)

Test 4 (turning)

Tip shape: Japan Industrial Standard SNP432

Work material: Japan Industrial Standard SNCM8

(Brinell hardness: BH300)

Cutting speed: 200 meter per minute

Feed rate: 0.38 millimeter per revolution

Depth of cut: 1.5 millimeter

**Estimation of life: Number of impact frequencies until broken
(under a condition that water**

soluble coolant was applied to the tip)

Table 6 shows the results of the four tests.

TABLE 1

NO.	RAW MATERIALS (COMPOUNDS, SOLID SOLUTIONS)	MEAN PARTICLE DIAMETER (μm)	MOLE RATIO OF THE COMPOUNDS OF THE SOLID SOLUTIONS (x, y, z)
1	TiC	1.0	
2	TiN	1.0	
3	TaC	1.5	
4	WC	1.0	
5	Mo ₂ C	1.5	
6	(Ta, Nb)C	1.0	x+y=1 x=0.33, 0.67, 0.20
7	(Ta, W)C	1.0	x+y=1 x=0.2, 0.33, 0.5, 0.67, 0.8
8	Ti(C, N)	1.0	x+y=1 x=0.1, 0.3, 0.5, 0.7
9	(Ti, Zr)(C, N)	1.7	x+y=1 x=0.75, 0.8, 0.85
10	(W, Mo)C	1.2	x+y=1 x=0.7
11	(Ti, Ta, W)C	1.0	x+y+z=1 $\begin{pmatrix} x=0.70 & 0.62 & 0.44 \\ y=0.15 & 0.19 & 0.28 \\ z=0.15 & 0.19 & 0.36 \end{pmatrix}$

TABLE 2

WEIGHT RATIO OF THE MIXED COMPOUNDS	MOLE RATIO OF THE COMPONENTS OF THE SOLID SOLUTIONS
(1) (Ta, Nb, W)C	
TaC : NbC : WC 1 : 1 : 2 3 : 1 : 4 1 : 3 : 4	(Ta0.21 Nb0.37 W0.42)C (Ta0.35 Nb0.20 W0.45)C (Ta0.10 Nb0.51 W0.39)C
(2) (Ti, Ta, W)(C, N)	
TiC : TiN : TaC : WC 2.8 : 3.2 : 2 : 2 1.8 : 2.2 : 2 : 2 2.8 : 3.2 : 2 : 4 2.8 : 3.2 : 4 : 2	(Ti0.82 Ta0.09 W0.09)(C0.61 N0.39) (Ti0.76 Ta0.12 W0.12)(C0.64 N0.36) (Ti0.76 Ta0.08 W0.16)(C0.65 N0.35) (Ti0.75 Ta0.17 W0.08)(C0.65 N0.35)
(3) (Ta, W, Mo)C	
TaC : WC : Mo ₂ C 1 : 1 : 1 2 : 3 : 1 3 : 2 : 1	(Ta0.26 W0.25 Mo0.49)C (Ta0.29 W0.43 Mo0.28)C (Ta0.44 W0.29 Mo0.27)C

TABLE 3

REFERENCE SYMBOL FOR EACH COMBINATION	COMBINATION	
	HARD DISPERSED PHASE	BINDER PHASE
A	TiC+TiN+TaC+WC	Ni+Co
B	TiC+TiN+TaC+WC+Mo ₂ C	
C	TiC+TiN+(Ta, Nb)C+WC	
D	TiC+TiN+TaC+(W, Mo)C	
E*	Ti(C,N)+(Ta, Nb, W)C	
F*	Ti(C, N)+(Ta, W)C	
G*	Ti(C, N)+(Ti, Ta, W)C	
H	TiN+(Ta, W)C	
I*	TiN+(Ti, Ta, W)C	
J*	(Ti, Zr)(C, N)+(Ta, W)C	
K	(Ti, Ta, W)(C, N)	
L	Ti(C, N)+(Ta, W, Mo)C	

* EMBODIMENTS FOR THE PRESENT INVENTION

TABLE 4

S A M P L E N O.	COMPONENTS OF HARD DISPERSED PHASE												BINDER PHASE		S I N T E R I N G T E M P E R A T U R E (°C)	
	C O M B I N A T I O N	MOLE PERCENT OF EACH ELEMENT IN METALS IN GROUPS IVa, Va, & VIa						MOLE PERCENT OF EACH GROUP IN ALL GROUPS			MOLE RATIO OF C TO N		VOLUME PERCENT WHEN MIXED	VOLUME PERCENT WHEN MIXED		
		Gr.IVa		Gr.Va		Gr.VIa		Gr. IVa	Gr. Va	Gr. VIa	C	N		Ni		Co
		Ti	Zr	Ta	Nb	W	Mo									
1	E	72	—	6	11	11	—	72	17	11	67	33	88	4	8	1450
2	E	74	—	9	5	12	—	74	14	12	65	35	88	4	8	1450
3	F	52	—	24	—	24	—	52	24	24	77	23	88	4	8	1450
4	F	62	—	19	—	19	—	62	19	19	72	28	88	4	8	1450
5	F	62	—	19	—	19	—	62	19	19	87	13	88	4	8	1440
6	F	62	—	19	—	19	—	62	19	19	68	32	88	4	8	1450
7	F	76	—	12	—	12	—	76	12	12	65	35	88	4	8	1450
8	F	76	—	8	—	16	—	76	8	16	64	36	88	4	8	1450
9	F	76	—	8	—	16	—	76	8	16	80	20	88	4	8	1400
10	F	76	—	17	—	7	—	76	17	7	64	36	88	4	8	1400
11	F	83	—	9	—	8	—	83	9	8	61	39	88	4	8	1500
12	F	68	—	16	—	16	—	68	16	16	69	31	88	4	8	1450
13	F	68	—	16	—	16	—	68	16	16	55	45	88	4	8	1550
14	F	68	—	7	—	25	—	68	7	25	70	30	88	4	8	1450
15	F	68	—	26	—	6	—	68	26	6	69	31	88	4	8	1450
16	G	76	—	12	—	12	—	76	12	12	61	39	88	4	8	1500
17	G	76	—	12	—	12	—	76	12	12	85	15	88	4	8	1400
18	I	76	—	12	—	12	—	76	12	12	44	56	88	4	8	1550
19	I	76	—	12	—	12	—	76	12	12	64	36	88	4	8	1500
20	I	83	—	8	—	9	—	83	8	9	61	39	88	4	8	1450
21	J	58	10	16	—	16	—	68	16	16	69	31	88	4	8	1500
22	J	64	16	10	—	10	—	80	10	10	63	37	88	4	8	1500
23	F	76	—	12	—	12	—	76	12	12	66	34	79	7	14	1450
24	F	76	—	12	—	12	—	76	12	12	65	35	94	2	4	1500
25	F	76	—	12	—	12	—	76	12	12	67	33	97	1	2	1550
26	F	76	—	12	—	12	—	76	12	12	66	34	67	11	22	1400
27	A	76	—	12	—	12	—	76	12	12	68	32	88	4	8	1450
28	A	76	—	8	—	16	—	76	8	16	67	33	88	4	8	1450
29	A	68	—	7	—	25	—	68	7	25	72	28	88	4	8	1450
30	A	52	—	24	—	24	—	52	24	24	82	18	88	4	8	1450
31	A	82	—	9	—	9	—	82	9	9	64	36	88	4	8	1500
32	B	73	—	11	—	11	5	73	11	16	67	33	88	4	8	1450
33	B	69	—	12	—	6	3	69	12	9	64	36	88	4	8	1400
34	C	72	—	6	11	11	—	72	17	11	69	31	88	4	8	1450
35	C	71	—	3	15	11	—	71	18	11	69	31	88	4	8	1450
36	D	73	—	11	—	11	5	73	11	16	66	34	88	4	8	1450
37	D	69	—	12	—	6	3	69	12	9	65	35	88	4	8	1400
38	E	72	—	6	11	11	—	72	17	11	69	31	88	4	8	1550
39	F	76	—	12	—	12	—	76	12	12	67	33	88	4	8	1550
40	F	83	—	9	—	8	—	83	9	8	63	37	88	4	8	1550

TABLE 4 (continuation)

41	F	52	-	24	-	24	-	52	24	24	81	19	88	4	8	1550
42	F	86	-	7	-	7	-	86	7	7	61	39	88	4	8	1500
43	F	86	-	7	-	7	-	86	7	7	63	37	88	4	8	1550
44	F	44	-	28	-	28	-	54	28	28	81	19	88	4	8	1500
45	G	76	-	12	-	12	-	76	12	12	92	8	88	4	8	1400
46	H	62	-	19	-	19	-	62	19	19	41	59	88	4	8	1550
47	H	62	-	30	-	8	-	62	30	80	42	58	88	4	8	1550
48	I	83	-	8	-	9	-	83	8	9	35	65	88	4	8	1550
49	J	54	18	14	-	14	-	72	14	14	67	33	88	4	8	1550
50	K	76	-	12	-	12	-	76	12	12	64	36	88	4	8	1450
51	K	76	-	8	-	16	-	76	8	16	64	36	88	4	8	1450
52	K	75	-	17	-	8	-	76	17	8	65	35	88	4	8	1450
53	K	52	-	24	-	24	-	52	24	24	77	23	88	4	8	1450
54	K	82	-	9	-	9	-	82	9	9	63	37	88	4	8	1500
55	K	82	-	9	-	9	-	82	9	9	44	56	88	4	8	1550
56	K	52	-	24	-	24	-	52	24	24	86	14	88	4	8	1400
57	L	62	-	10	-	10	18	62	10	28	72	28	88	4	8	1450
58	L	65	-	10	-	15	10	65	10	25	71	29	88	4	8	1450
59	L	52	-	12	-	12	24	52	12	36	77	23	88	4	8	1450
60	L	65	-	15	-	10	10	65	15	20	72	28	88	4	8	1450

TABLE 5

SAMPLE NO.	MOLE PERCENT OF N IN C AND N	TYPES OF PARTICLES CONTAINED IN EACH SAMPLES				VOLUME PERCENT OF TYPE-I PARTICLES OF ALL TYPES OF PARTICLES IN HARD DISPERSED PHASE
		TYPE-I	TYPE-II	TYPE-III	TYPE-IV	
1	33	X	X			24
2	35	X	X			23
3	23	X	X			13
4	28	X	X			19
5	13	X	X			7
6	32	X	X			20
7	35	X	X			25
8	36	X	X			26
9	20	X	X			14
10	36	X	X			25
11	39	X	X			28
12	31	X	X			17
13	45	X	X			35
14	30	X	X			19
15	31	X	X			16
16	39	X	X			31
17	15	X	X			7
18	56	X	X			46
19	36	X	X			27
20	39	X	X			34
21	31	X	X			28
22	37	X	X			39
23	34	X	X			27

TABLE 5 (continuation)

24	35	X	X			26
25	33	X	X	X		
26	34	X	X			
27	32			X	X	0
28	33			X	X	0
29	28			X	X	0
30	18			X	X	0
31	36			X		0
32	33			X		0
33	36			X	X	0
34	31			X	X	0
35	31			X	X	0
36	34			X	X	0
37	35			X	X	0
38	31			X		0
39	33			X		0
40	37			X		0
41	19		X	X	X	0
42	39	X	X	X		
43	37			X		0
44	19	X	X			
45	8			X		0
46	59	X	X	X		
47	58			X		0

TABLE 5 (continuation)

48	65	X		X		
49	33	X	X	X		
50	36			X		0
51	36			X	X	0
52	35			X		0
53	23			X	X	0
54	37			X		0
55	56			X		0
56	14			X	X	0
57	28		X	X		0
58	29	X	X	X		
59	23		X	X		0
60	28		X	X		0

TABLE 6

SAMPLE NO.	TEST 1	TEST 2	TEST 3	
	TIME REQUIRED FOR FLANK WEAR TO REACH 0.2 mm (MINUTES)	←----	NUMBER OF IMPACT FREQUENCIES UNTIL BROKEN	←----
1	16	23	963	716
2	18	25	1046	875
3	13	15	1195	1087
4	18	25	1052	947
5	16	21	825	704
6	18	25	1174	1049
7	19	27	1064	979
8	21	28	1005	846
9	17	19	875	729
10	22	28	793	654
11	19	26	1192	1105
12	17	22	1041	879
13	19	22	1165	891
14	18	23	1170	1105
15	16	21	974	956
16	19	25	1102	1007
17	17	22	806	695
18	19	28	1241	1092
19	17	24	1049	974
20	23	29	965	822
21	25	31	729	713
22	25	32	652	634
23	8	15	>3000	>3000

TABLE 6 (continuation)

24	>40	>40	342	214
25	>40	BROKEN	<10	<10
26	<2	<2	>3000	>3000
27	15	21	743	621
28	16	20	367	420
29	18	22	235	127
30	11	17	743	524
31	23	29	322	<10
32	21	21	522	341
33	13	20	345	378
34	11	19	820	543
35	8	14	718	629
36	17	22	624	452
37	15	20	467	401
38	10	15	992	735
39	11	16	1032	879
40	12	19	1003	724
41	<2	7	1246	729
42	16	21	<10	123
43	13	17	322	275
44	<2	<2	725	793
45	10	13	210	123
46	<2	<2	<10	39
47	13	17	<10	<10

TABLE 6 (continuation)

48	8	<2	<10	<10
49	19	28	<10	476
50	10	14	974	652
51	10	16	876	613
52	13	17	764	657
53	7	9	974	963
54	10	14	934	728
55	11	17	<10	675
56	6	8	524	432
57	9	10	478	363
58	8	13	847	776
59	6	11	684	296
60	8	10	742	666

As is clearly shown in the test results, Samples No. 1 to 24, which are sintered bodies for tool cermet for the present invention, have superior breaking-resistance, shock-resistance, temperature adhesion-resistance, and plastic deformation-resistance because Sample No. 1 to 24 have the compositions shown in Table 4 and consist of Type-I and Type-II particles as the structural types of the particles as shown in Table 5.

Samples No. 1 to 24, which are sintered bodies for tool cermet for the present invention, have superior wear-resistance to those of Samples No. 25 to 60 provided for the purpose of comparison as the results of Tests 1 and 2 clearly indicates. The results of Test 3 and 4 show that Samples No. 1 to 24 take a greater number of collisions to break than Samples No. 25 to 60, thereby proving superior breaking-resistance of Samples No. 1 to 24.

The cermet for tools for the present invention has the predetermined compositions and Type-I and Type-II particles as the structural types of the particles as described above, which improves mechanical breaking-resistance, thermal shock-resistance, and plastic deformation-resistance without sacrificing superior mechanical wear-resistance and temperature adhesion-resistance which are inherent properties of cermet.



CLAIMS

1. A cermet for use in tools comprising:
70 to 95 volume percent of a hard dispersed phase
comprising 5 to 50 volume percent of Type-I particles,
5 which are single phase particles; and 95 to 50 volume
percent of Type-II particles, which are dual phase
particles, said hard dispersed phase containing at least
one Group IVa transition metal, at least one Group Va
transition metal, tungsten, carbon and nitrogen, wherein
10 (a) the mole ratio of the total amount of Group IVa
transition metal, Group Va transition metal and tungsten to
the total amount of carbon and nitrogen is 1.0 : 0.85-1.0,
(b) the mole ratio of Group IVa transition metal to Group
Va transition metal to tungsten is 0.50-0.85 : 0.05-0.30 :
15 0.05-0.30, (c) titanium is used as a Group IVa transition
metal and tantalum is used as a Group Va transition metal,
the mole ratio of titanium to Group IVa transition
metal(s) is 0.8-1 : 1 and the mole ratio of tantalum to
Group Va transition metal(s) is 0.30-1.0 : 1.0, (d) the
20 mole ratio of carbon to nitrogen is 0.40-0.90 : 0.10-0.60;
and (e) the mole ratio of nitrogen to carbon and nitrogen
in the Type-I particles is 0.25-1.0 : 1; and 30 to 5
volume percent of a binder phase composed of at least one
Group VIII metal.
- 25 2. A cermet according to claim 1 wherein:
the Type-I particles are composed of at least one
nitride or carbonitride of a Group IVa transition metal and



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the Type-II particles are composed of at least one Group IVa transition metal, at least one Group Va transition metal and tungsten.

3. A cermet according to claim 1 or 2 wherein the
5 composition of the Type-II particles varies from a core to a least one outer layer.

4. A cermet according to claim 3, wherein the
composition of the Type-II particles varies such that the
at least one outer layer is composed of more Group IVa
10 transition metal than the core, and the core is composed of more Group Va transition metal and tungsten than the at least one outer layer.

5. A cermet according to claim 3 or 4, wherein the
composition of the Type-II particle varies gradually and
15 sequentially from the core through each successive outer layer.

6. A cermet according to claim 1 substantially as
described with reference to any one of Samples 1 to 24.

7. Tools fabricated at least in part of a cermet as
20 claimed in any one of the preceding claims.
