

Multi-layered Hard Material Coating for Tools

Technical Field

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This invention refers to multi-layered hard material coatings for tools (hard metal and rapid machining steel) for machining applications - in particular drilling applications.

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1 a) Hard material coated work pieces with a sequence of several different layers of aluminium chromium nitride and aluminium carbon nitride respectively and titanium silicon nitride and titanium carbon nitride respectively.

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1 b) Tools, in particular cutting and non-cutting tools (drills, milling cutters, screw taps, thread formers, hob cutters, dies, dies-plates, drawing punches etc.) with a sequence of several different layers of aluminium chromium nitride and aluminium carbon nitride respectively and titanium silicon nitride and titanium carbon nitride respectively as well as the application of those tools.

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1 c) A process for the production of a sequence of several different layers of aluminium chromium nitride and aluminium carbon nitride respectively and titanium silicon nitride and titanium carbon nitride respectively with defined layer structures.

State of the Art

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EP 1174528 A2 describes a coating on tools, consisting of a sequence of several individual layers, for which the first layer is composed of a nitride, carbide, carbon nitride, boride, oxide etc. of the elements Ti, Al and / or Cr, and a second layer consisting of a nitride, carbide, carbon nitride, boride, oxide etc. of Si and at least one element from the groups 4a, 5a and 6a of the periodic table of the elements. The advantage of that coating is given as the major improvement of abrasion resistance and the oxidation resistance due to the Si in the upper layer. In particular covering coatings on the basis of Cr-Si showed improvements in the tool life. Layers of TiAlN, CrAlN and TiN were chosen as lower layers.

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EP 1422311 A2 describes hard material layers on an Al-Cr-(Si)-O basis, which can be developed as nitride, carbide, oxide, boride etc. It applies to all layers that the respective layers contain a low proportion of oxygen (1-25at%). In addition, it is mentioned that a further hard

material layer can be applied on top of the coating mentioned in the invention. Among others Ti-Si-N, Ti-B-N, BN, Cr-Si-N etc. are stated as examples for this. In particular the inclusion of low quantities of oxygen or silicon and oxygen are given here as an advantage of the invention, because this results in increased hardness as well as improved wear and tear resistance and high temperature oxidation resistance.

EP 1219723 A2 introduces a coating on a Ti-Al-Cr-X-N basis, where X may stand for Si, B and / or C. The advantage of that coating is given as laying in the improvement of the abrasion resistance in comparison with conventional coatings. The invention furthermore describes a target, which has to consist at least of Ti, Al and Cr.

Disadvantages of the State of the Art

Hard material coated tools in accordance with the state of the art (Ti-Al-N based coatings) show lower tool lives than the newly optimised $(Al_{1-x}Cr_xX)-(Ti_{1-y}Si_y)X$ - hard material layers for $X = N$ and CN respectively.

The disadvantages of the state of the art show furthermore that in the case of Al-Cr-N coatings at higher temperatures in an inert gas atmosphere (e.g.: argon atmosphere) the decomposition of the coating starts as early as around 900°C. If that heat treatment process is carried out in an oxygen atmosphere, that decomposition process is moved to a higher temperature range. If a continuous cut is now examined in the machining process, locally very high temperatures (in part over 1000°C) will be found on the contact area between the tool surface and the work piece. If that contact area is so large that no / little oxygen is able to have a stabilising effect at the surface of the coating, the cubic CrN disintegrates into the hexagonal Cr₂N and subsequently at even higher temperatures into metallic Cr. That decomposition process of the coating leads to premature wear and tear of the coating during use, which develops in particular as crater wear.

Tasks of the Invention

This invention is meant to avoid the disadvantages of the state of the art and serves in particular the improvement of the tool life of coated work pieces, as for example machining tools, cutting
5 and non-cutting tools and components respectively for the construction of machines and moulds. It is furthermore the task of this invention to make available a process for the depositing of such layers, in particular for the depositing of such layers on the aforementioned work pieces.

Description of the Solution and the Path to the Solution Respectively

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The invention solves the task through a hard material coating in accordance with Claim 1 and a tool with such a coating in accordance with Claim 12 respectively. Further designs in accordance with the invention are described in the subsidiary claims.

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The invention describes a particular multi-layer structure of a coating, which is meant to prevent the premature decomposition (wear and tear) of the coating during use. The multi-layer structure prevents or at least delays the decomposition and the subsequent diffusion of the CrN portion within the AlCrN coating at high temperatures.

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An industrial coating installation of the type RCS of company Balzers was used for the depositing of the Al-Cr-(X)-N/Ti-Si-N hard layers, an installation as it is also, for example, described in EP 1186681 in Fig. 3 to 6, description column 7, line 18, to column 9, line 25. For that purpose, the cleaned work pieces - depending on their size - were mounted on double-rotating substrate carriers and on triple-rotating substrate carriers respectively for work pieces with a diameter of less than 50 mm and two Ti-Si targets produced by fusion metallurgy and four
25 targets of Al-Cr-(X) alloys produced by powder metallurgy were installed in six cathode arc sources that were mounted on the walls of the coating installation. In this, the geometry of the target arrangement is mainly determined by the octagonal layout of the RCS installation, in which two heating segments arranged on opposite sides separate two groups of three consecutive segments with one mounted arc cathode each. For these tests one SiTi target each
30 was installed in the centre element opposite of each group of three. However, other target arrangements for the production of such layers are possible. In principle, such layers can be deposited in any installation that has at least two arc cathodes in an geometrically equivalent position, e.g. at the same coating height of a single or multiple rotating substrate holder. An

expert knows how - depending on the type of installation -he can further influence the layer thickness of the individual layers through the arrangement of the target and the adjustment respectively of the respective substrate movement or rotation or the angular frequency of a work piece rotation.

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Afterwards the work pieces were initially heated to temperature of approx. 500°C through radiation heaters that were also mounted in the installation and following that the surface was subjected to a caustic cleaning by Ar ions by applying a DC bias voltage of -100 to -200 V in an Ar atmosphere and under a pressure of 0.2 Pa.

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Afterwards an Al-Cr-N adhesive layer of approx. 0.2 µm thickness was deposited through the operation of four Al-Cr sources with an output of 3 kW and the application of a substrate bias of -50 V for a period of time of approx. 5 minutes. Subsequently, a multiple coating was build up in targeted manner, for which 2 Ti-Si sources with 3 kW each are initially patched in in addition to the 4 Al-Cr sources and are then operated together for approx. 1 minute. Afterwards the 4 Al-Cr sources are switched off and for approx. 3 minutes a pure Ti-Si-N coating is deposited. After that the 4 Al-Cr sources are again switched on for approx. 1 minute. Subsequently the Ti-Si sources are switched off again and a pure Al-Cr-N coating is deposited for another 5 minutes. Within the framework of the invention, this sequence for the layer packet is run several times during the deposition process. Afterwards a cover layer, which is produced exclusively from Ti-Si sources, is deposited with a thickness of approx. 0.5 µm. Alternatively, a thicker AlCrN cover layer can also be deposited in that process. All layers were deposited in a pure nitrogen atmosphere with a pressure of approx. 3 Pa and a negative substrate bias voltage of approx. 50 volt. In principle, the process pressure can be set for each of these steps in a range from 0.5 to approx. 8 Pa, but preferably between 0.8 and 5 Pa, for which a pure nitrogen atmosphere or a mixture of nitrogen and an inert gas, such as for example Argon for nitridic layers, or a mixture of nitrogen and a carbon containing gas, which can be mixed with an inert gas if required, is used for carbon nitridic layers. Correspondingly, oxygen or a boron containing gas can be admixed as known for the depositing of oxygen or boron containing layers.

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Target composition, crystal structure of the layer and adhesiveness are shown in Table 1. Process parameters such as target output, negative substrate bias voltage, process pressure and temperature are compiled in Table 2.

Work pieces in accordance with the invention are characterised by the fact that a cubic ($\text{Al}_y\text{Cr}_{1-y}$) X coating with X = N and CN respectively, but preferably N, and $0.2 \leq y < 0.7$, preferably $0.3 \leq y \leq 0.5$ is deposited alternating with a cubic ($\text{Ti}_z\text{Si}_{1-z}$) X coating with X = N and CN respectively, but preferably N, and $0.99 \leq z < 0.7$, preferably $0.97 \leq z \leq 0.85$ (see Fig. 1a), for which at least one layer packet and at least one additional ($\text{Al}_y\text{Cr}_{1-y}$) X and ($\text{Ti}_z\text{Si}_{1-z}$) X layer respectively is applied. In both layers the layer structure is microcrystalline with an average grain size of approx. 5 - 150 nm, but preferably of approx. 10 - 120 nm.

Advantageous for the coating are additional intermediate layers between the pure ($\text{Al}_y\text{Cr}_{1-y}$) X layers and the ($\text{Ti}_z\text{Si}_{1-z}$) X layers, for which all coating sources are running and thus a ($\text{Al}_y\text{Cr}_{1-y}\text{Ti}_z\text{Si}_{1-z}$) X layer is deposited (see Fig. 1b). If required, these intermediate layers can effect an improved adhesiveness between the individual layers, depending on the order and composition respectively and the properties of the individual layer systems. Due to the geometric target arrangement within the coating installation, the work piece rotation - during the depositing of this intermediate layer - is causing an additional multi-layer structure with very fine layers to be deposited, because individual targets on the basis of Al-Cr and Ti-Si are still used for the coating process. The width of the individual layers within this intermediate layer lies in the range of a few nanometres.

Another possibility for building up the desired multi-layer system can be carried out through periodic switching on and off of coating sources, analogous to Fig. 1c. There the coating sources for a coating material are running throughout the entire depositing process, while the coating sources with the second coating material are periodically switched on in addition. In that case the aforementioned additional multi-layer structure can be generated during the joint operation of the arc sources.

The processes in accordance with the invention are characterised by the fact that a process management is selected for depositing the layer packet described above. The multi-layer structure is achieved by the targeted switching on and off of coating sources. The multi-layer substructure is additionally achieved through the rotation and movement respectively of the work pieces to be coated within the coating installation.

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Example 1 compares coatings with a defined number of layers and layer packets respectively, where each layer packet consists of a layer sequence, an AlCrTiSiN layer followed by a TiSiN layer, an AlCrTiSiN layer as well as an AlCrN layer. It is easily recognisable that in comparison with the layer tested in Experiment No. 1, which was deposited in accordance with the state of

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the art, an improved tool life can be achieved with the coating in accordance with the invention. It is also recognisable that an optimum layer thickness of the individual layers of $\text{Al}_y\text{Cr}_{1-y}\text{N}$ and $\text{Ti}_z\text{Si}_{1-z}\text{N}$ is important for the required increase of the tool life. For $\text{Al}_y\text{Cr}_{1-y}\text{N}$ this layer thickness lies between 75 nm and 200 nm, preferably at 120 nm to 170 nm, and for $\text{Ti}_z\text{Si}_{1-z}\text{N}$ between 50 and 150 nm, preferably between 70 to 120 nm. Within the framework of this example these layer thicknesses were changed in the course of the coating time so that a comparable total layer thickness of approx. 4 μm could be achieved for all experiments. For these experiments the layer structure described in Fig. 1b was chosen. The layers, for which all coating sources were in operation, were not changed for the respective experiments and resulted in an individual layer thickness of approx. 20 ± 10 nm each.

In principle, very different work pieces can be advantageously coated with such $\text{Al}_y\text{Cr}_{1-y}\text{N}$ / $\text{Ti}_z\text{Si}_{1-z}\text{N}$ multi-layer coatings. Examples for this are cutting tools such as milling tools, gear hobbing, ball head, planar and profile milling tools as well as drills, screw tabs, clearing tools, reamers and indexable inserts for turning and milling processes and non-cutting tools respectively, such as for example dies, die-plates, drawing dies, ejection cores or thread formers. Injection moulding tools, too, for example for metallic injection moulding alloys, resins or thermoplastic plastics, in particular injection moulding tools as used for the production of plastic performs and data carriers respectively such as CD's, DVD's etc. can advantageously be protected with such coatings. Even though better results are not always achieved for all applications on various tools by coatings in accordance with the invention, it is at least possible to achieve a significantly higher abrasion resistance than with the previous known coatings for certain applications as shown in the examples as well.

Furthermore, an improvement of the wear and tear behaviour is to be expected due to the principally similar behaviour of $\text{Al}_y\text{Cr}_{1-y}\text{X}$ / $\text{Ti}_z\text{Si}_{1-z}\text{X}$ multi-layer coatings, if the target compositions and coating parameters for the following layer systems are chosen in such manner that $\text{X} = \text{N}$, C , B , CN , BN , CBN , NO , CO , BO , CNO , BNO , CBNO , but preferably N and CN respectively, and $0.2 \leq y \leq 0.7$, preferably $0.40 \leq y \leq 0.68$ and $0.01 \leq z \leq 0.3$, but preferably $0.05 \leq z \leq 0.15$.

A way to improve the layer properties of the $\text{Al}_y\text{Cr}_{1-y}\text{N}$ / $\text{Ti}_z\text{Si}_{1-z}\text{N}$ multi-layer coatings is the adding by alloying of further chemical elements from one or several groups of the groups IVb, Vb and / or VIb of the periodic table of the elements and of Silicon respectively. Particularly

advantageous can be the adding by alloying within the packet of layers of the $Al_yCr_{1-y-m}M_mN$ layer, with $0 \leq m \leq 0.25$, preferred $0 \leq m \leq 0.15$. Especially the elements for $M = W, V, Mo, Nb$ and Si have proven to be advantageous (see also example No. 5).

- 5 Another way of improving the layer properties of the layer system is the application of an additional sliding layer on the layer packet or on the cover layer closing the hard material layer off to the outside. The sliding coating system can be made up of at least one metal or a carbide of at least one metal and disperse carbon, MeC/C , for which the metal is a metal from the Group IVb, Vb and / or VIb and / or Silicon. For example, especially suitable for this is a WC/C cover layer with a hardness that can be set between 1000 and 1500 HV and that has excellent run-in properties. CrC/C layers as well show similar behaviour, however with a somewhat higher friction coefficient.

- 10 With deep-hole drills coated in this way, an additional run-in smoothing of the machining surfaces could be determined after the production of one drill hole, something which to this day has only been achieved through expensive mechanical machining. This results in an improvement in chip transport along the chip groove and the minimization of friction torque during the drilling process. Such properties are of interest in particular also for component applications with sliding, friction or rolling stresses, especially when there is a lack of lubrication or when they run dry or if an uncoated counter body is to be protected at the same time.

Other ways for the formation of a final sliding layer are metal-free diamond-like carbon layers and MoS_x , WS_x layers respectively or titanium containing MoS_x and MoW_x layers respectively.

- 25 As mentioned, the sliding layer can be applied directly onto the multi-layer system or following the application of another adhesive layer, in order to achieve the best possible adhesion of the layer composite. For this purpose, the adhesive layer can be executed as a metallic, nitridic, carbidic, carbonitridic layer or as a gradient layer.
- 30 For example, after the application of a sputtered or arced Cr and Ti adhesive layer respectively, WC/C and CrC/C layers respectively can be produced advantageously by sputtering a WC target while adding a carbon-containing gas. For this purpose, the percentage of the carbon-containing gas is increased over time, in order to achieve a larger percentage of free carbon in the layer.

Further Advantageous Effects of the Invention

The following illustrates advantageous applications of the invention, using the example of its use in various cutting operations.

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Example 1:

Drilling with internally cooled HM drills in structural steel

Tool:	Drill hard metal with cooling ducts Diameter D = 6.8 mm
Work Piece:	Structural steel DIN 1.1191 (Ck45)
Drilling Parameters:	Cutting speed $v_c = 120$ m/min Tooth feed $f_z = 0.2$ mm/rotation Drill hole depth $z = 34$ mm (5xD)
Cooling:	Emulsion 5 %
Process:	Pocket hole
Wear and Tear Criterion	Corner wear and tear VB = 0.2 mm

Experiment No.	Layer Thickness [μ m]	Tool Life Travel [m]
1 AlCrN + TiSiN	3.9	54.3
2 AlCrN + 2 x Layer packet 1 + TiSiN	4.2	43.9
3 AlCrN + 4 x Layer packet 1 + TiSiN	3.9	65.2
4 AlCrN + 8 x Layer packet 1 + TiSiN	4.0	76.2
5 AlCrN + 12 x Layer packet 1 + TiSiN	4.0	54.3
6 AlCrN + 15 x Layer packet 1 + TiSiN	3.9	43.9

10 * In this one (1x) layer packet corresponds to a one-time sequence of 'AlCrTi-SiN+TiSiN+AlCrTiSiN+AlCrN'.

** For which a wear and tear mark width VB = 0.2 mm was achieved.

Example 1 shows a comparison of the tool lives of coated HM drills, to which a different number of layer packets had been applied, each with the same adhesive layer, namely AlCrN, and top layer, namely TiSiN. The coating times of the TiSiN and the AlCrN layer were each adjusted in
15 such way that at the end a comparable total layer thickness was achieved. An optimum for the

overall tool life was found in Experiment Nr. 4, with a total number of 37 layers, which shows a clear improvement in comparison with the state of the art in Experiment No. 1.

Example 2:

5 Drilling with internally cooled HM drill in structural steel

Tool: Drill hard metal with cooling ducts
Diameter $D = 6.8$ mm

Work Piece: Structural steel DIN 1.1191 (Ck45)

Drilling Parameters: Cutting speed $v_c = 120$ m/min
Tooth feed $f_z = 0.2$ mm/rotation
Drill hole depth $z = 34$ mm ($5 \times D$)

Cooling: Emulsion 5 %

Process: Pocket hole

Wear and Tear Criterion: Corner wear and tear $VB = 0.2$ mm

Experiment No.	Tool Life Travel $VB = 0.2$ mm in meter
6 (TiAlN/TiN multiple layer)	32.3
8 (TiAlN individual layer)	32.3
9 (AlCrN individual layer)	65.9
10 AlCrN + 8 x Layer packet 1 + TiSiN	76.2

Example 2 shows a comparison of the tool lives of coated HM drills. Here, too, the tool life could be improved through the AlCrN / TiSiN multi-layer coating in comparison with the industrially used hard material layers of TiAlN / TiN multi-layer and TiAlN mono-layer coatings.

Example 3:

Drilling with externally cooled HM drill in structural steel

Tool: Drill hard metal with cooling ducts
Diameter $D = 6.8$ mm

Work Piece: Structural steel DIN 1.1191 (Ck45)

Drilling Parameters: Cutting speed $v_c = 120$ m/min

Tooth feed $f_z = 0.2$ mm/rotation
 Drill hole depth $z = 23.8$ mm ($3.5 \times D$)
 Cooling: Emulsion 5 %
 Process: Pocket hole
 Wear and Tear Criterion Corner wear and tear $VB = 0.15$ mm

Experiment No.	Tool Life Travel $VB = 0.15$ mm in meter
11 (TiAlN/TiN multi layers)	46.1
12 (TiAlN mono-layers)	42.3
13 (AlCrN)	22.6
14 AlCrN + 8 x Layer packet 1 + TiSiN	61.5

- 5 Example 3 shows a comparison of the tool lives of coated HM drills. Here, too, the tool life could be improved through the AlCrN / TiSiN multi-layer coating in comparison with the industrially used hard material layers of Ti-Al-N basis.

Example 4:

Drilling with internally cooled HM drill in cast iron (GGG-50)

Tool: Drill hard metal with cooling ducts
 Diameter $D = 6.8$ mm
 Work Piece: Cast iron with spherical graphite GGG-50
 Drilling Parameters: Cutting speed $v_c = 200$ m/min
 Tooth feed $f_z = 0.3$ mm/rotation
 Drill hole depth $z = 34$ mm ($3.5 \times D$)
 Cooling: Emulsion 5 %
 Process: Pocket hole
 Wear and Tear Criterion Corner wear and tear $VB = 0.1$ mm

Experiment No.	Tool Life Travel $VB = 0.1$ mm in meter
15 (TiAlN/TiN multi-layer)	57.1
16 (TiAlN mono-layer)	142.8

17 (AlCrN)	185.6
18 AlCrN + 8 x Layer packet 1 + TiSiN	199.9

Example 4 shows a comparison of the tool lives of coated HM drills. Here, too, the tool life could be improved through the AlCrN / TiSiN multi-layer coating in comparison with the industrially used hard material layers of TiAlN / TiN multi-layer coatings and TiAlN mono-layer coatings.

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Example 5:

Drilling with internally cooled HM drill in structural steel

Tool: Drill hard metal with cooling ducts
Diameter D = 6.8 mm

Work Piece: Structural steel DIN 1.1191 (Ck45)

Drilling Parameters: Cutting speed $v_c = 120$ m/min
Tooth feed $f_z = 0.2$ mm/rotation
Drill hole depth $z = 34$ mm (3.5xD)

Cooling: Emulsion 5 %

Process: Pocket hole

Wear and Tear Criterion Corner wear and tear VB = 0.2 mm

Experiment No.	Al at%	Cr at%	M at%	Layer Thickness [μ m]	Tool Life Travel at VB = 0.2 mm in meter
19 AlCrWN + 8 x Layer packet 2 + TiSiN	70	28	2	3.8	65.8
20 AlCrWN + 8 x Layer packet 2 + TiSiN	70	25	5	3.4	59.3
21 AlCrNbN + 8 x Layer packet 2 + TiSiN	70	25	5	3.8	57.8
22 AlCrMoN + 8 x Layer packet 2 + TiSiN	70	25	5	4.8	61.2
23 AlCrVN + 8 x Layer packet 2 + TiSiN	70	25	5	4.2	68.0
24 AlCrSiN + 8 x Layer packet 2 + TiSiN	70	25	5	4.0	54.4

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* One (1x) layer packet 2 corresponds to a one-time layer sequence of 'AlCrMTi-SiN+TiSiN+AlCrMTiSiN+AlCrMN', in which M stands for one of the elements W, Nb, Mo, V or Si in each case. .

- 5 Example 5 shows a comparison of the tool lives of HM drills coated in accordance with the invention, on which multi-layer systems with different chemical composition, but the same cover layer (TiSiN) were deposited. The target composition as a chemical composition was varied, while Al was kept constant, and Cr was partially replaced by a third element. The process parameters during depositing of the layer were kept the same analogous to the other
10 experiments.

Another way of producing a corresponding layer packet is created, if analogous to Fig. 1 c either the AlCr or the AlCrM sources or the TiSi source or sources are operated continuously and if the respective other source or sources are switched on if and as necessary. In particular in the case of the continuous operation of the aforementioned 4 AlCr and AlCrM sources respectively the
15 depositing rate can be increased and, for example, the following layer system can be deposited:

- one (AlCrTiSi) X mixed layer
- followed by another (Al_yCr_{1-y}) X layer
- followed by another (AlCrTiSi) X mixed layer
- followed by another (Al_yCr_{1-y}) X layer.

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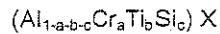
Description of Figures

Figure 1 shows different layer variations. FIG. 1 a-c discuss three variations as to how a multi-layer coating can be build up.
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FIG. 1a illustrates a sequence of layers with sharp transitions. A layer system (2) is deposited directly onto a second layer system (1). This process is repeated until the desired total layer thickness has been achieved. A cover layer (3) with a greater thickness can be deposited as the last layer.

30 In Fig. 1b mixed layers (4), in which both layer systems are applied simultaneously, are deposited between the individual layers. Here, too, an additional cover layer can be applied as the last individual layer. The mixed layer can be executed either thin as a sliding transitional layer or thicker with an area of constant layer composition. Such a layer can, for example,

have the following composition: Al = 40.7 at%, Cr = 21.2 at%, Ti = 32.8 at% and Si = 5.3 at%. This composition results if AlCr targets with a composition of Al=70 at% and Cr=30 at% and TiSi targets with a composition of Ti=85at% and Si=15at% are operated simultaneously. In general, the composition of a mixed layer with a constant composition is advantageously set in
5 the following range:



where $0.18 \leq a \leq 0.48$; $0.28 \leq b \leq 0.4$; $0.004 \leq c \leq 0.12$. The aluminium content is advantageously kept at above 10 at%. If, as aforementioned, other elements are added to achieve a corresponding effect, a minimum concentration of 0.5 to 1 atomic percent and a
10 maximum concentration of 15% to 25% should be added depending on the element.

In FIG. 1c, a multi-layer coating is deposited by applying a layer system (5) during the entire coating time and by periodically mixing the second layer system into it by turning on the corresponding coating source.
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Figure 2 shows the design of the layer packets of Figure 1 in a change illustration.

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Test	Crystal Structure	Target composition					Target Thickness [μm]	Adhesive-ness
		Target 1			Target 2			
		Al at%	Cr at%	M at%	Ti at%	Si at%		
A	B1	70	30	-	85	15	4.0	HF1
B	B1	70	28	W = 2	85	15	3.8	HF1
C	B1	70	25	W = 5	85	15	3.4	HF1
D	B1	70	25	Nb = 5	85	15	3.8	HF1
E	B1	70	25	V = 5	85	15	4.8	HF1
F	B1	70	25	Mo = 5	85	15	4.2	HF1
G	B1	70	25	Si = 5	85	15	4.0	HF1

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Table 1

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Test	$P_{\text{Target Al-Cr-M}}$ [kW]	$P_{\text{Target Ti-Si}}$ [kW]	$U_{\text{Substrate}}$ [V]	P_{N_2} [Pa]	Temp. [°C]
A	3	3	-50	3	500
B	3	3	-50	3	500
C	3	3	-50	3	500
E	3	3	-50	3	500
D	3	3	-50	3	500
F	3	3	-50	3	500
G	3	3	-50	3	500

15 Table 2

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Patent Claims

1. A hard multilayer coating for improving the wear resistance of workpieces, said multilayer coating comprising:
 - at least one layer selected from the group consisting of:
 - an $(Al_yCr_{1-y})X$ layer, wherein $0.2 \leq y \leq 0.7$ and X is selected from the group consisting of N, C, B, CN, BN, CBN, NO, CO, BO, CNO, BNO, and CBNO, and
 - a $(Ti_zSi_{1-z})X$ layer, wherein $0.99 \leq z \leq 0.7$, and
 - at least one layer stack comprising the following layers:
 - one $(AlCrTiSi)X$ mixed layer
 - followed by another $(Ti_zSi_{1-z})X$ layer
 - followed by another $(AlCrTiSi)X$ mixed layer
 - followed by another $(Al_yCr_{1-y})X$ layer,
 wherein X, y and z are as previously defined.
2. The hard coating in claim 1, characterized by the fact that the at least one $(Al_yCr_{1-y})X$ layer, the other $(Al_yCr_{1-y})X$ layer and the $(AlCrTiSi)X$ mixed layers contain at least one other element from Group IVb, Vb and/or VIb of the Periodic Table of the Elements, or silicon.
3. The hard coating in claim 2, characterized by the fact that the at least one $(Al_yCr_{1-y})X$ layer and the other $(Al_yCr_{1-y})X$ layer contain 0.5 to 25 atom % of the other element or silicon, setting the concentration of the elements and of the silicon in the other $(AlCrTiSi)X$ mixed layers.
4. The hard coating in claim 1, characterized by the fact that the layers in the layer stack have the following thickness:
 - $Al_yCr_{1-y}N$ layer between 75 nm and 200 nm
 - $Ti_zSi_{1-z}N$ layer between 50 and 150 nm.
 - $(AlCrTiSi)X$ mixed layer 20 ± 10 nm.

5. The hard coating in claim 1, characterized by the fact that the coating includes several layer stacks in a row.
6. The hard coating in claim 5, characterized by the fact that the coating contains 4,
5 8 or 12 layer stacks.
7. The hard coating in claim 1, characterized by the fact that at least one $(Al_yCr_{1-y})X$ layer is deposited directly on the workpiece or on an adhesive layer.
- 10 8. The hard coating in claim 1, characterized by the fact that a $(Al_yCr_{1-y})X$ cover layer or a $(Ti_zSi_{1-z})X$ layer forms the outer last layer of the hard coating.
9. The hard coating in claim 1, characterized by the fact that an additional sliding layer is deposited on the hard coating.
- 15 10. A hard multilayer coating for improving the wear resistance of workpieces, said multilayer coating comprising:
 - at least one layer selected from the group consisting of:
 - an $(Al_yCr_{1-y})X$ layer, wherein $0.2 \leq y \leq 0.7$ and X is selected from the group
 - 20 consisting of N, C, B, CN, BN, CBN, NO, CO, BO, CNO, BNO, and CBNO, and a
 - $(Ti_zSi_{1-z})X$ layer, wherein $0.99 \geq z \geq 0.7$, and
 - at least one layer stack comprising the following layers:
 - one $(AlCrTiSi)X$ mixed layer
 - followed by another $(Al_yCr_{1-y})X$ layer
 - 25 followed by another $(AlCrTiSi)X$ mixed layer
 - followed by another $(Al_yCr_{1-y})X$ layer,
 - wherein X, y and z are as previously defined.
11. The hard coating in claim 1 or 10, characterized by the fact that the mixed layers
30 contain a multilayer structure.

12. A workpiece, characterized by the fact that the workpiece includes the coating in claim 1 or 10.
13. The workpiece in claim 12, characterized by the fact that the workpiece is a component for machining and forming, a tool, a machining tool, a cutting or forming tool.
14. The workpiece in claim 13, said workpiece being a drill.
15. The hard coating in claim 1, wherein X is selected from the group consisting of N and CN.
16. The hard coating in claim 6, said coating containing 8 layer stacks.
17. The hard coating in claim 1, wherein:
X in said at least one layer is N or CN,
X in said $(\text{Ti}_z\text{Si}_{1-z})\text{X}$ layer is N or CN, and
 $0.95 \geq z \geq 0.85$.
18. The hard coating in claim 1, wherein X is N or CN in every recited layer.
19. The hard coating in claim 1, wherein:
X in said at least one layer is N,
X in said $(\text{Ti}_z\text{Si}_{1-z})\text{X}$ layer is N, and
 $0.95 \geq z \geq 0.85$.
20. The hard coating in claim 1, wherein $0.3 \leq y \leq 0.5$.
21. The hard coating in claim 10 wherein $0.3 \leq y \leq 0.5$.