About the Synthesis of Next Generation High Oxidation Resistant Hard Coatings by Means of Novel High Ionization Hybrid PVD Processing HI3

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Abstract

Technology and process experts provide unique and dedicated solutions for user´s current and future challenges using various deposition and surface treatment technologies. One novel holistic approach to tailored solutions is the use of hybrid PVD process technology. The term hybrid processes applies when several processes for the generation of layer-forming particles are combined in a single coating system. HIPAC (High-Ionization Plasma Assisted Coating) sputtering technology, in combination with the APA-Arc technique (Advanced Plasma Assisted) represents the HI3 (High Ionization Triple) hybrid approach to coated high performance precision tools and components of today, tomorrow and the day after.
The present work will highlight the deposition techniques to apply novel micro alloyed hybrid coatings such as patented SIBONICA ((Al,Ti)N/SiBNC(O)). Oxidation tests were carried out at elevated temperatures to show the outstanding properties perfectly adapted for challenging cutting operations of exotic materials. The technical potential for those applications where high thermal stability, high oxidation resistance and low friction are pre-dominant requests are illustrated. This is emphasized by first cutting test results.

Keywords

SIBONICA, HI3, HIPAC, APA, hybrid PVD, oxidation resistance, high performance coatings

Introduction

In a constantly growing and developing high precision tools and components market, demands for better coatings are an incentive for coating developers to find unique and customized solutions for their current challenges. Alloying and especially micro-alloying of materials is a technique used to alter materials properties in order to obtain better oxidation and corrosion resistance as well as higher strength and ductility.

With the ever increasing request to higher productivity especially the conditions at the cutting edges during machining are becoming more and more severe, especially while machining exotic materials like for instance complex Ti alloys, austenitic steels or high temperature alloys. At the cutting edges temperatures can exceed easily 1.000 °C and pressures close to the cutting edge could end up at 2 GPa and higher. We see thermal shock stress for instance during milling and as a result also thermal cracks especially at the flank face. Tribo-chemical wear is leading to crater wear at the rake face and fatigue can occur as a result from vibrations. Resulting from that tailored coating solutions have to meet more and more the challenging demands.

In the following the aspiration to a novel high temperature resistant tool coating is described.

The Genesis of the HI3 SIBONICA Approach

The Motivation

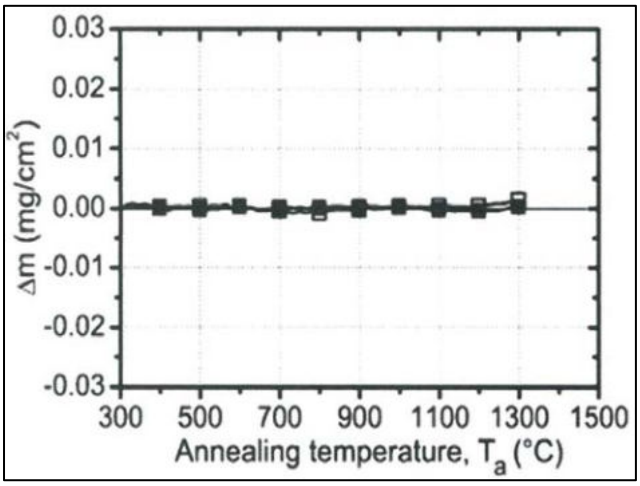
The above described ever increasing demands of innovative cutting applications can only be met by tailored coating solutions starting with the selection of the correct substrate material, the most appropriate shape and micro geometry. An application specific surface and edge preparation, a top of the edge coating solution with an innovative and outstanding coating design and a post treatment to structure and smooth out the coated surface are strong determinants for success.

The coated surface has to protect against thermal degradation, abrasive wear, chemical and tribo-chemical wear. There has to be best adhesion and well matched stress values between substrate and coating but low adhesion tendency of the coating and work piece material. The predominant determinant to machine more productively exotic materials is the thermal stability of the coating material. Best high temperature properties are requested. So, to achieve “best high temperature properties” was the trigger to start a feasibility study on the most promising approaches to a novel coating and coating design. After intensive research we ended up with SiBCN based coating systems.

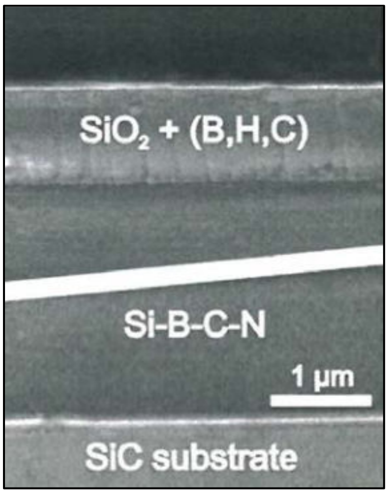
Why Consider Si-B-C-N Based Coatings?

The highest scientific published oxidation resistance for a coating system that might be best suited for cutting applications is SiBCN. J.J.Gengler et al [1], J.Vlcek et al [2,3], Kalas et al [4] and others reported on outstanding temperature stability and oxidation resistance of 1,400°C and even higher. Under specific conditions and environment 1,700 [3,5] could be achieved. Zeman [5] reported that e.g. a $Si_{32\text{-}33}B_{10}C_2N_{50\text{-}51}$ films with N/(Si+B+C) = 1.1-1.2, retained their amorphous structure up to 1,600°C without any structural transformations and detectable mass changes. A slight crystallisation started to develop just above this temperature. SiBCN coatings have a low thermal coefficient of expansion, a low thermal conductivity (< 2 $Wm^{-1}K^{-1}$)[1], they show low residual stress and the hardness is in the range of 27GPa [4] with a pretty high elastic recovery (72%- 88% [1,2,4]). So, Gengler [1] concluded that especially the lower thermal transport property of these films, due to the stability of the amorphous state at high temperatures, is one material aspect that is ideal for thermal barrier applications such as non-oxide ceramic coatings for cutting tools.

Considering the mass change at elevated temperatures one can see no change at all up to 1,300°C [4]. Fig. 1(a) illustrates the mass change versus the annealing temperature. In some reports one can also find oxidation stability up to 1,700°C [3], depending on the coating composition. A stable, amorphous oxide top layer is generated pretty fast protecting against bulk oxidation (Fig. 1(b)). Most probably also B_2O_3 providing low friction at elevated temperature and other complex oxides are generated.



(a)



(b)

Figure 1: (a) Mass change for oxidation stability of a SiBCN coating (N/(Si+B+C) = 1.16) vs. the annealing temperature [4] (b) SEM of an amorphous top-layer with an optimized structure after annealing protecting against SiBCN bulk oxidation [1]

So the decision was clear. The overall very encouraging scientific results were the reason why decided for the development of a SiBCN based high performance coating on an industrial coater.

Selection of the Development Platform and the Deposition Technique

Experimental Setup

The SIBONiCA coatings presented in the following were prepared in an industrial DOMINO S PVD coating unit from Sulzer Metaplas. The platform to apply high performance coatings with APA Arc, HIPAC (Sulzers HIPIMS), HI3 or other hybrid combinations (AEGD soft nitriding, PACVD) was the modular unit for production and development (Fig. 2). The system could be configured according to the needs of the process by using different modules.

(a)

(b)

Figure 2: (a) METAPLAS.DOMINO S, L (b) METAPLAS.DOMINO MINI

APA (Advanced Plasma Assisted) Arc and sputtering technology (dc, mf, HIPAC, rf) modules were implemented in the equipment concept to provide any solution for thin coatings. Furthermore DLC coating modules and combination treatment modules, the combination of nitriding and PVD or PACVD, were available. The latest HIPAC and HI3 technology modules have been demonstrating perfect fit to industrial and production related requirements. The coater was equipped with the highly efficient plasma cleaning process AEGD (Arc Enhanced Glow Discharge) as well. This additional fine-cleaning led to unchallenged coating adhesion. The HIPAC and HI3 technology also took advantage of the extremely high ionization of process gases provided by AEGD.

The technical features of the used coater allowed producing an enormous number of individually tailored coatings fast, reliably and fully automatic on metal, ceramic and plastic surfaces for different applications. First milestones in coating development coming with the unit were films also known as Micro Alloyed Coatings (MAC) [6]. MAC should be the starting point for the combination with SiBCN. The modular system allowed the combination of different modules and technologies to hybrid processes. The availability of two high-ionization processes, HIPAC and APA-Arc, obviously led to the logical combination of both processes to a hybrid process meeting industrial standards, known as HI3.

The next step in the development sequence was, choosing the right modules from the DOMINO universe to apply the novel SiBCN based films. As we aspired for a certain coating design we had to select the most appropriate deposition technology.

How to Orchestrate the Available Modules to Approach Si-B-C-N Based High Performance Coatings?

For a high performance SiBCN based tool coating we aspired to a coating design, with a bulk hard coating e.g. AlTiN or TiSiXN, a graded nano-structured transition zone, a mixed zone of AlTiN/SiBCN or TiSiXN/SiBCN before merging into a SiBCN amorphous top-layer. Figure 3 illustrates the basic coating design we aimed for.

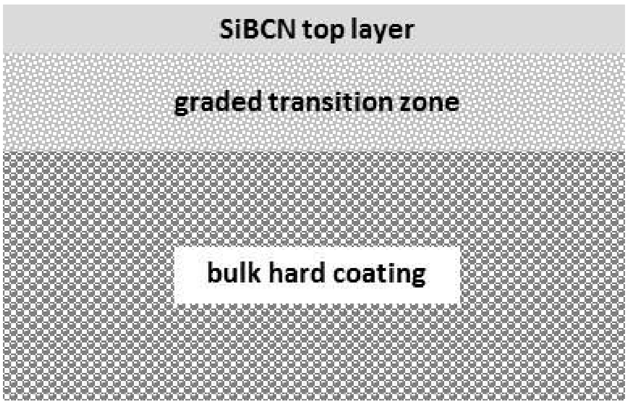
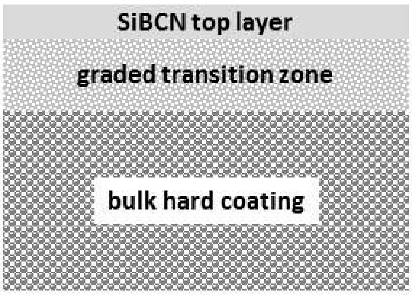


Figure 3: The principle coating design aspired to.

The constraints for the most appropriate technology were: feasibility, operating and energy efficiency, reliability, reproducibility, flexibility, low cost of ownership, high ion-to-neutral ratio of evaporated species. Taking these constraints into consideration the next step was to assess the different modules or a combination of these modules.

The unit was equipped with 4 flanges. In principle the flanges can be equipped only with Arc evaporators, only with sputtering magnetrons or any mix of both technologies. Taking into account the above constraints especially the aspiration to keeping the ion-to-neutral ratio at the highest level the technology or the technology combination should be chosen with best match of technical feasibility, productivity and quality. Fig 4 provides an overview of the different options that were assessed.



option:	1	2	3	4	5	6
SiBCN top layer	mf/ rf	Arc	mf/ rf	HiPIMS	HiPIMS	HiPIMS
graded transition zone	dc + dc/ mf/ rf	Arc	Arc + mf/ rf	HiPIMS	dc + HiPIMS	APA Arc + HiPIMS
bulk hard coating	dc	Arc	Arc	HiPIMS	dc	APA Arc

Figure 4: Possible technologies and technology combinations to apply SiBCN based coatings.

The bottom row of the table indicates the technology to deposit the bulk hard coating e.g. from AlTi targets, the top row the one for applying the SiBCN top layer evaporated from SiBC targets. For the graded transition zone both materials are evaporated simultaneously.

In the following the conclusions of a detailed assessment process of the different options, based on data and test results, is presented. The bench mark with respect to highest ion-to-neutral ration, efficiency and productivity was always the tool market dominating Arc technology.

Option 1: No option regarding the constraints and aspiration, low productivity.

- in general sputtering only plays a minor role in tool coating
- very low ion-to-neutral ratio
- low energy specific deposition rate
- resulting in an inefficient process
- high cost of ownership
- hard struggle to fine tune coating properties
- with mf / rf SiBC evaporation is possible

Option 2: Straight Arc is unfortunately no option as SiBC evaporation is nearly impossible.

- being the predominant technology in tool coating
- very high ion-to-neutral ratio depending on the material
- very efficient process
- highest energy specific PVD deposition rate
- low cost of ownership
- it is much easier to improve the surface quality of Arc coatings than improving the properties of sputtered films
- but, unfortunately SiBC evaporation is impossible

Option 3: No option regarding the constraints and aspiration, mf / rf jeopardizes Arc efficiency and thus productivity.

- combination of high and low ionization processes
- mf/ rf will reduce significantly the positive ion-to-neutral ratio in the plasma coming from Arc
- Arc ions will be lost for film growth as they contribute to sputtering on the mf/ rf magnetrons
- this would be acceptable as Arc provides the highest energy specific PVD deposition rate
- higher efficiency of the process compared with option 1
- low to medium cost of ownership
- in case of rf high effort regarding shielding etc.
- with mf / rf SiBC evaporation is possible

Option 4: No option regarding the constraints and aspiration, pretty low productivity, no outstanding advantages that would justify a stand-alone solution.

- expensive niche technology
- relatively high ion-to-neutral ratio depending on the material
- as straight configuration it is a very inefficient process
- very low energy specific deposition rate
- factor 2-10 lower than Arc (depending on parameter set-up and distance to the substrates)
- pretty high cost of ownership
- as stand-alone solution it is not and won´t be competitive in tool coating
- SiBC evaporation is possible

Option 5: No option regarding the constraints and aspiration, low productivity, a combination with dc sputtering in general jeopardizes any approach to a higher portion of ionized species.

- it represents a combination of 2 inefficient processes
- dc will reduce significantly the positive ion-to-neutral ratio in the plasma coming from HIPIMS
- ionized metal species from HIPIMS will be lost for film growth as it contributes to sputtering on the dc magnetrons
- so a twofold negative effect on the ionization
- low energy specific deposition rate
- inefficient process
- high cost of ownership
- HIPIMS SiBC evaporation is possible

Option 6: The only option regarding the constraints and aspiration. The Arc- HIPIMS hybrid configuration is the only way to keep the ion-to-neutral ratio of the evaporated species on the highest level and being able to synthesis material combinations that can´t be achieved with straight Arc. There is no other option, as HIPIMS as stand-alone solution might be interesting on lab scale but not when efficiency, productivity and cost are the dominant driving factors. Where Arc as stand-alone solution is not an option the Arc – HIPIMS hybrid technology makes sense.

- combination of 2 high ionization processes
- for the predominant Arc technology the possibility to synthesize unique material compositions is worth more than the minor loss in efficiency due to HIPIMS
- the much higher ion flux from Arc evaporators contributes to the sputtering on the HIPIMS magnetrons
- this would be acceptable as Arc provides the highest energy specific PVD deposition rate anyway
- efficient process
- low to medium cost of ownership
- HIPIMS SiBC evaporation possible

The selection process resulted in option 6 the HI3 technology, the combination of APA Arc and HIPAC, Sulzers HIPIMS technology. The production coating unit used for the development work was configured as hybrid system equipped with four flanges for Arc evaporators and/or sputtering magnetrons. Two flanges were arranged each provided with innovative APA Arc evaporators and planar sputtering magnetrons on the opposite side of the chamber. On the sputtering magnetrons the SiBC targets were mounted and on the APA Arc evaporators the targets to evaporate the material for the hard bulk coating, in the first approach with AlTi. The arrangement is illustrated in Fig. 5.

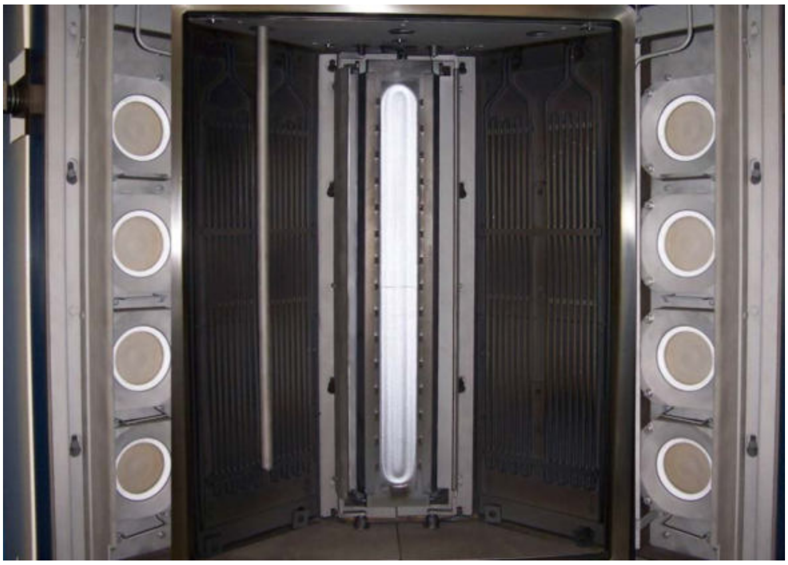


Figure 5: The HI3 hybrid arrangement in a DOMINO L system, the combination of 2 APA Arc flanges and 2 planar sputtering magnetrons. The second sputtering magnetron sits in the opened front door. In the future one could also think about an arrangement from 2 APA Arc flanges and 2 flanges with APA sputtering magnetrons that run in a cascaded HIPIMS mode.

HI3, High Ionization Triple, represents a holistic approach to a unique hybrid technology. It is the combination of 3 high ionization processes in one PVD coating system:

APA* Arc + HIPAC*** *(HIPIMS + AEGD**)* = HI3

*Advanced Plasma Assisted, ** Arc Enhanced Glow Discharge, *** High Ionization Plasma Assisted Coating

The AEGD (Arc Assisted Glow Discharge) process is always used as an exceptionally effective ion-cleaning method prior to film deposition. The generation of an extremely dense inert gas plasma (generally argon) and application of a negative bias voltage to the tools and components results in cleaning of the latter by means of ion bombardment. Such ion etching is described very graphically in the relevant technical literature as “micro-blasting in the atomic range”. [7] In combination with HIPIMS during film deposition the AEGD supports the process by means of pre-ionization of the reactive gases to suppress any poisoning effect to the greatest possible extent. In principle the AEGD process could also be used for electron heating also during film growth. This can be achieved by a positive or a bipolar pulsed bias voltage.

The Al55Ti45 was evaporated by APA Arc and the SiBC by HIPIMS in a reactive nitrogen atmosphere with the initial parameter set for HIPIMS shown in Fig. 6. These parameters resulted from a first optimisation loop ideally adapted to the needs of a high performance tool coating for the machining of exotic materials. HIPIMS offers a wide range of possible parameter set-ups best suited to various applications.

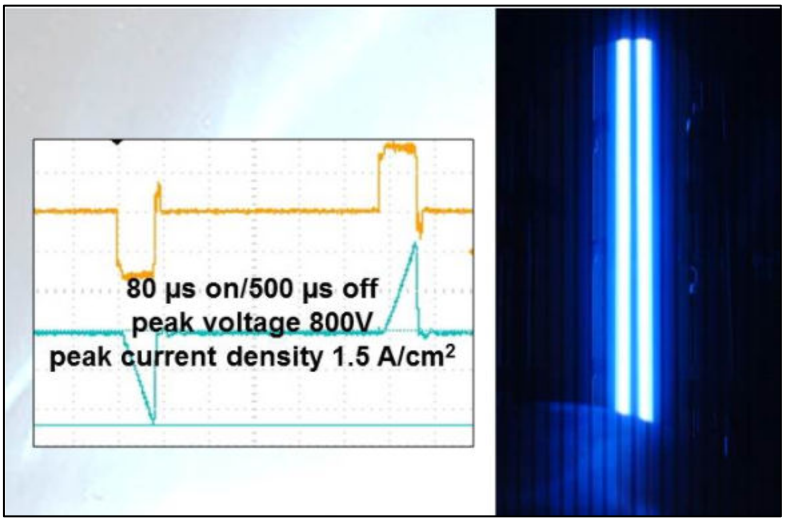


Figure 6: Initial HIPIMS parameter set-up during the HI3 hybrid deposition of a first SIBONICA system

Results and Discussion

SIBONICA, the High Performance Tool Coating for Today and Tomorrow

SIBONICA is one of the first layers applied using the HI3 technology From the fracture image (Fig. 7) one gets the compact structure with the amorphous top layer.

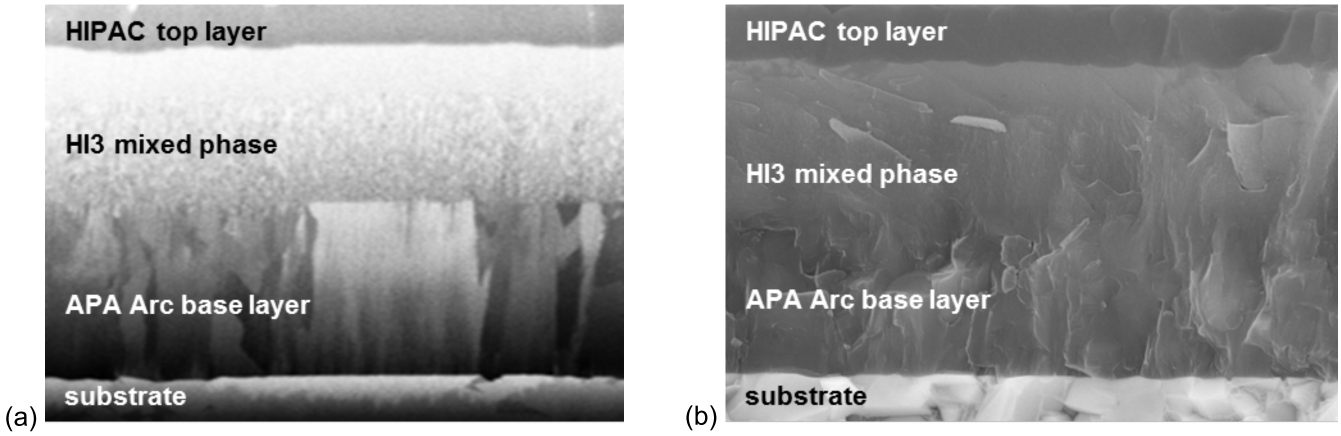


Figure 7: Trend setting coating designs by HI3 with highest oxidation resistance, SIBONICA

(a) FIB (focussed ion beam) prepared cross section, (b) fracture cross section

The FIB cut (Fig. 7(a)) provides a better impression about the micro structure. A fine columnar structured bulk layer followed by a mixed phase resulting from hybrid (HI3) operation, merging into a transition, nano composite like zone and ending up in an amorphous SiBCN top layer deposited with straight HIPAC. The properties of each layer were measured as follows:

HIPAC: SiBCN
micro hardness: 20 GPa
E-Modulus: 250 GPa
elastic recovery: 72%
amorphous

HI3 mixed phase: Al55Ti45/SiBNC
micro hardness: 28 GPa
E-Modulus: 350 GPa
elastic recovery: 68%
nano structured, fine columnar

APA Arc base layer: Al55Ti45
micro hardness: 27 GPa
E-Modulus: 300 GPa
elastic recovery: 65%
fine columnar

Interesting is the high elastic recovery, that fraction of a given deformation of the amorphous film which behaves elastically. The coating thickness was in the range of 3µm typical for a tool coating. Rockwell C indentation tests on cemented carbide inserts showed a perfect adhesion of HF1. So the process set-up of the above coating (Fig. 7) was the basis for further adaptation and optimization. After several optimization loops Inconel substrates were prepared for oxidation tests. Taking the fractional TEM image (Fig. 8) one can see again clearly the 3 zones of different structure. Higher magnification identified the nano-structured character.

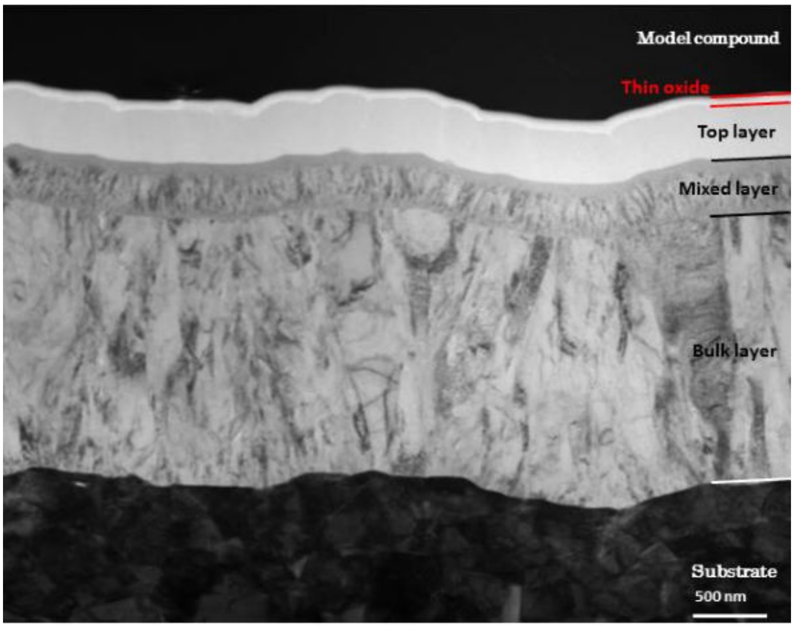


Figure 8: SIBONICA fractional TEM image

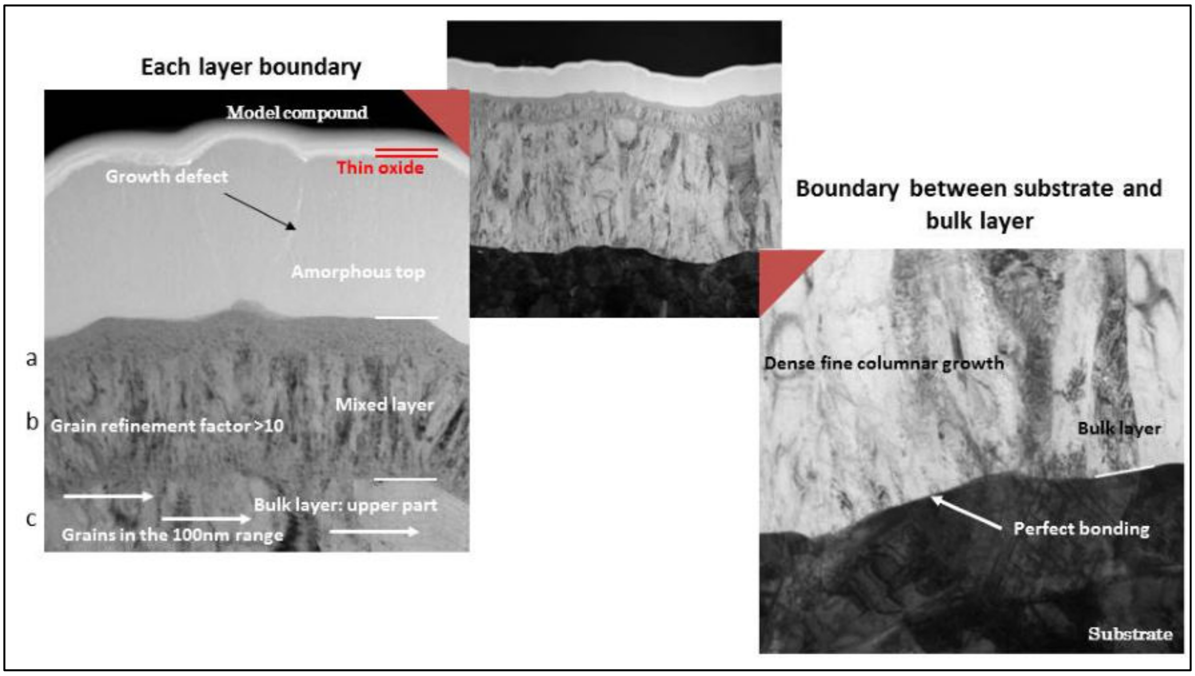
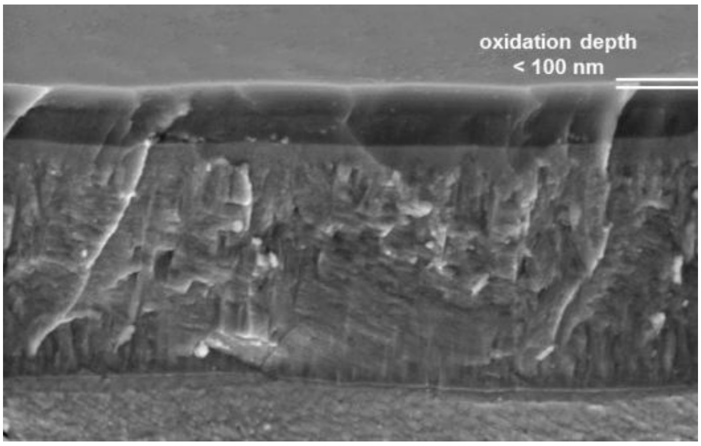


Figure 9: SIBONICA fractional TEM images of the interfaces

Investigating the interfaces one can see a very good bonding between the different layers. Considering the image on the left hand side of Fig. 9, there is again the amorphous top, not 100% defect free, the transition zone, the mixed phase and the dense fine columnar bulk layer. From the bulk to the mixed phase (from c to b) the grain refinement is obvious driven by the Si. As we have grains in the hundreds of nm range inside the bulk, the grain size in the mixed zone is in the 10nm range. The mixed zone has a nano-laminated structure caused by the use of HIPIMS SiBC and APA Arc AlTi evaporation at the same time and the rotational speed. Before merging into the amorphous top layer a SiBCN/AlTiN nano-composite zone (a) is passed with a dominating SiBCN amorphous matrix because Arc AlTi evaporation was stepwise reduced to zero before ending up with a SiBCN top layer. The bonding of the dense and fine columnar AlTiN bulk layer to the substrate is perfect as shown in Fig. 9, right hand side image.

The coating with the illustrated layer design was chosen for first tempering trials. The SIBONICA coated Inconel sample was exposed to a temperature of 950°C in air for 3h. Very fast a stable protective oxide layer with a thickness of about 100nm was generated. This reactive layer protected the underlying coating stacks against oxidation. The cross section of such tempered SIBONICA film is shown in Fig. 10 (a).

(a)


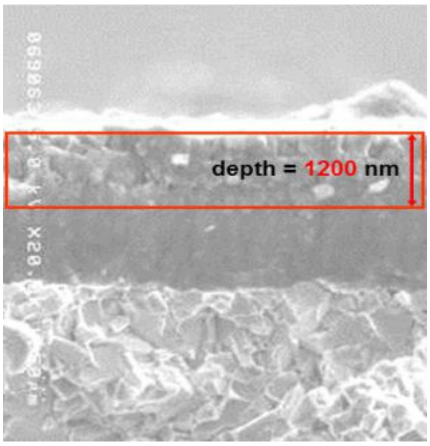
(b)


Figure 10: (a) SIBONICA fractional cross section after tempering at 950°C in air for 3 hours

(b) fracture cross section of a partly oxidized Ti80Si20N coating after tempering at 950°C in air for 3 hours

Fig. 10 (b) illustrates the result after tempering a Ti80Si20N coated sample at 950°C in air for 3 hours as reference. The coating was partly oxidised with an oxidation depth of 1,200nm. The substrate is still protected. By optimizing the coating composition as well as the texture, such TiSiN based coatings show higher oxidation resistance like for instance a micro-alloyed APA Arc TiSiXN coating also known as M.POWER.

The next step was to increase the temperature while tempering SIBONICA in air. 3 hours at 1,200°C in air led again to a fast generation of an oxide layer that stayed within the SiBCN toplayer (Fig. 11). The thickness of the oxide layer (200nm) slightly increased compared with the result shown in Fig. 10.

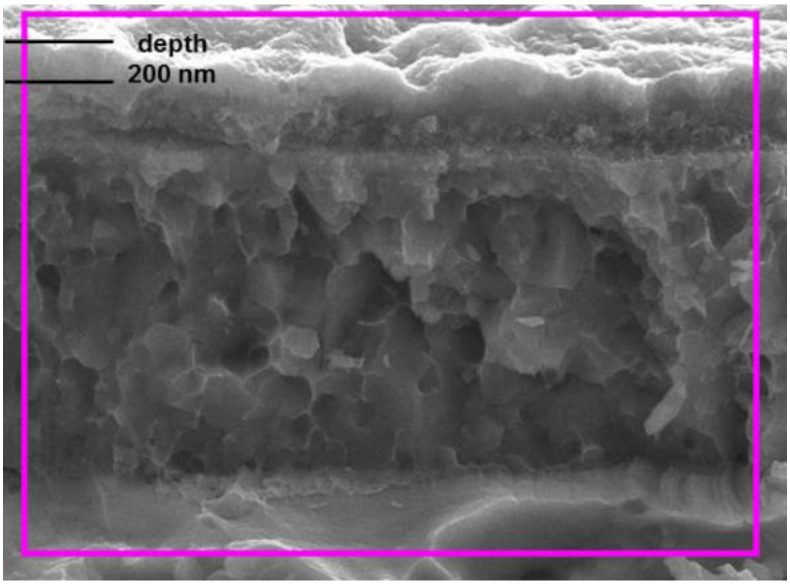


Figure 11: SIBONICA fractional cross section after tempering at 1,200°C in air for 3 hours

SIBONICA films have been showing outstanding thermal properties so far. Most probably the protective layer is composed of Si and O as reported in [3]. First analysis proved that. Whether also silica and boron oxide is generated that usually comes with nice lubricious properties hasn´t been clear so far but appears most likely. The analysis will be carried out during next phase annealing tests at temperatures higher than 1,200°C.

First Cutting Test Results

First cutting tests should prove the overall coating properties. Cemented carbide inserts were coated with a 3µm thick AlTiN based SIBONICA film. Turning tests with different materials were carried out and the results were compared with the particular references. Fig. 12 shows the results of turning Ti6Al4V, hardened steel and Inconel. The increase in performance machining these exotic materials has been at least 50%. These are very encouraging results and underline the high potential of SIBONICA films to become the next generation of high performance tool coatings.

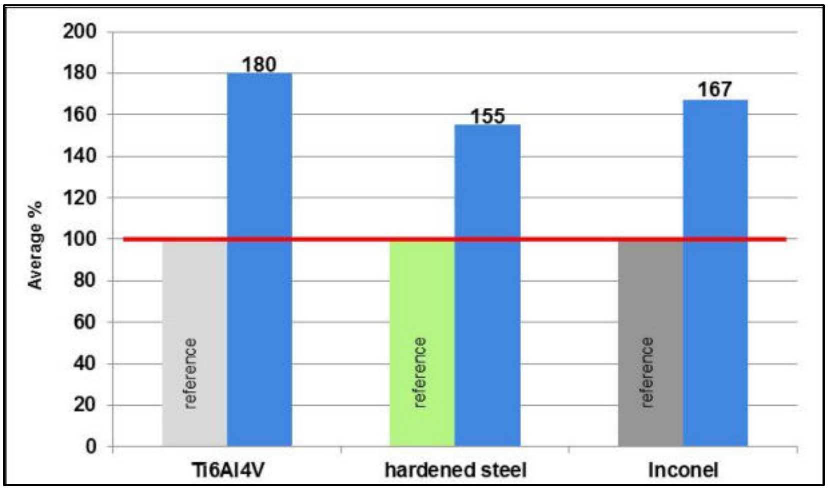


Figure 12: Results from cutting tests with AlTiN based SIBONICA

Outlook

To further prove the outstanding thermal properties of the above illustrated SIBONICA films, the next step will be to extend the time the coated part is exposed to 1,200°C in air and to further increase the temperature.

With the clear objective to further increase the oxidation resistance and phase stability the SiBC will be for instance evaporated in a nitrogen/oxygen atmosphere to get SiBCN(O) films. SiBCN based coatings will be doped with additional elements like Y, Hf, Ce or other rare earth metals or in general other elements supporting the thermal stability. To further improve the stability of the bulk layer and the mixed zone, SiBCN will be combined with e.g. AlCrXN, CrSiXN, TiSiXN or other hard coating compositions. Initial trials with the combination Arc TiSiXN and HIPAC SiBCN already showed promising results.

The properties of the single layers were measured as follows and the coating design one can get from the ball crater image presented in Fig. 13:

SiBCN
micro hardness: 20 GPa
E-Modulus: 250 GPa
amorphous

Al55Ti45/TiSiXN/SiBCN
micro hardness: 26 GPa
E-Modulus: 320 GPa
nano structured, fine columnar

Al55Ti45/TiSiXN
micro hardness: 30 GPa
E-Modulus: 360 GPa
nano structured, fine columnar

Al55Ti45
micro hardness: 27 GPa
E-Modulus: 300 GPa
fine columnar

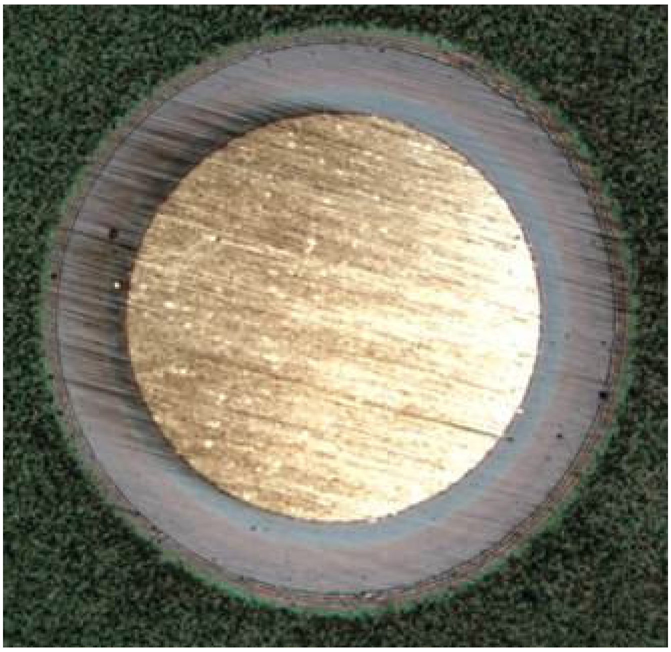


Figure 13: Ball crater of a TiSiXN based SIBONICA coating

Further steps will be taken to design the transition zone more into the direction of a nano composite, where a predominant amorphous SiBCN or SiBCN(O) phase serves as matrix as well as reducing the bulk thickness and thus increasing the nano composite transition zone.

MoSiB is well known for high temperature applications [8]. Using MoSiMe(C)B for reactive evaporation in N, O or C containing atmospheres in combination with MeN, MeCN, Me_xO_y, MeON, MeCON hard coatings containing Me = Ti, Al, Si, Cr, Zr, Nb, Y, and related mixtures could be another approach to novel high performance and high temperature resistant films for various applications.

The basis for these developments will be the HI3 technology. Considering the above mentioned technology options the question remains open what will be the future of HIPIMS as stand-alone solution or the combination with technologies other than Arc. HIPIMS is and will be an interesting complementary technology. As stand-alone solution most probably it is not going to play a major role for tool coatings in the future as it has not been valid for MSIP in general so far. It might substitute here and there dc sputtering but apart from that it could become complementary as for the HI3 technology. The installed base for PVD tool coatings is dominated by the Arc technology and this will not change within the next decades because of the installed base itself and the ever improving Arc evaporator technology. Figure 14 illustrates impressively what most innovative Arc technology can do.

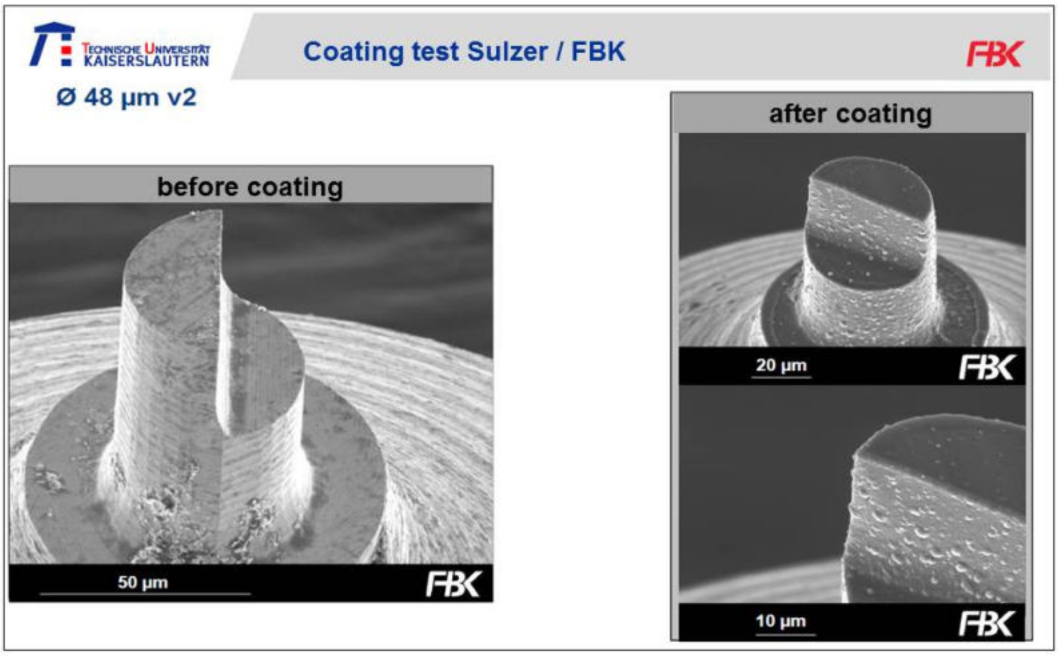


Figure 14: Applying a hard coating on a super mini tool with a diameter of 48µm using the APA Arc technology.

The continuous development of Arc evaporators like for the APA Arc technology resulted in a dramatic reduction of the amount and the size of the emitted micro particles. Thus also super mini tools with diameters in the 50µm range can be coated with top quality (Fig.14, right hand). Considering a standard industrial production not operated under clean room conditions and with highest maintenance effort after each batch, there will never be a defect free PVD tool coating. Besides the tool preparation the coated parts should be post treated anyway to improve the performance, because the surface quality can always be improved no matter what technology was used to apply the films. For HIPIMS there could be some niche applications. Feasibility studies are on the way e.g. for HSS thread cutters. To coat temperature sensitive materials, the low temperature deposition and the combination with PAVCD could become a scope of application where is a chance that HIPIMS will replace in part conventional sputtering.

In the future may be it will make sense to use the ionized species coming from magnetrons run in HIPIMS mode for the sputtering on dc magnetrons (metal ion sputtering). That might be of interest for materials that are not easy to be sputtered in a Argon plasma. In any case once one combines a high ionization process like HIPIMS or Arc with a low ionization process like conventional dc sputtering, a decrease in the ion-to-neutral ratio will be the result. In contrast, the combination of two high ionization processes like HIPIMS and Arc will always stay on a high degree of the ion-to-neutral ration even if the ions extracted from the Arc source are additionally used for sputtering on the HIPIMS magnetron. One will lose highly ionized film growing species but the sputtering rate on the HIPIMS target could be increased. That might be of interest to increase the deposition rate especially for such materials that can´t be evaporated by Arc. During the development of SIBONICA this effect has been seen when operating in the hybrid mode. Running the Arc sources and superimposing the HIPIMS deposition, resulted in a slight decrease in bias current. It indicated that less ionized species coming from the Arc sources reached the substrate. The assumption was that ions extracted from the Arc evaporators contributed to the sputtering on the HIPIMS targets driven by the ionization gradient. Of course there are more parameters to be considered like power level of the evaporators, the duty cycle, the distance between the evaporators and the positioning, the power applied as bias, etc. Further analysis and measurements have to prove this effect to decide how this effect can be useful used to improve the overall coating properties.

Conclusions

It has been demonstrated the systematic approach to the development of next generation high oxidation resistant tool coatings. Considering industrial needs and technological and economic constraints it could be shown that HI3, the combination of HIPIMS, APA Arc and AEGD, represents a hybrid technology most suitable for the development and production of novel high temperature stable tool coatings based on SiBC. As a result from a theoretical and practical feasibility study it can also be concluded, that HIPIMS as stand-alone solution is not going to play any major role in the tool coating business as already conventional sputtering has not been playing any major role so far. First SiBCN films in combination with micro alloyed hard coatings were applied onto HSS, cemented carbide and Inconel substrates following a clear layering design path. Standard quality inspections were carried including SEM and TEM analysis to optimize the parameter setup for deposition. The SIBONICA coating especially the SiBCN toplayer showed properties similar to those one can get from literature [1-5] and that characterize amorphous SiBCN based films like hardness values of 20GPa and an elastic recovery in the range of 70%. SIBONICA was applied onto Inconel samples and tempered upto 1,200°C in air. The coating showed impressive resistance against oxidation due to a fast generation of a dense and protective oxide layer. Cemented carbide inserts were coated and first tests machining so called exotic materials proved the outstanding properties of SIBONICA. The next development steps will focus on doping the SiBCN films, to further increase the oxidation stability, combining SiBCN films with different micro alloyed hard coatings and fine tuning of the coating design towards a higher nano-composite proportion to influence the mechanical properties.

The promising results from oxidation tests and first machining tests emphasise the right approach to SIBONICA based films as the next generation of high performance tool coatings using the HI3 technology for deposition.

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