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Hard and Super Hard Coating Materials Used for Tribological Applications

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ABSTRACT

Diamond like coating (DLC) and Cubic boron nitride (cBN) are the advanced coating materials used for coating automobile components and cutting tools. Diamond like coating are coated an coating thickness of 3 μm) on automobile components like camshafts, piston, piston rings , roller tappets, plungers (Common rail Diesel injection pump) and nano-composite materials by reactive magnetron sputtering method (PACVD) to increase the wear resistance properties by decreasing the friction, reduce CO_2-emission and to improve fuel efficiency. Various test such as abrasive wear test (calo test), scratch test and Rockwell hardness test is carried out on coated components to check the properties of coating and results are enclosed, Reference [1].

Cubic boron nitride (cBN) coating materials are coated on cemented carbide and HSS tools to withstand high temperature stability, to increase wear resistance properties, increase the hardness of the cutting tool and to enhance longer life of the cutting tool. cBN layer of thickness (3 - 5μm) is deposited on the tool substrate at a temperature ≤ 650ºC by reactive sputtering system, and turning experiment is carried out on cnc inclined bed turning lathe by using the cBN coated tool, results are enclosed and it has been found that by coating cBN layer > 2 μm results in high potential for cutting tools, Reference [1 & 2].

INTRODUCTION:

Diamond is one of the hardest and strongest metal formed by Sp^3 hybridized carbon atoms having tetrahedral amorphous crystal structure. Diamond like coating (DLC) is basically a carbon based coating having low friction coefficient, better adhesion, toughness, better electrical conductivity**,** high hardness and high wear resistance properties. DLC coatings can be made that at the same time are amorphous, flexible, and yet purely sp^3 bonded "diamond". The hardest, strongest, and slickest is such a mixture, known as tetrahedral

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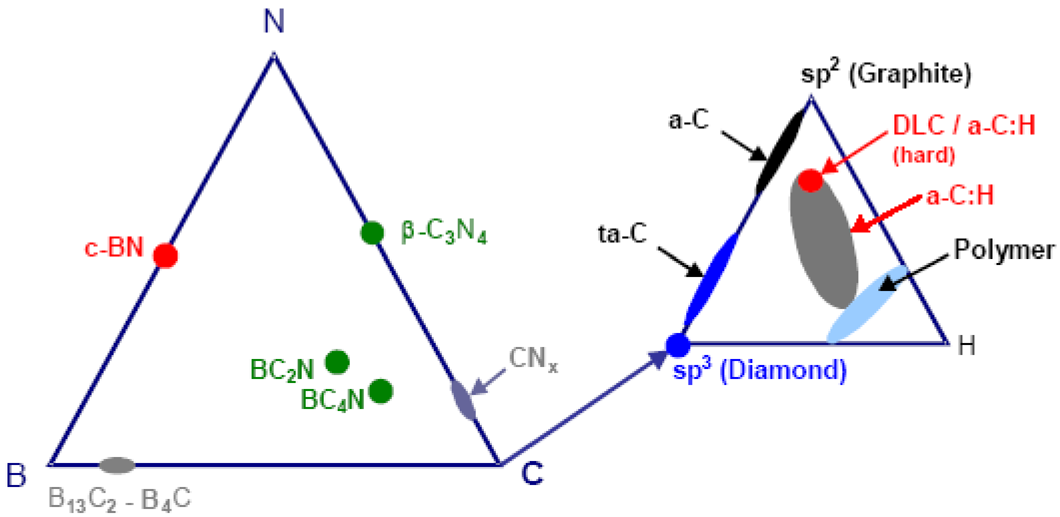
amorphous carbon, or ta-C. For example, a coating of only 2 μm thickness of ta-C increases the resistance of common stainless steel against abrasive wear; changing its lifetime in such service from one week to 85 years. Such ***ta-C*** can be considered to be the "pure" form of DLC, since it consists only of sp^3 bonded carbon atoms. Fillers such as hydrogen, graphitic sp^2 carbon, and metals are used in the other 6 forms to reduce production expenses or to impart other desirable properties. The various forms of DLC can be applied to almost any material that is compatible with a vacuum environment.



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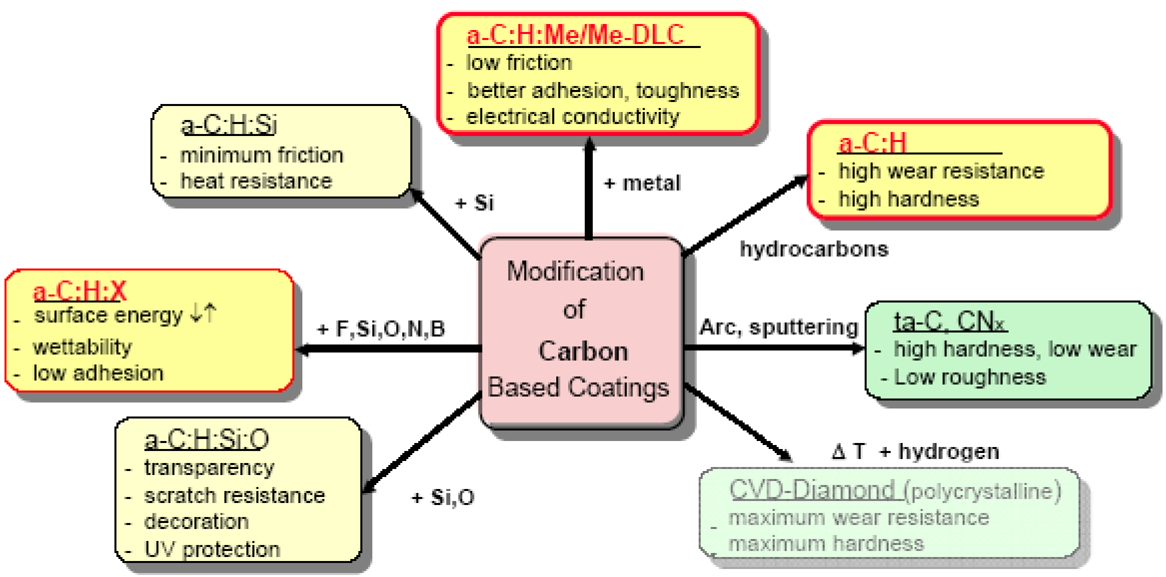

Carbon based coatings: **DLC**, *Diamond*

Due to their unique properties, they are used extensively for coating almost all sliding and rolling components where the components are subjected to friction between two lower pair and higher pair contact surfaces. Plasma assisted CVD techniques (PACVD), which employs RF and DC glow discharges in hydrocarbon gas mixtures produce smooth amorphous carbon and hydrocarbon films in the high-vacuum environment inside the machine chamber by reactive magnetron sputtering system (Hauzer HTC 1000) as shown in Fig.1, references [1].

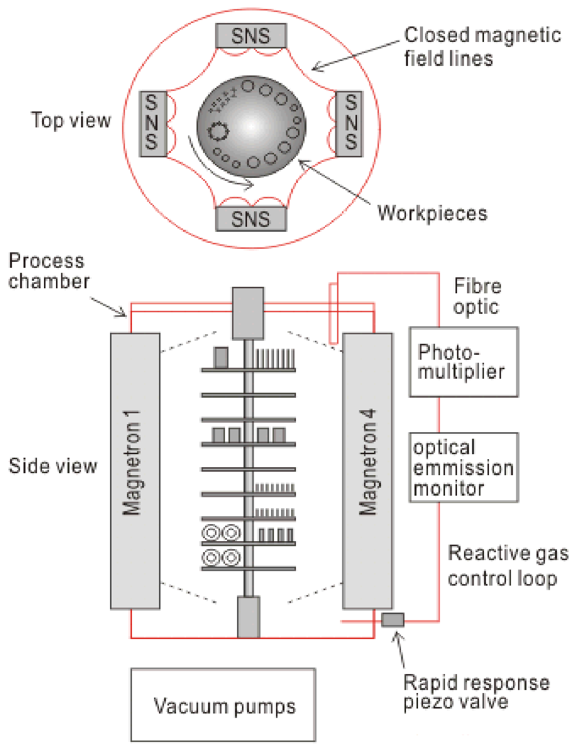

Fig 1. Schematic of a four magnetron closed field reactive magnetron sputtering system (Hauzer HTC 1000)

The coating flux impinges on the substrates from all directions and only simple single axis rotation during deposition is necessary. DLC coating exhibit hardness values of 900-3000H_v. The CVD processes will generally require deposition temperatures of at least 600°C to give the required combination of properties, which have mixed sp^2 and sp^3 bonds . The CVD processes gives good deposition rates and very uniform coatings and is well suited for coating automobile components.

Typical applications of Diamond like coatings are:

1) Automotive components (camshafts, piston, piston rings, roller tappets, gears, valves, bearing, fuel injection pump's plunger).

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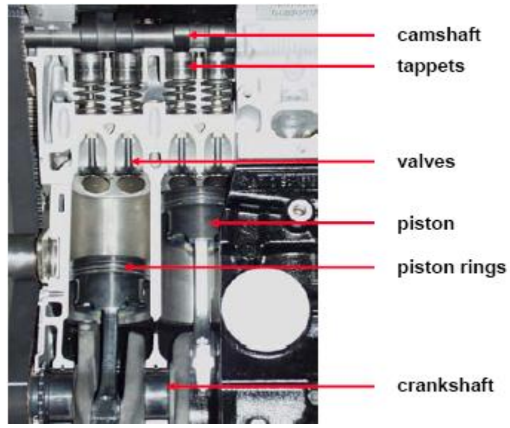


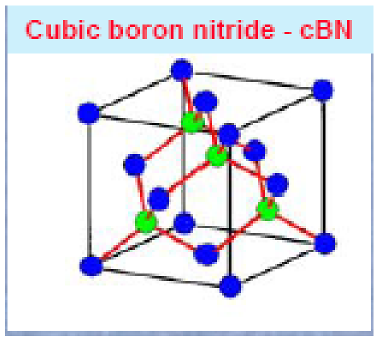
2) Forming tools for aluminum and stainless steel deep drawing.

Forming tools

3) Press stamps for pellet manufacturing and forming stamps for production of beverage cans and for coating nano composite sensor .

Cubic boron nitride (cBN)

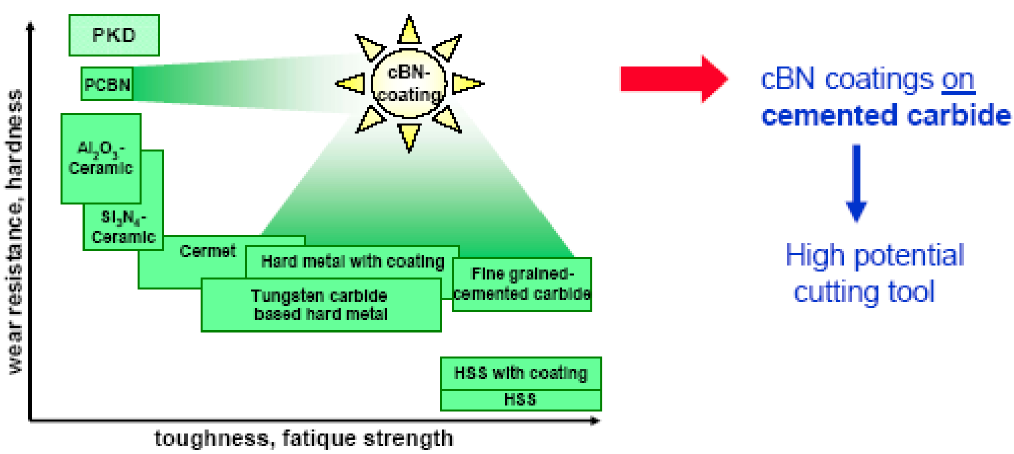
Cubic boron nitrides are very hard and wear resistance especially at high temperatures and low reactivity with Fe. Thick cBN based coatings were deposited by PVD and PACVD techniques, e.g. by reactive sputter deposition using boron carbide targets. These sputter deposited coatings are long – time stable and not sensitive against humidity. Cubic boron nitride coatings on cemented carbide results in high potential cutting tools.



Crystal Structure

Cubic boron nitride coatings for tools:

- Very high hardness + Wear resistance especially at high temperatures.
- Low reactivity with Fe (in contrast to diamond) → Steel machining.



cBN layer system on tool substrates

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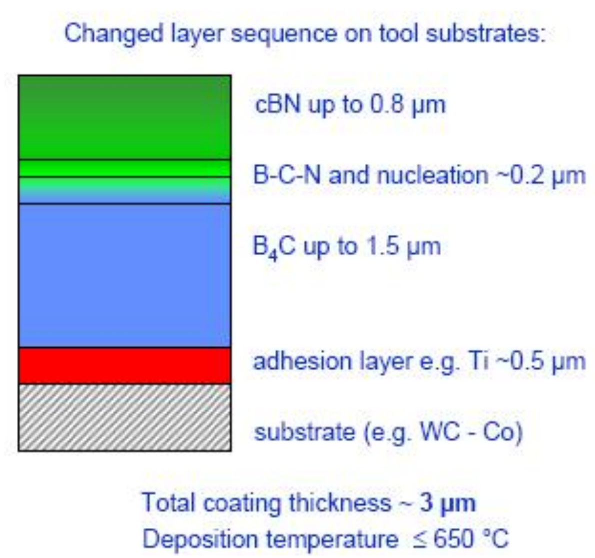
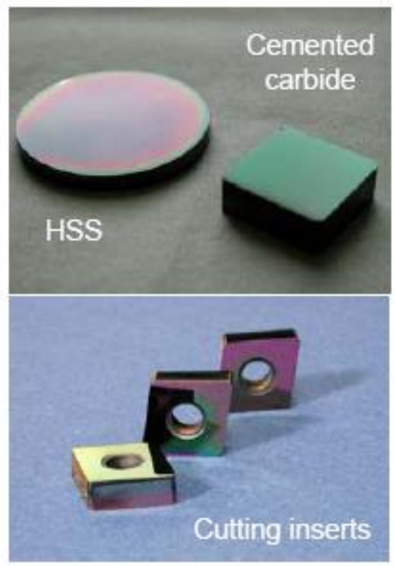
Cubic boron nitride (cBN) is advanced engineering ceramics materials which have very high hardness and high wear resistance especially at temperatures. It has low reactivity with Fe, hence suitable for turning and machining steel. cBN materials are coated on cemented carbide and HSS tools to enhance longer life of the cutting tool, to withstand high temperature stability, to increase wear resistance properties and increase the hardness of the cutting tool. cBN layer of thickness (3 - 5μm) is deposited on the tool substrate at a temperature ≤ 650ºC by reactive sputtering system, references [1]. The typical application of cBN coatings are milling cutters, inserts, drill bits, thread forming tools, punches and dies.





Applications:

Properties	Type	C1	C2	C3	C5	C7 PLUS
Nanohardness (GPa)		25	33	30	18	45
Coefficient of friction (dry against steel)		0.5	0.2	0.6	0.3	0.45
Maximum usage temperature		600	400	750	700	1100
Layer thickness (µm)		3 ± 1	3 ± 1	3 ± 1	3 ± 1	2.5 ± 0.5
Colour		Golden	Copper	Violet	Metal	Black
Structure		Monolayer	Gradient	Multilayer	Monolayer	Gradient

EXPERIMENTATION AND RESULTS:

Various tests conducted on Diamond like coated components:

1) Calo test to determine the abrasive wear in DLC components.

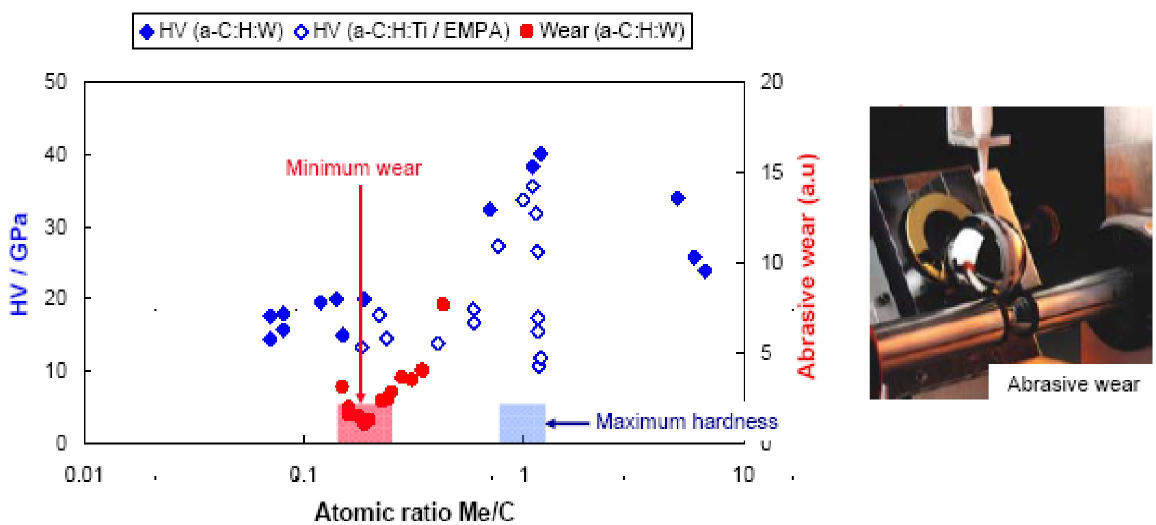


Fig.2. Hardness and wear of Me-DLC, References [1].

Calo test was carried out to determine the abrasive wear of DLC coated components. It has been found that DLC components have Minimum wear and maximum hardness.

2) Friction – Pin on disk test to determine friction coefficient.

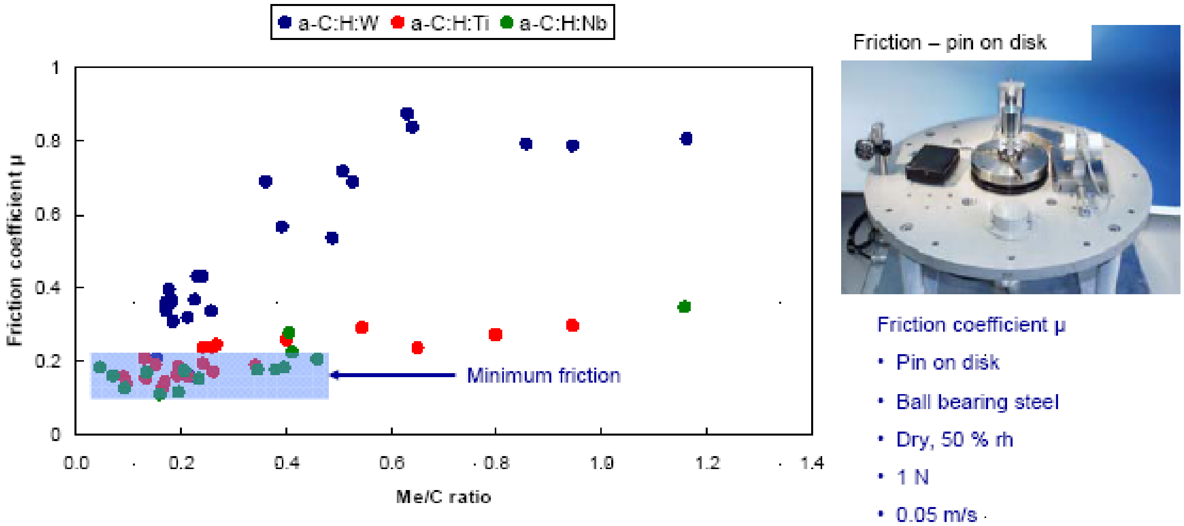
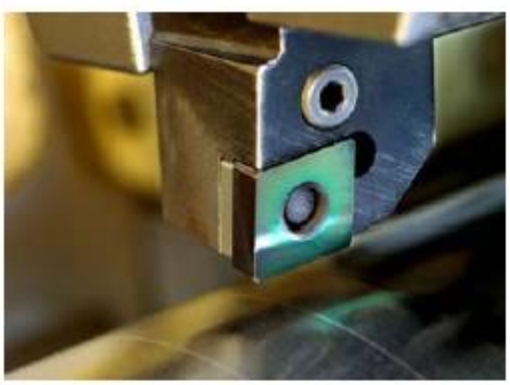


Fig.3. Friction coefficients of Me-DLC, References [1].

Friction – Pin on disk test was conducted to determine coefficient of friction on DLC coated component. It has been found that DL coated components exhibits minimum friction.

Turning experiment by using the cBN coated tool:

1) Turning experiment was carried out on cnc inclined bed turning lathe by using the cBN coated tool.



Turning Experiment, References [2]

Experimental setup:

Machine tool:	cnc inclined bed turning lathe
Machining process:	external cylindrical turning
Worpiece material:	0.7050
Hardness:	200 HB 30
Cutting velocity:	v_c = 1000 m/min
Cutting depth:	a_p = 0.5 mm
Feed:	f = 0.1 mm
Cooling lubricant:	dry
Workpiece geometry:	hollow cylinder
Workpiece dimensions:	150 x 65 x 195 mm
Common parts:	crank shaft, gear parts
Commonly used cutting material:	PCBN, oxide ceramics

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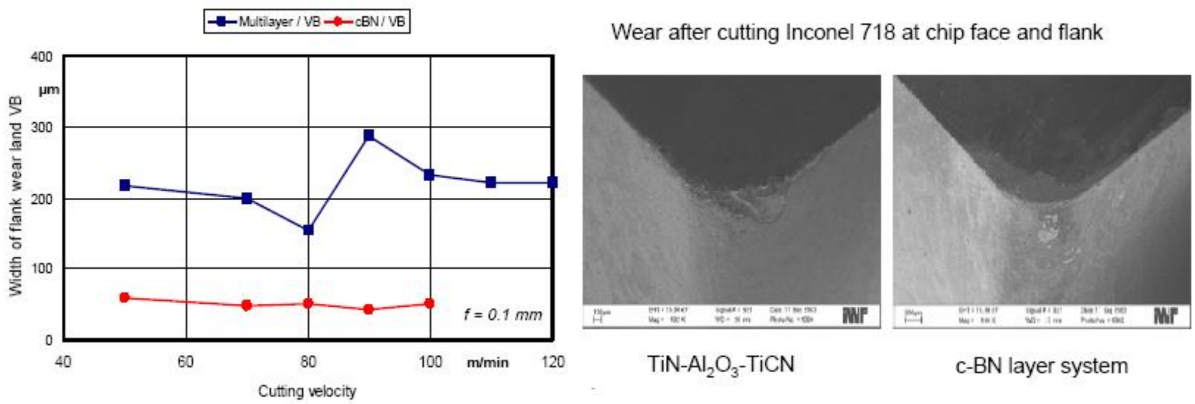

Fig.4. Graph, cutting velocity versus tool flank wear

It has been found that the cBN coated tools have minimum flank wear land than TiN-Al_2O_3-TiCN.

Conclusion:

Various applications of DLC and cBN coating has reduced wear and friction of components and tools. These sputter deposited coatings are long – time stable and not sensitive against humidity. Turning tests reveal the high potential of cBN coated tools.

Future work, increase cBN thickness on cemented carbide, improved adhesion.

Acknowledgement:

I would like to thank my parents and friends for their whole hearted support.

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2) Turning Experiments by E. Wiemann, Institute for machine tools and factory management, TU Berlin, Germany.

3) Unimerco surface coatings technologies, Germany