
Diamond-like Low-friction Coatings for Tools and Components

Forum "Innovations for Industry"

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S. Makowski

H.-J. Scheibe, V. Weihnacht, A. Leson

Fraunhofer-Institute for Material and Beam Technology, Dresden, Germany

Outline

- Fundamentals
- Deposition Technology
- Properties and Potential
- Application on Tools and Components

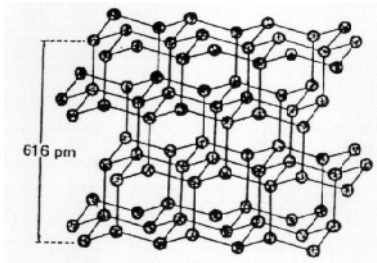
Fundamentals

Fundamentals: The different faces of carbon

Diamond



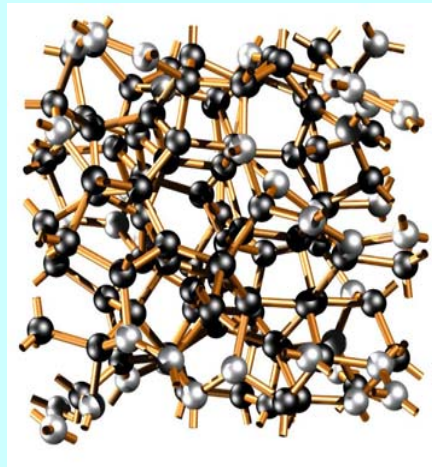
Very hard
No electric conductivity
Transparent



sp^3 - crystalline

Amorphous Carbon

“Diamond-Like Carbon”

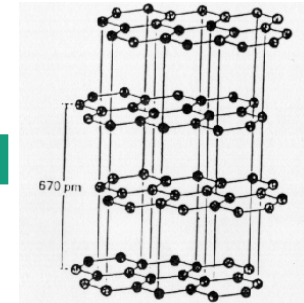


$sp^2 + sp^3$ - amorphous

Graphite

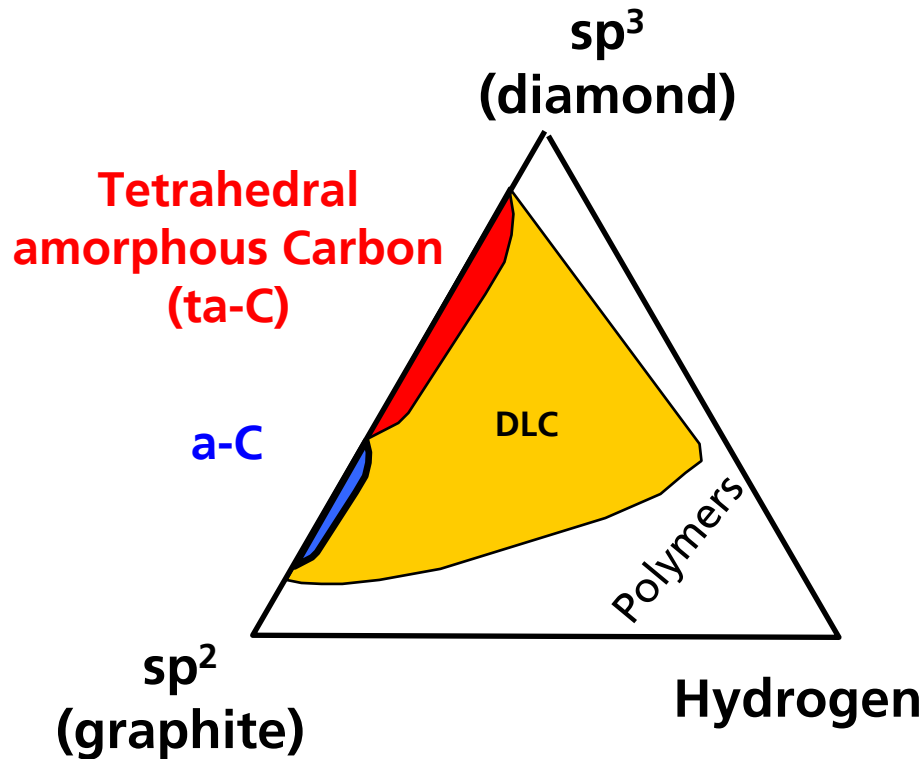


Soft
High electric conductivity
Black color



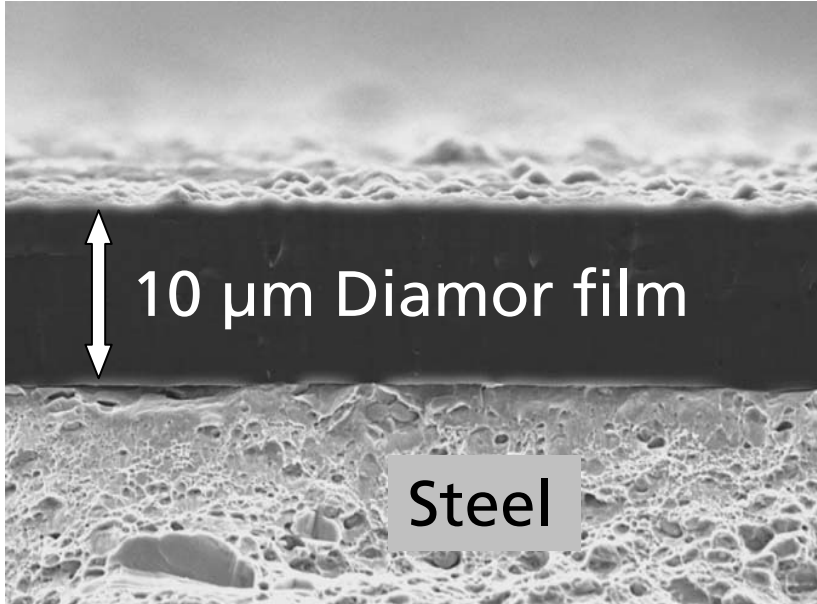
sp^2 - crystalline

Fundamentals: Diamond-Like Carbon



- Broad range of properties
- Not all DLCs have "diamond-like" properties
- ta-C is hardest, most diamond-like type of DLC
- Fraunhofer's ta-C: Diamor[®]

Fundamentals: Diamor® Films



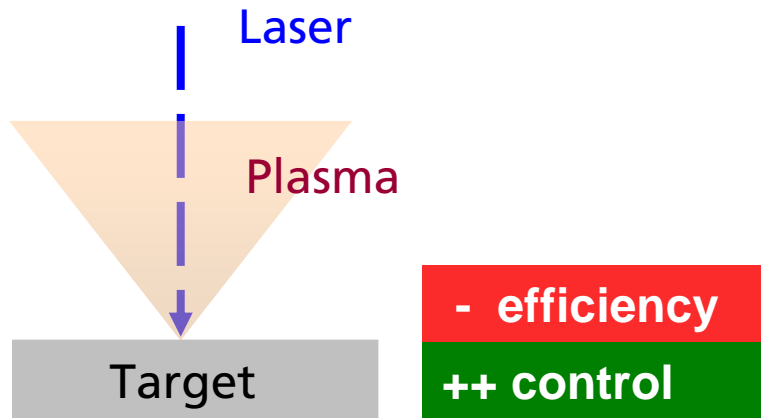
- High hardness: 40...70 GPa (4000-7000 Vickers hardness)
- Thermal stability: <math><400^{\circ}\text{C}</math>
- Biocompatible
- Low adhesion – low friction (dry: $\mu < 0,1 \dots 0,2$)
- High wear resistance

- Substrates: metals, polymers
- Deposition: 50...150°C, vacuum
- Typical film thickness: 2...5 μm

Deposition Technology

Deposition Technology: PVD

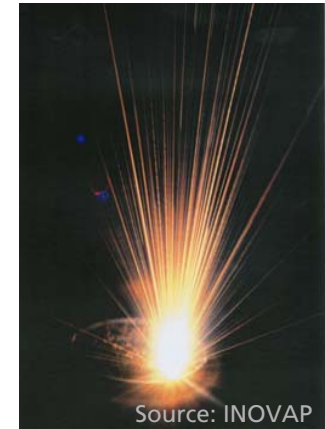
Pulsed Laser Deposition (PLD)



Vacuum Arc Deposition (VAD)

Uncontrolled cathode spot motion & particle emission

++ efficiency
- control



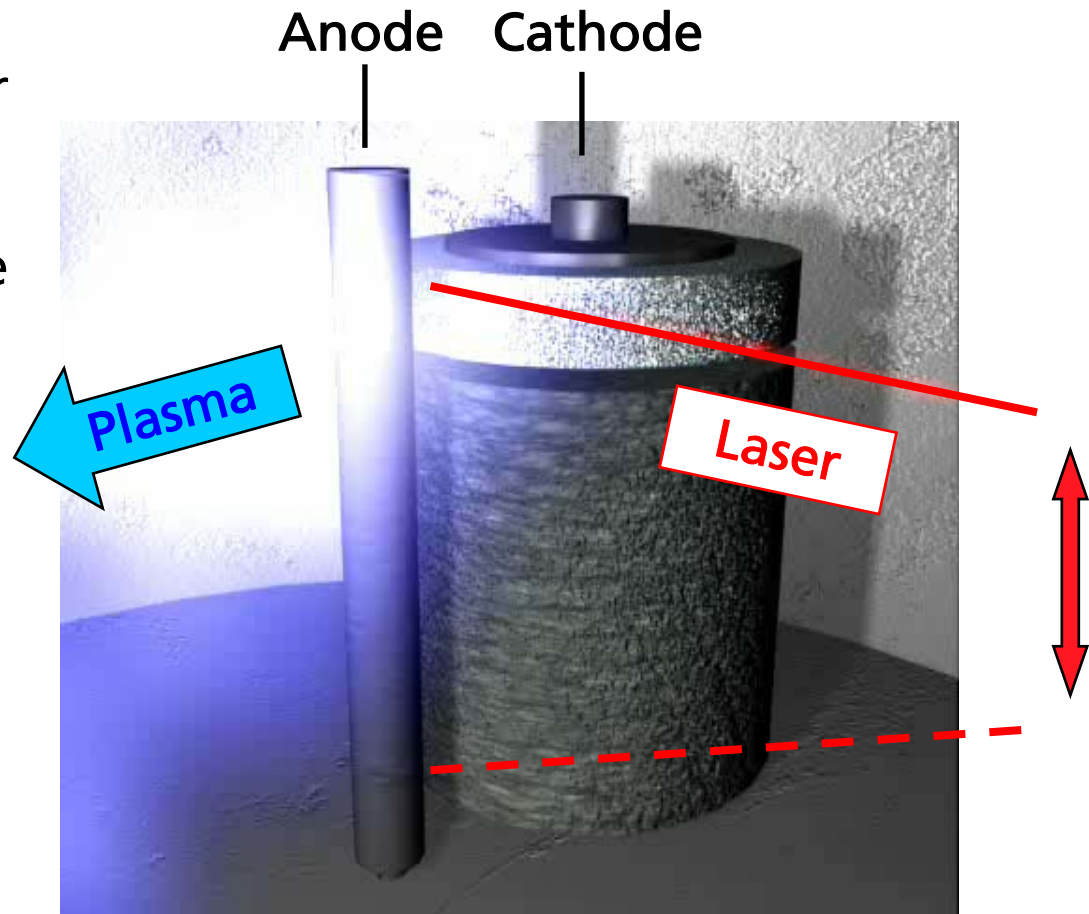
Laser-controlled Arc



+ efficiency
++ control

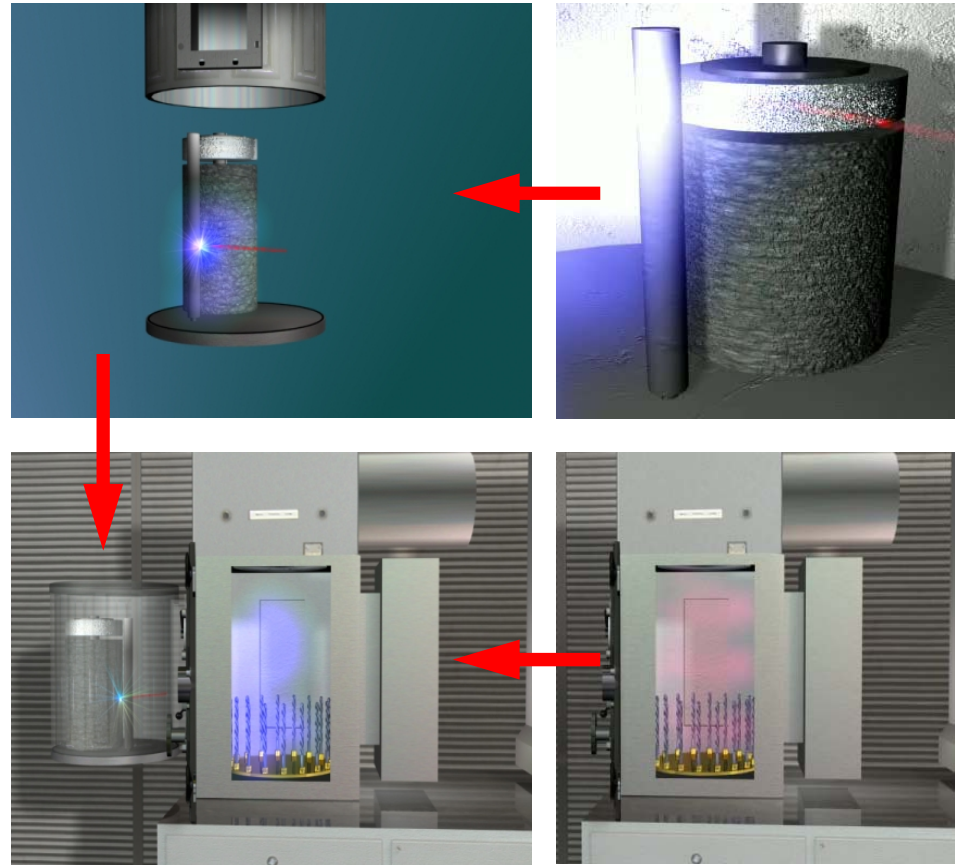
Deposition Technology: Laser-Arc Technology

- Rotating cathode cylinder
- Material stacking possible
- Laser ignites vacuum arc
- "Line source" through laser scanning
- Highly ionized plasma, sp^3 -rich carbon films



Deposition Technology: The Laser Arc Module (LAM)

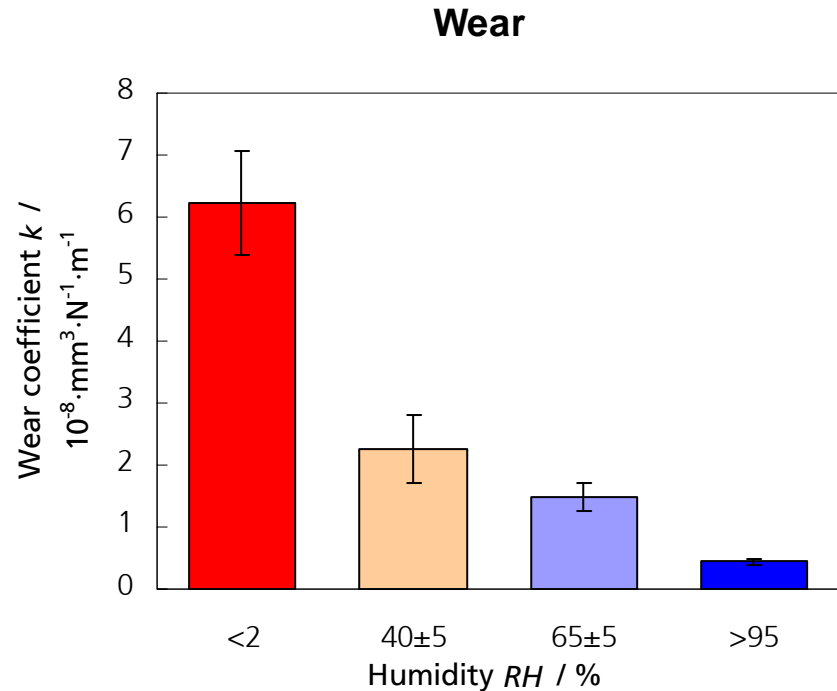
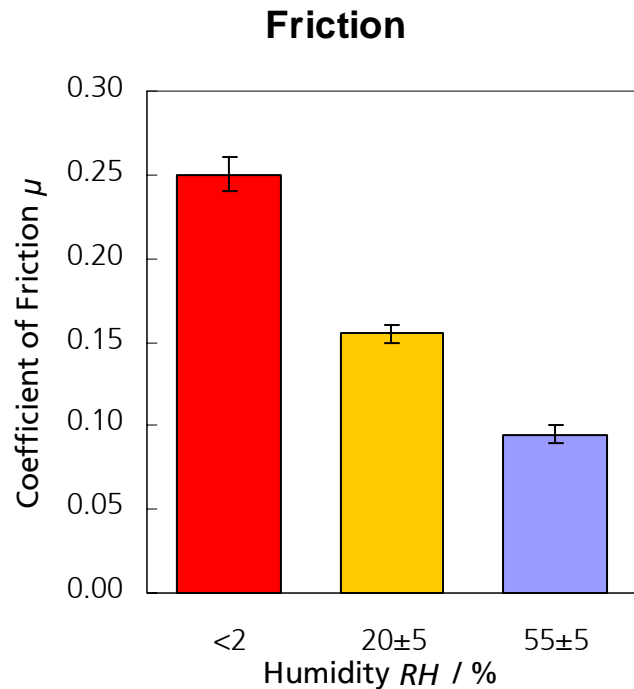
- Laser-Arc technology available as external module
- Can be added to commercial coating systems
- Developed for application in industry environment



Properties and Potential

Properties and Potential: Wear & Friction - Unlubricated

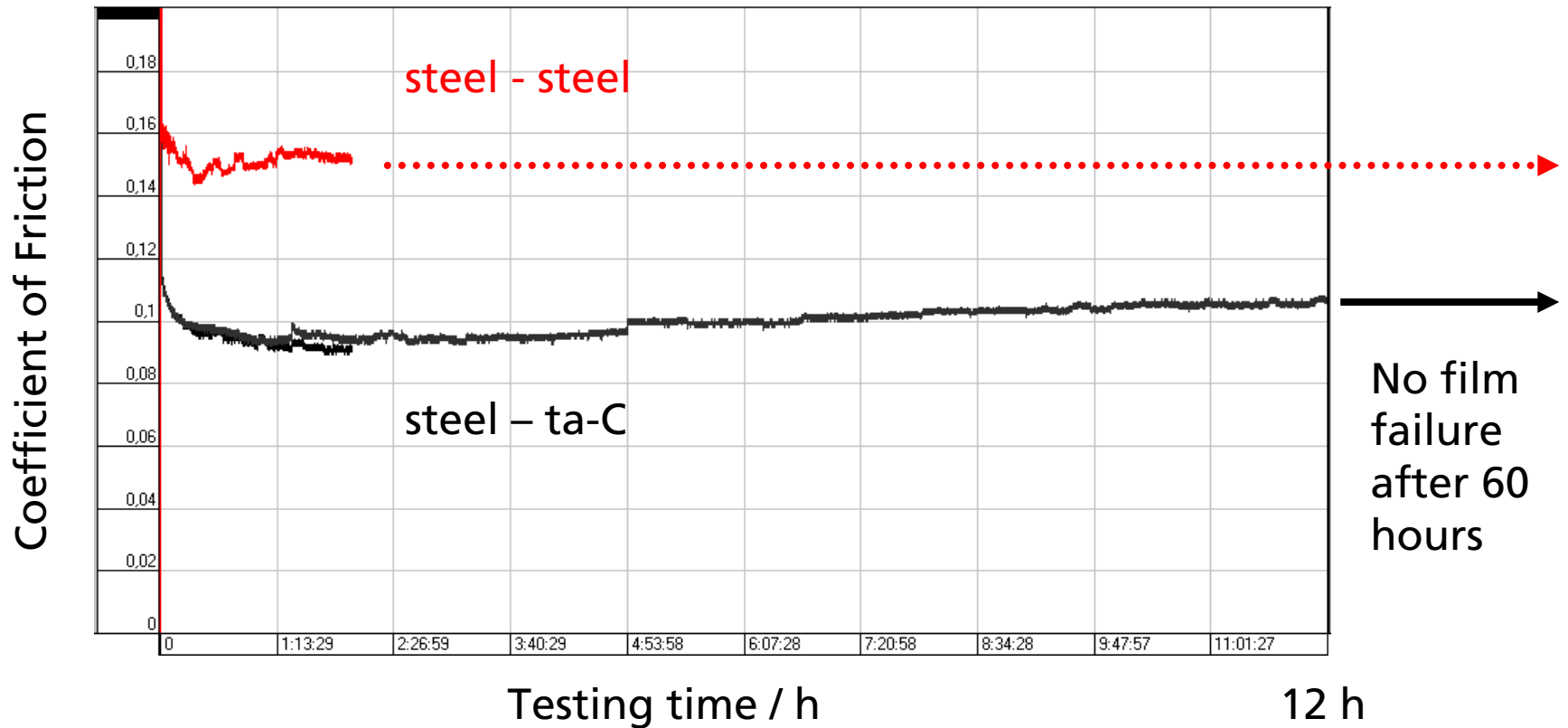
Tribometer Testing: Steel against Diamor, unlubricated



Ball-on-flat, 10 Hz, 40 N, 1 mm, ~22°C, 10 mm hardened steel ball on ta-C

Properties and Potential: Friction - Lubricated

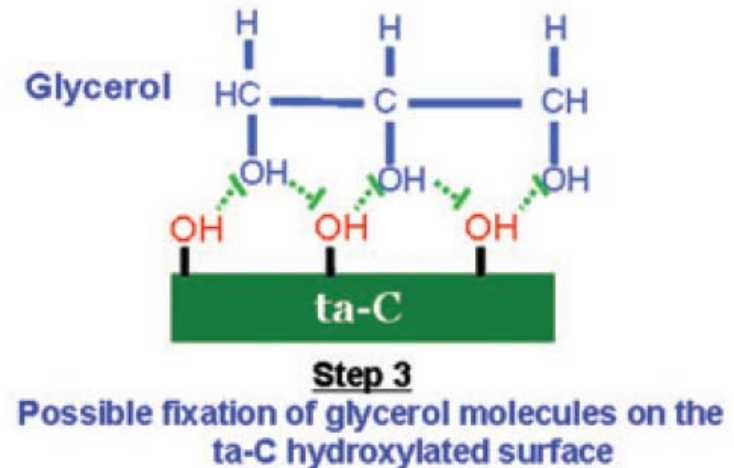
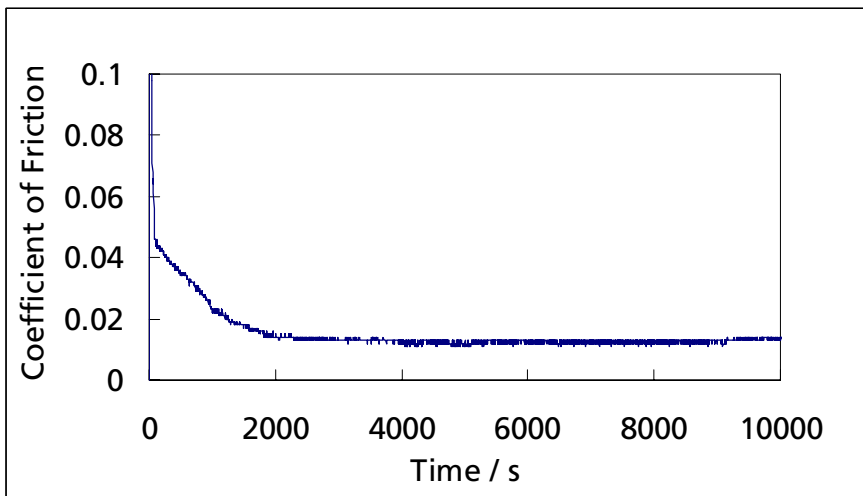
Tribometer testing: "Castrol VP1" engine oil at 150°C



Ball-on-flat, 50 Hz, 150 N, 2 mm, 150°C, 10 mm hardened steel ball on ta-C

Properties and Potential: Ultralow friction

- Superlow friction in ta-C/steel contact with special additives like GMO (Glycerol-Monooleat)
- Potential for industrial application is investigated



Ball-on-flat, 50 Hz, 150 N, 2 mm, 150°C, 10 mm hardened steel ball on ta-C

Source: Matta et. al, 2009

Properties and Potential: Summary

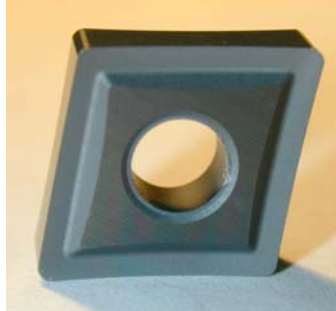
Diamor® coating:

- High hardness, high abrasion resistance
- Low adhesion
- Low reactivity; biocompatibility
- Friction reduction in common lubricated steel-steel contacts
- Low friction in unlubricated systems
- Ultralow friction with special additives
- ➔ **Less friction, less wear**
- ➔ **Better performance in case of lubrication failure**

Application on Tools and Components

Application: Coated Tools

Machining Tools



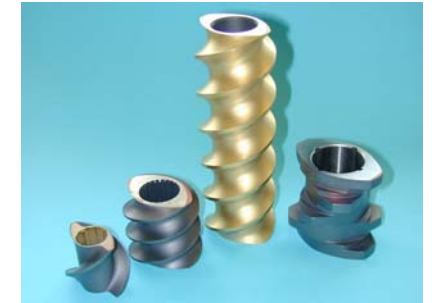
Powder Processing



Forming Tools

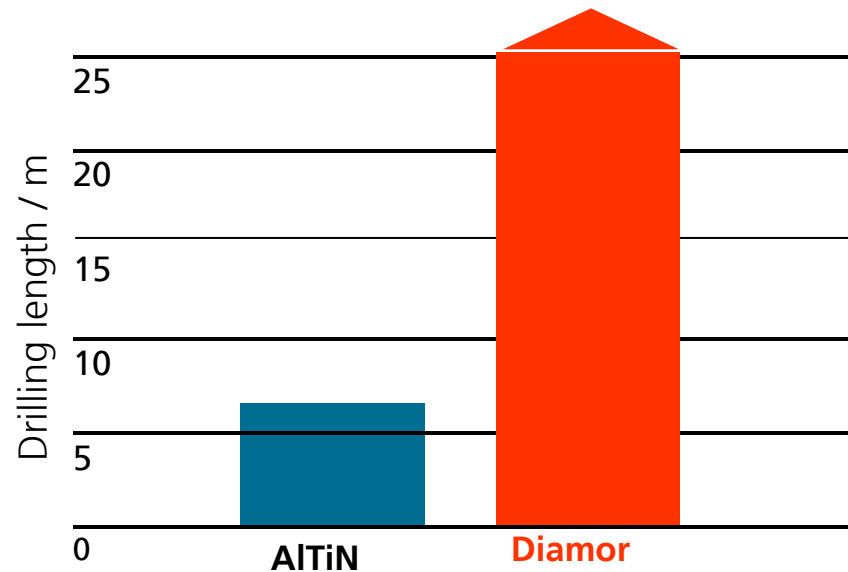


Polymer Processing



Application: Coated Aluminum Drill

Drilling of „hard“ Aluminium (Al6061) without lubrication



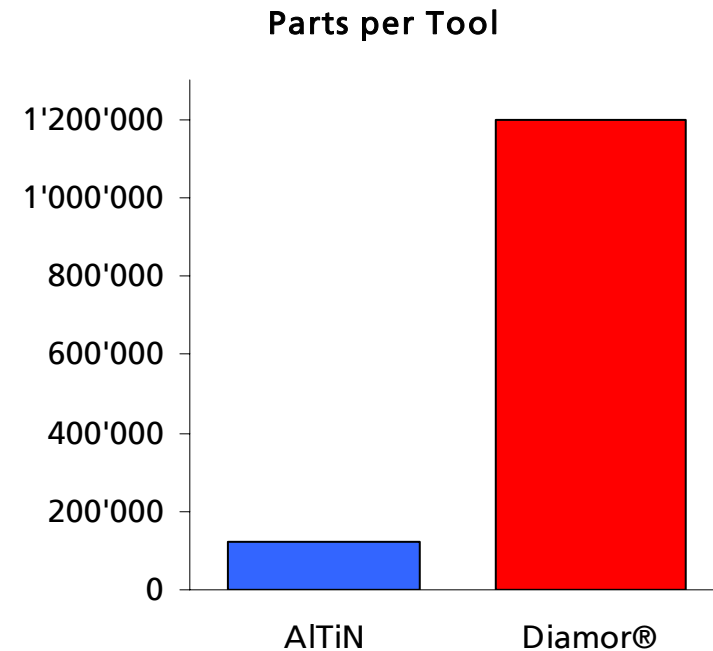
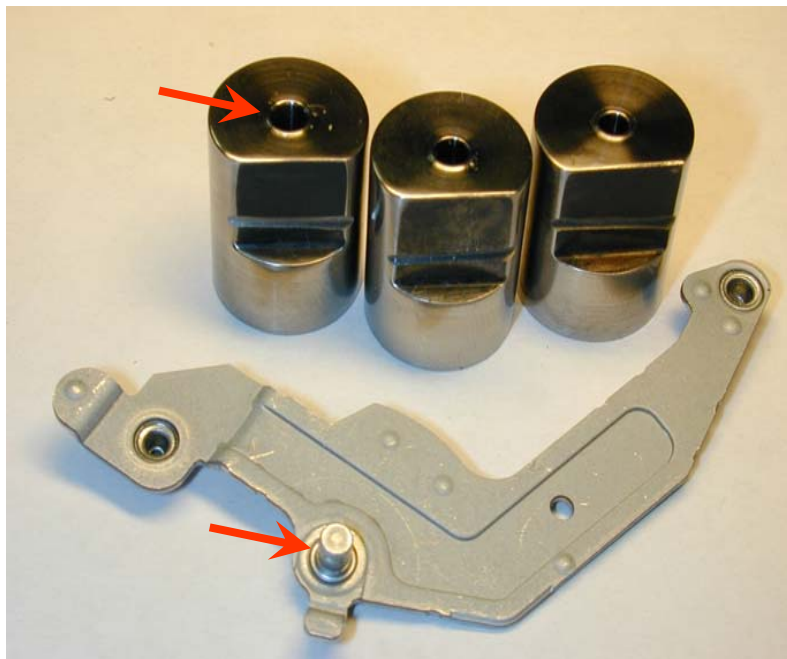
$v_c=180$ m/min, $f=0.3$ mm

Tool life increased more than five times compared to conventional coating (AlTiN)

Application: Coated Deep Drawing Tool

Benefits

- 10x longer tool life
- Water-based lubricant instead of oil-based lubricant



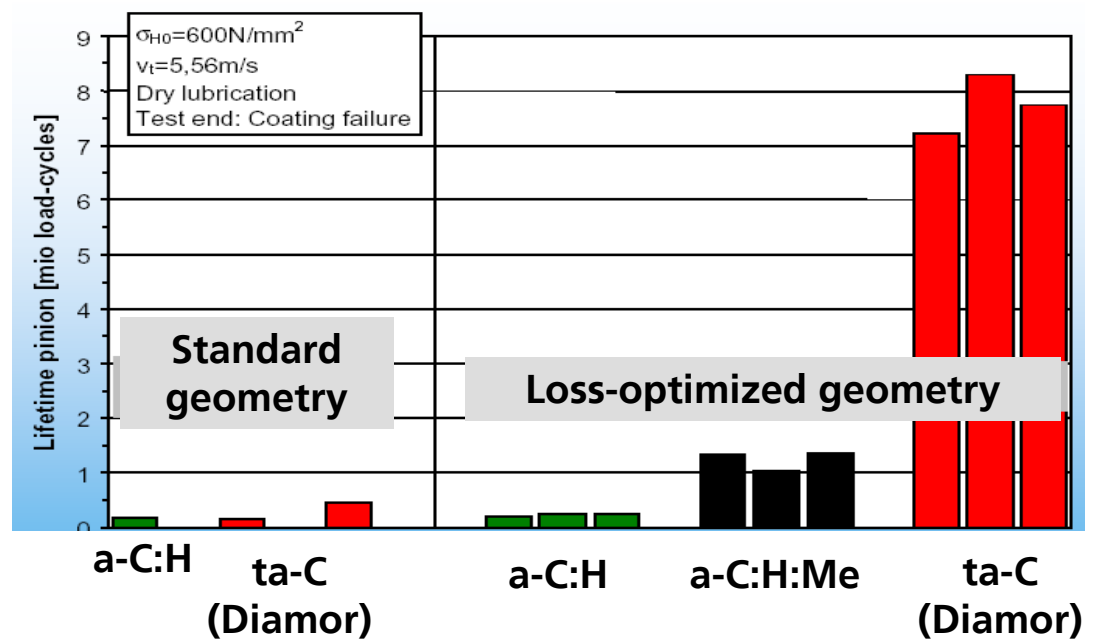
Application: EU research project "Oil-Free Power Train"

Investigation of new methods and materials for oil-free power-train technology



Standard geometry

Optimized geometry



Application: Self sharpening blade

Self sharpening technology through hard-soft-composite ("rat tooth")



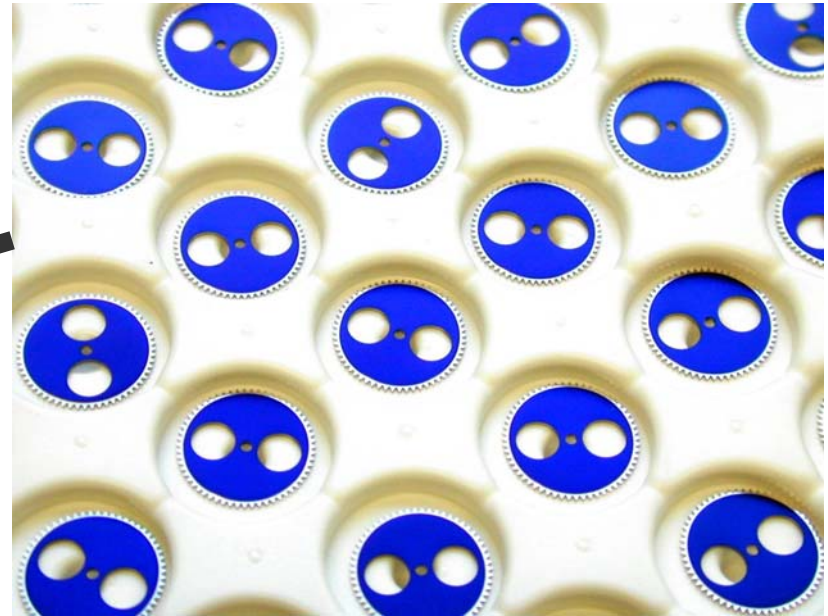
Source: Nesmuk

Application: Decorative Coatings

Opaque, colored coatings in the hundred nanometer range can be deposited on almost all substrates



Source: Lange Uhren GmbH



Thank you for your attention

Diamor® coated parts are on exhibit at



***ECEMP – European Centre for Emerging
Materials
and Processes Dresden***

in hall 2, booth E53