Temperature Dependent Failure Modes of DLC Coatings on High Speed Steels Investigated by the Impact Test

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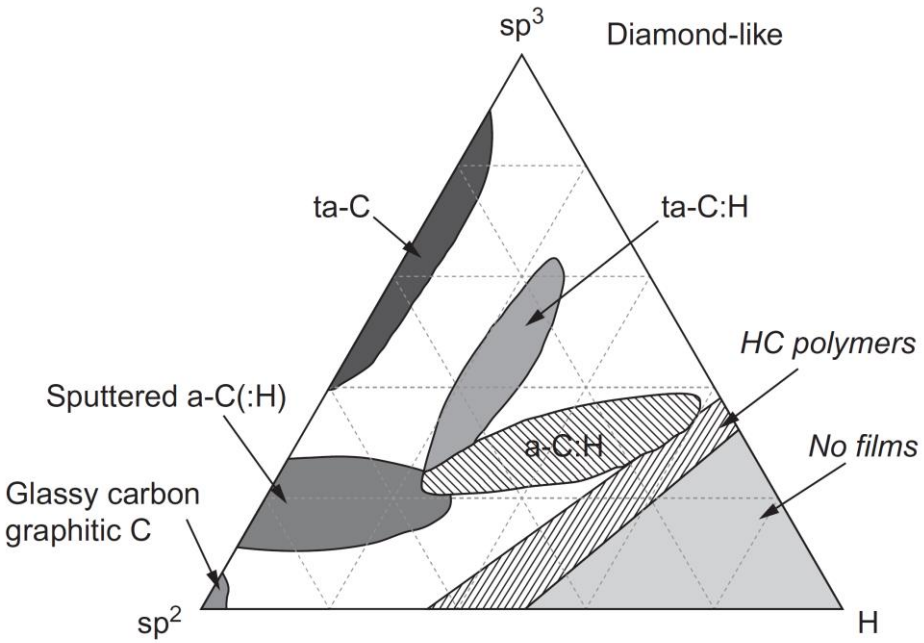
Photo: Specht-Maschine, FFG-Werke

Outline

Photos: VDW

Diamond-like carbon (DLC) coatings

- High hardness
- Low coefficients of friction
- Applications:
  - Automotive components
    e.g. camshafts and tappets
  - Biomedical implants
  - Blades in disposable razors etc.

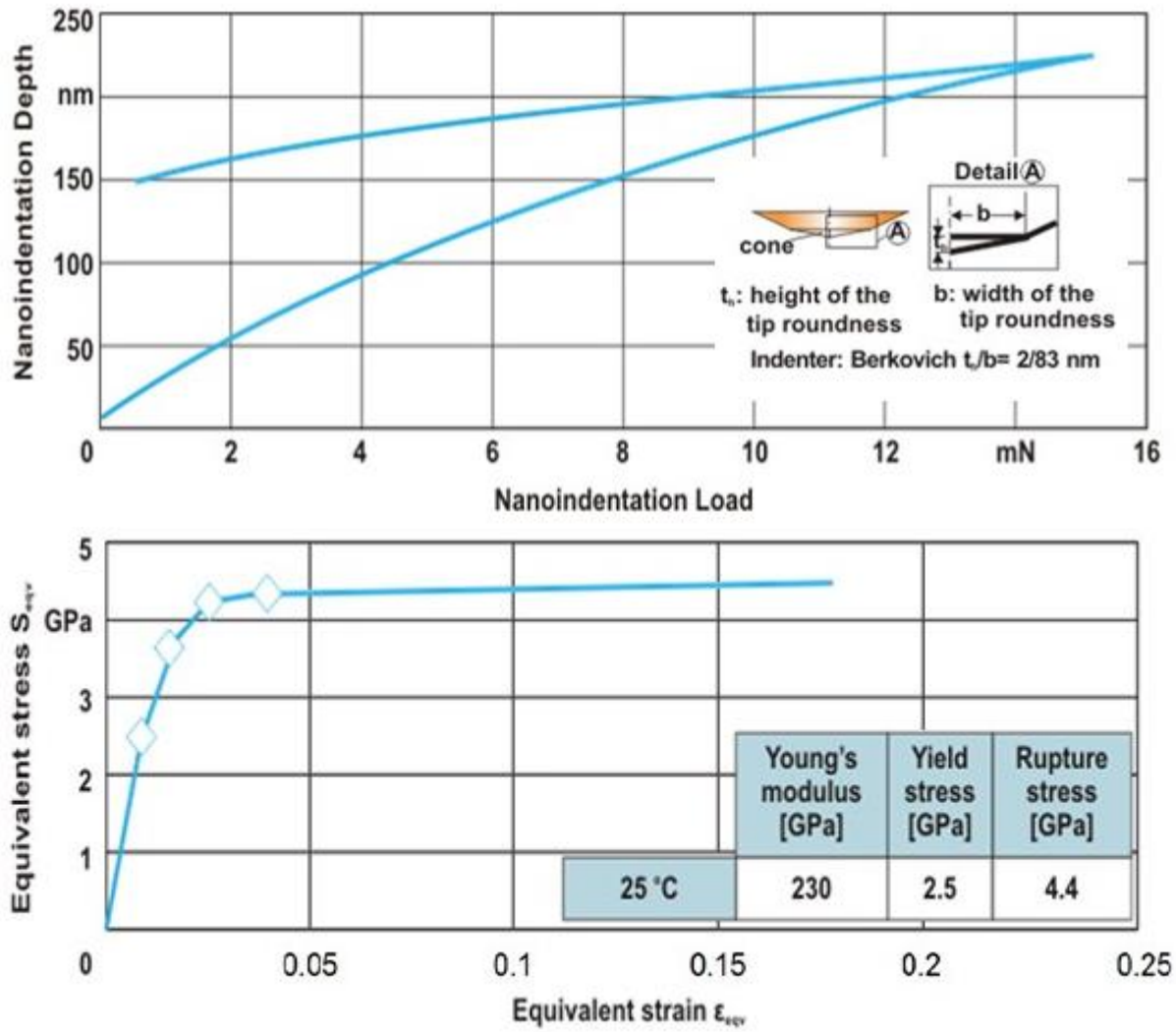


Source: Hutchings, I. & Shipway, P. (2017), in: Tribology: Friction and Wear of Engineering Materials. Surface engineering, 237-281

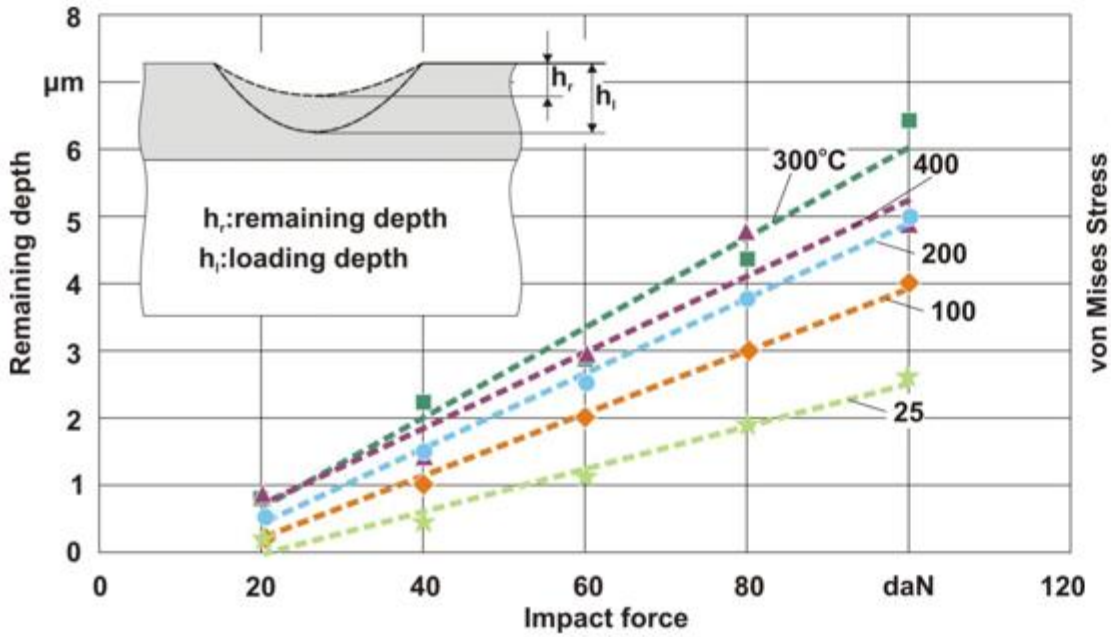
Outline

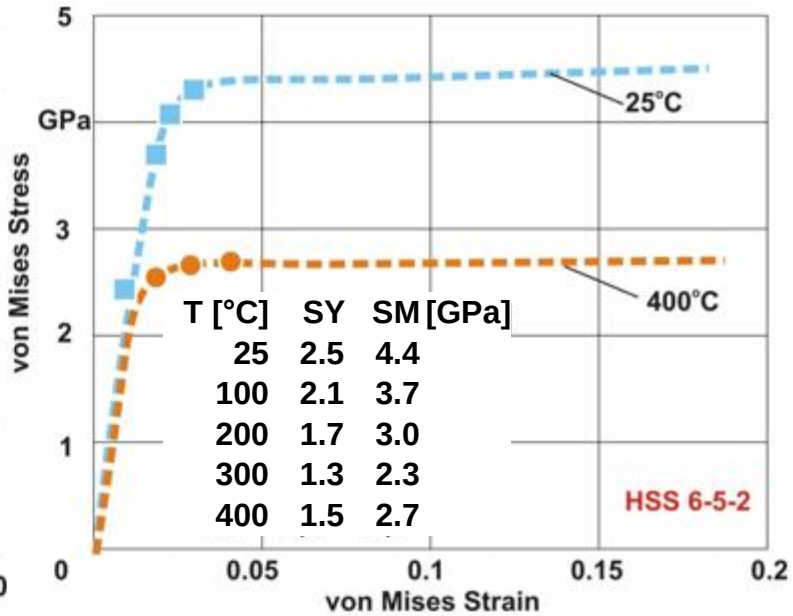
Photos: VDW

Stress–strain curve of HSS substrate at ambient temperature, attained via an FEM supported evaluation of nanoindentation results



Remaining imprint depths on HSS substrate at various temperatures and determined stress–strain data





T [°C]	SY	SM [GPa]
25	2.5	4.4
100	2.1	3.7
200	1.7	3.0
300	1.3	2.3
400	1.5	2.7

Outline

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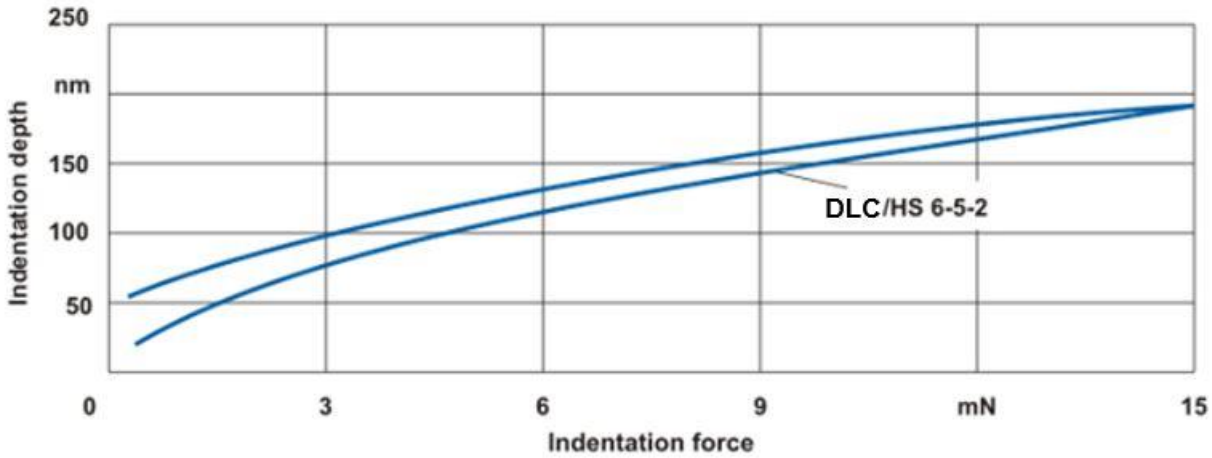
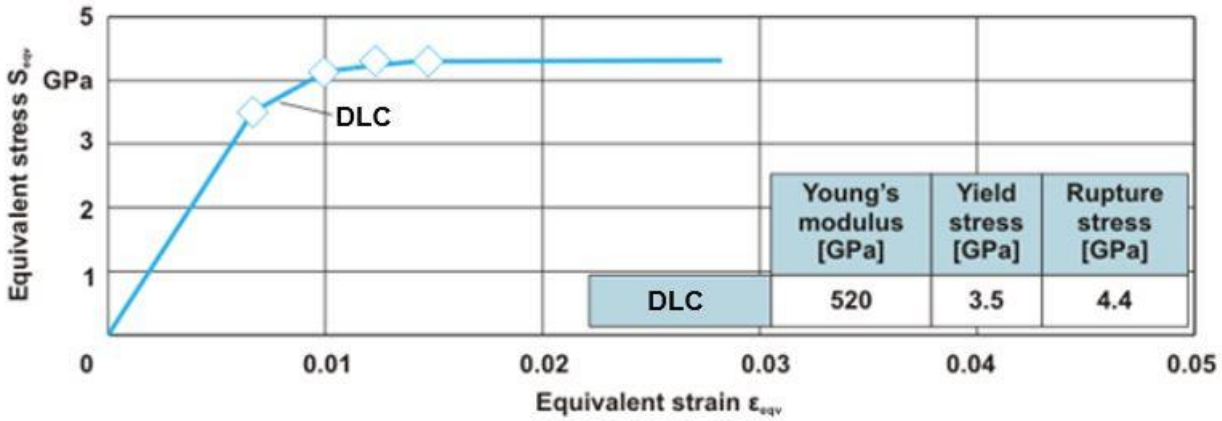
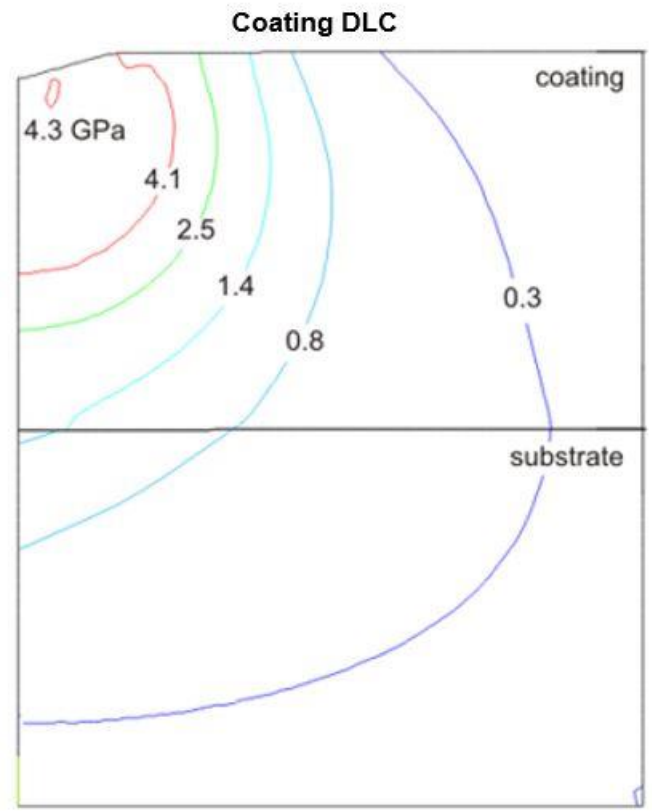
Stress–strain curve of DLC coating at room temperature via FEA calculation and developed stress field during nanoindentation



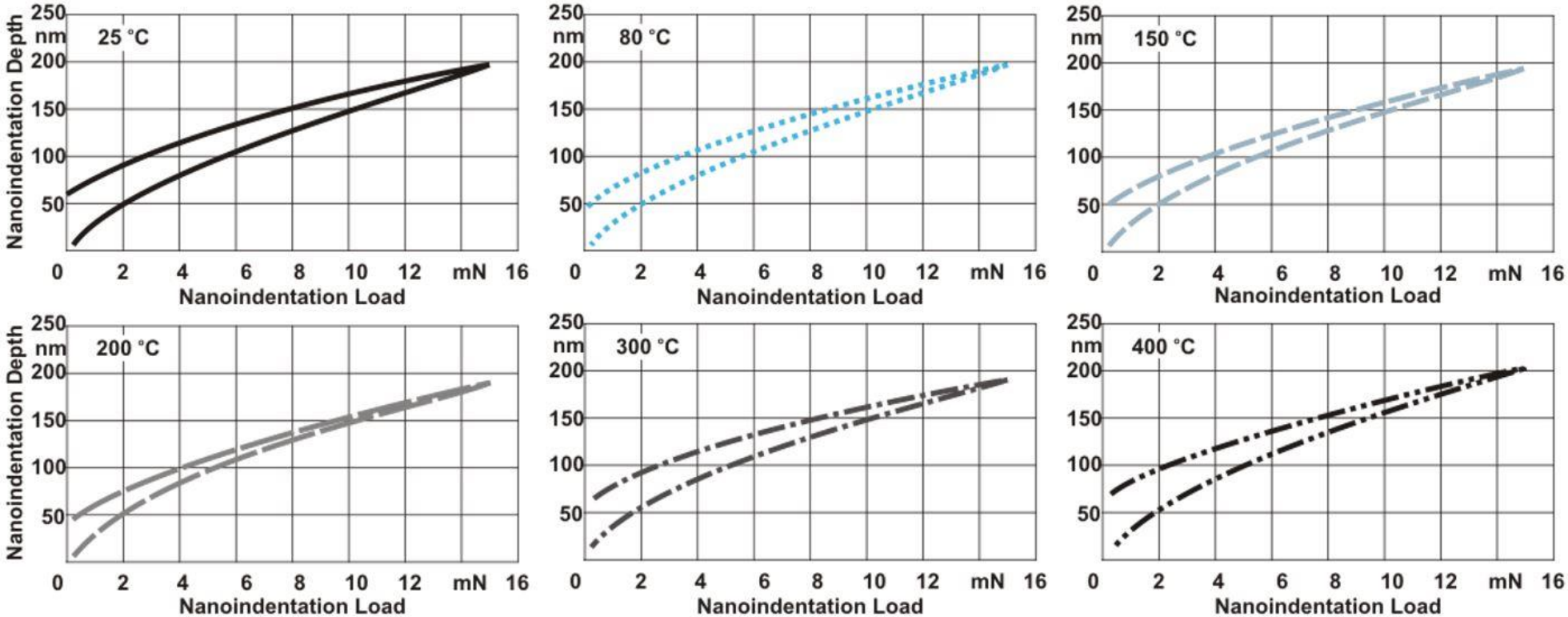


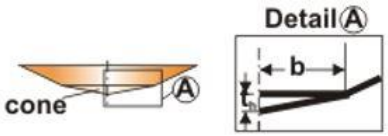
	Young's modulus [GPa]	Yield stress [GPa]	Rupture stress [GPa]
DLC	520	3.5	4.4



indentation load: F = 15 mN
Berkovich indenter, ANSYS simulation

Nanoindentations on DLC coating at temperatures up to 400 °C





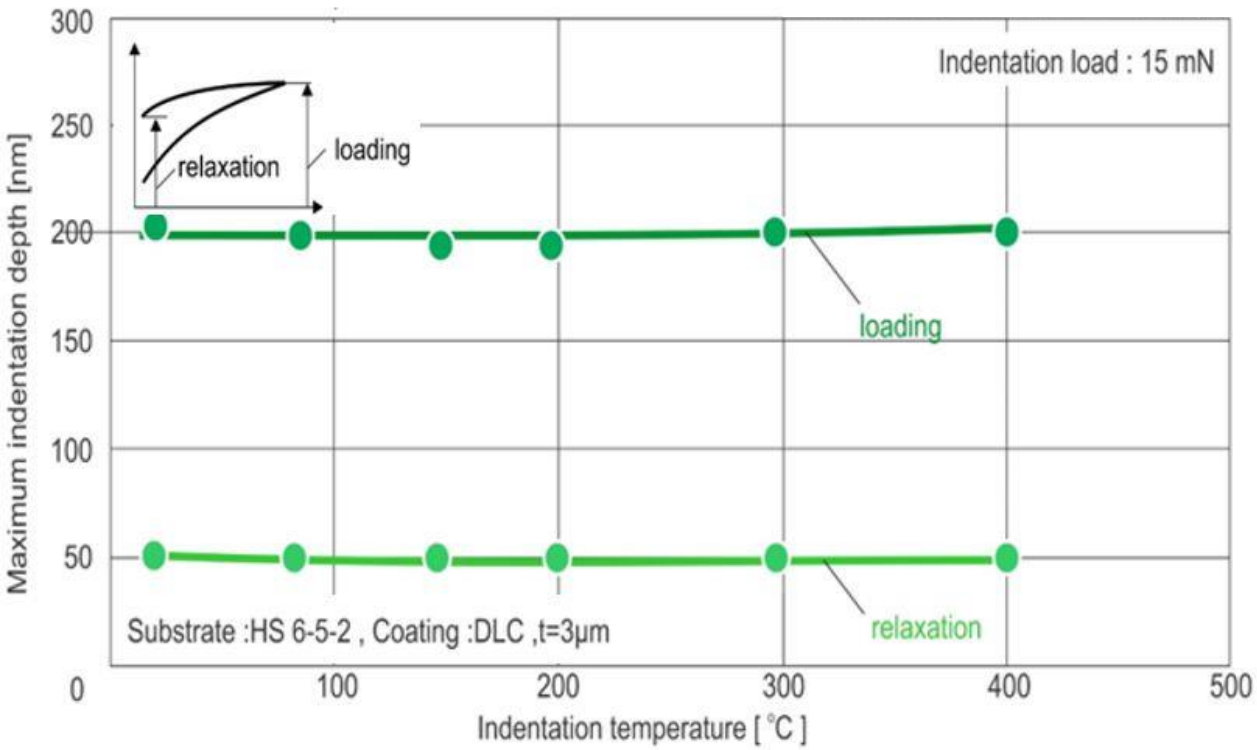
Coating : DLC, Substrate : HS 6-5-2

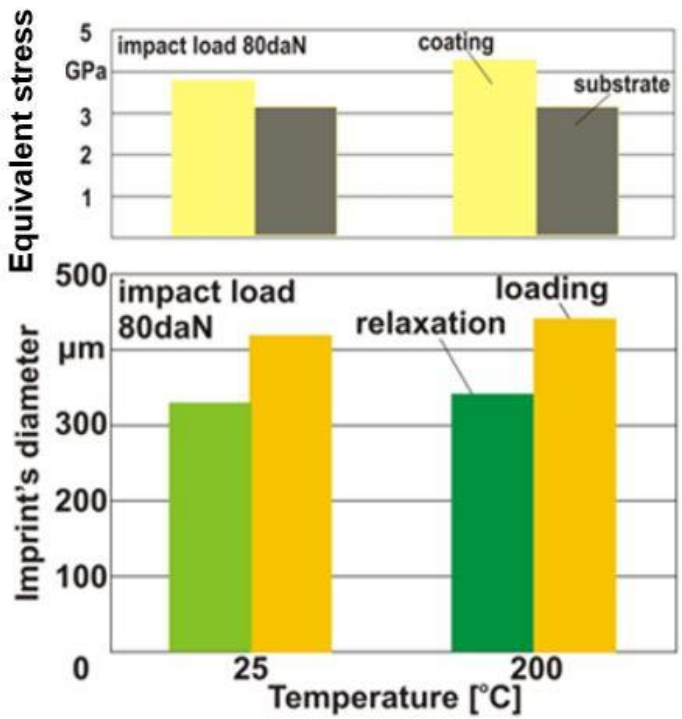
t_h: height of the tip roundness

b: width of the tip roundness

Indenter: Berkovich t_h/b= 2/83 nm

DLC coating maximum indentation and remaining depth at various temperatures and effects of impact test on coating/substrate





Outline

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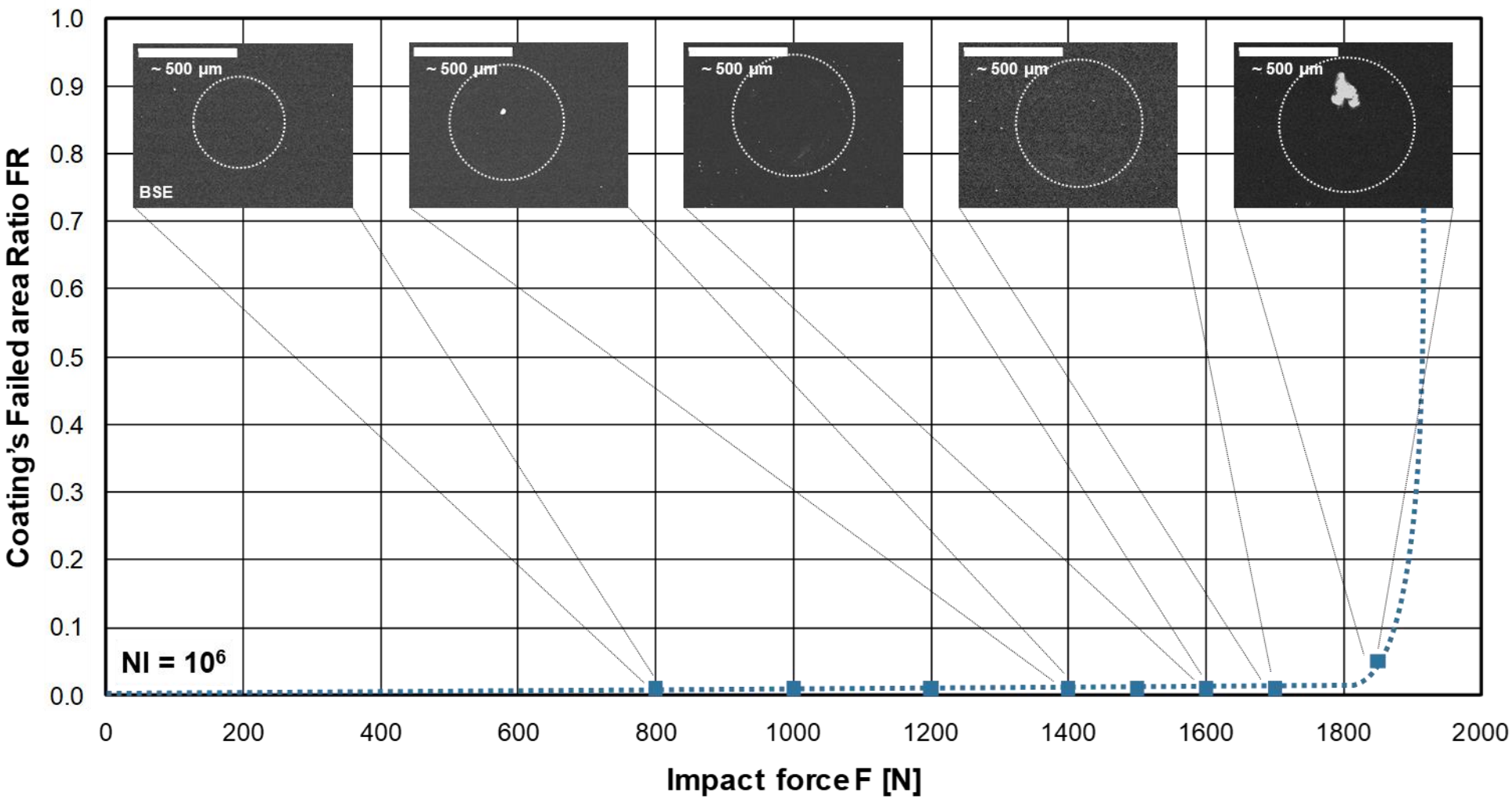
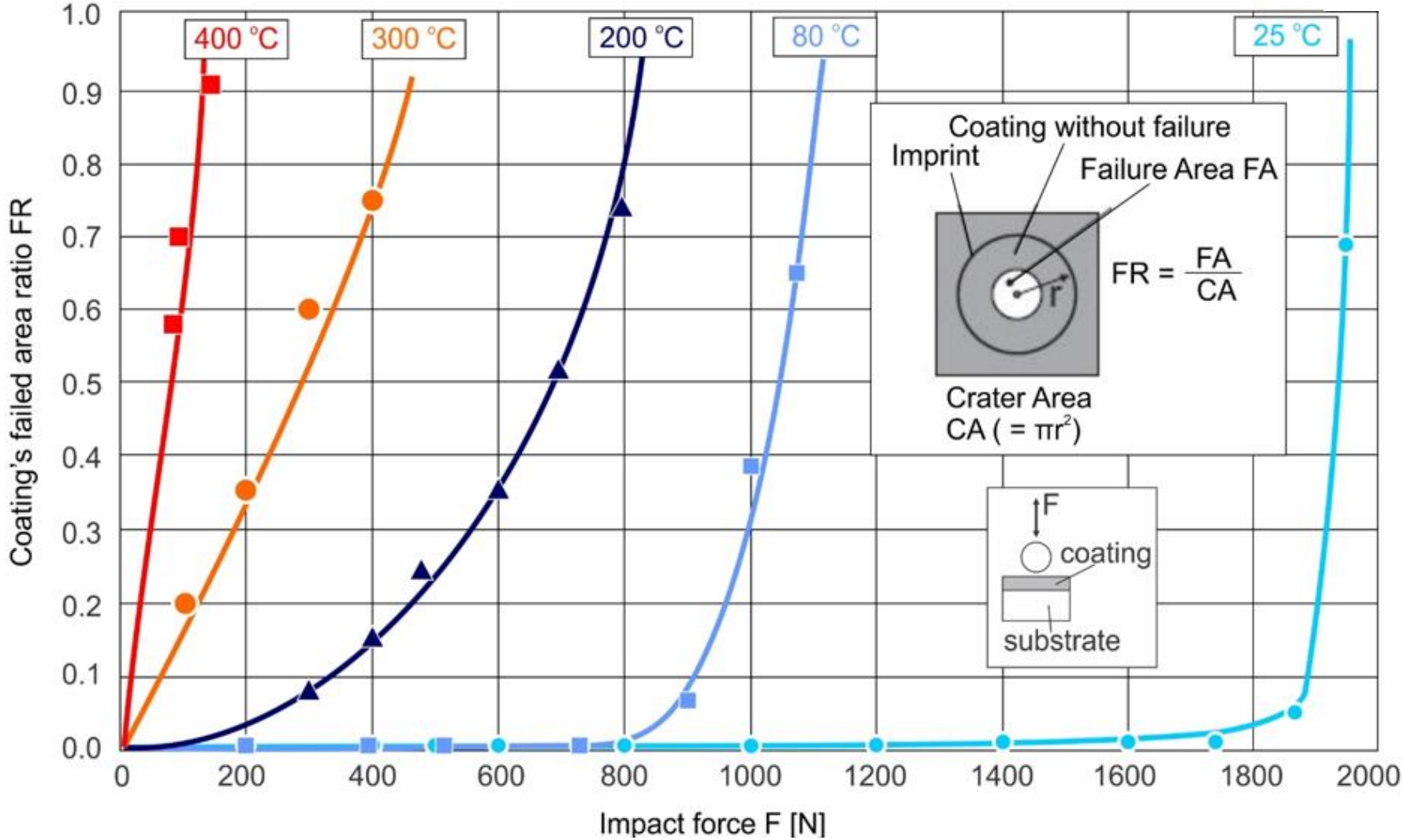
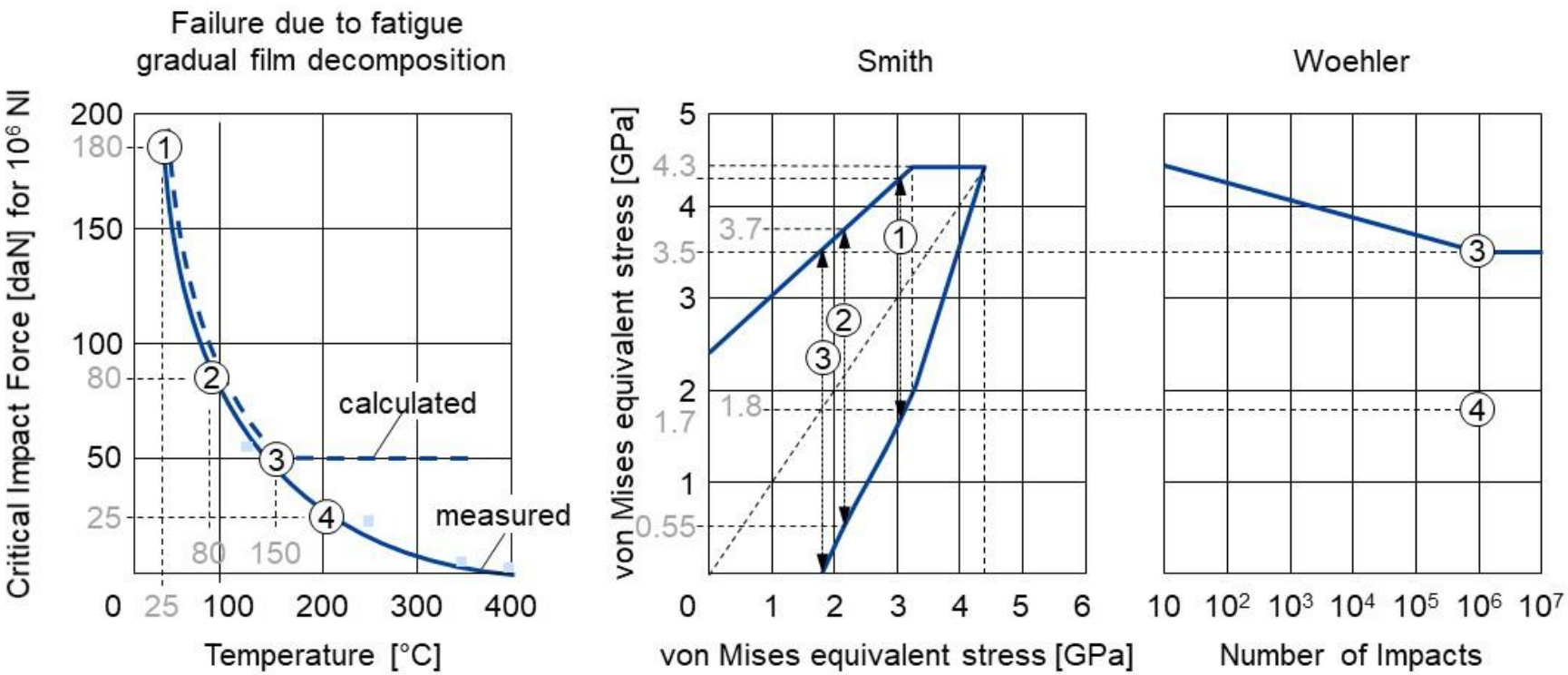
Impact test imprints on DLC coated HSS specimens at various impact forces after 10^6 impacts



DLC coating fatigue failure after 10^6 impacts at various temperatures and impact forces



DLC coating temperature depended fatigue endurance force, Smith- and Wöhler-like diagram



Point Nr.	①	②	③	④
Temperature [°C]	25	80	~150	~200
Critical impact force: measured / calculated [daN/daN]	180 / 180	80 / 80	50 / 50	25 / 50
Coating von Mises stress: max / min [GPa/GPa]	4.3 / 1.7	3.7 / 0.55	3.5 / 0	1.8 / 0

Outline

1 Introduction

2 HSS substrate temperature depended strength

3 Characterization of DLC coating mechanical properties

4 DLC coating's load capacity versus the temperature during the impact test

5 Summary

Photos: VDW

Summary

- DLC coatings retain their mechanical properties up to approximately 400 °C.
- Potential deterioration of the substrate strength at high temperatures might cause fatigue phenomena, and thus affect the load capacity of the coatings.
- Their load capacity declines further due to brittleness induced by non-bonded hydrogen displacements at temperatures over 150 °C, and due to desorption of hydrogen and hydrocarbon fragments over 300 °C.
- The film fatigue failure critical loads on the DLC / HSS substrate, can be predicted up to 150 °C, considering among others, the related Smith- and Wöhler diagrams as well as the substrate temperature depended mechanical properties.