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"Blickpunkt Forschung"

Ceramic Data Storage – Sustainable, Energy-Efficient Long-Term Archiving of Digital Information

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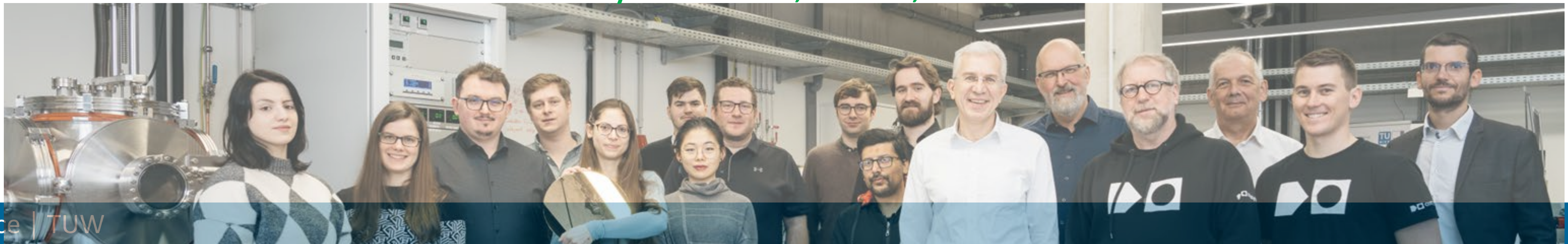

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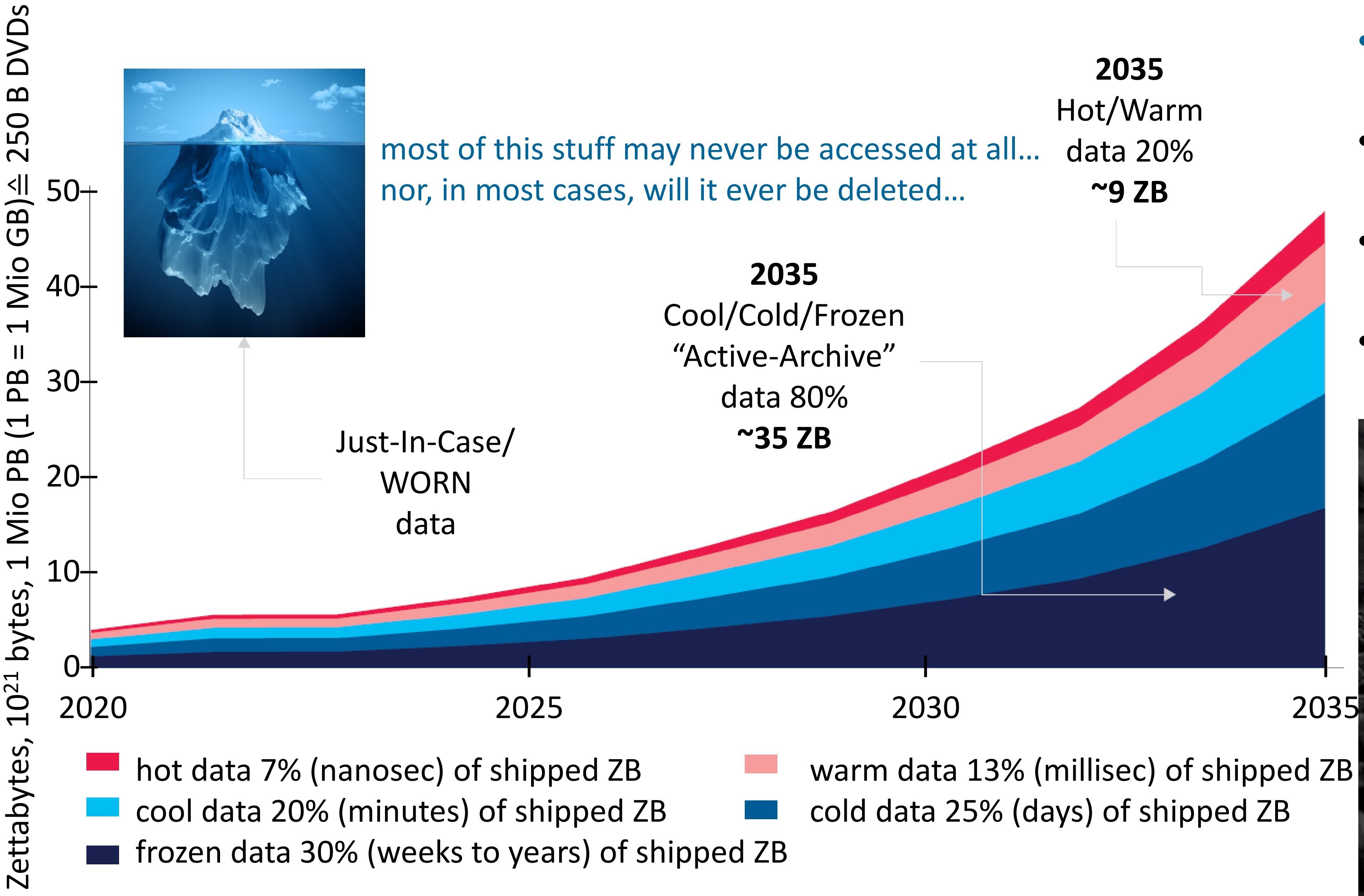
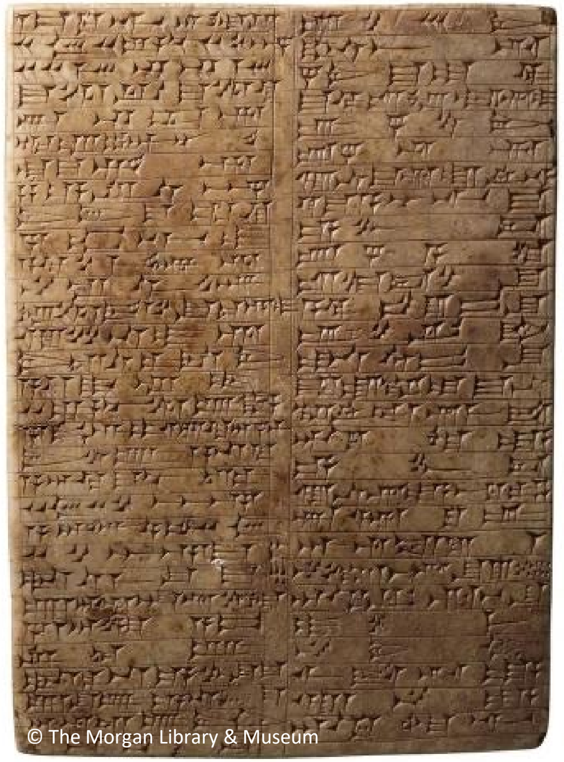
Motivation – The growing enormity of frostbitten Data

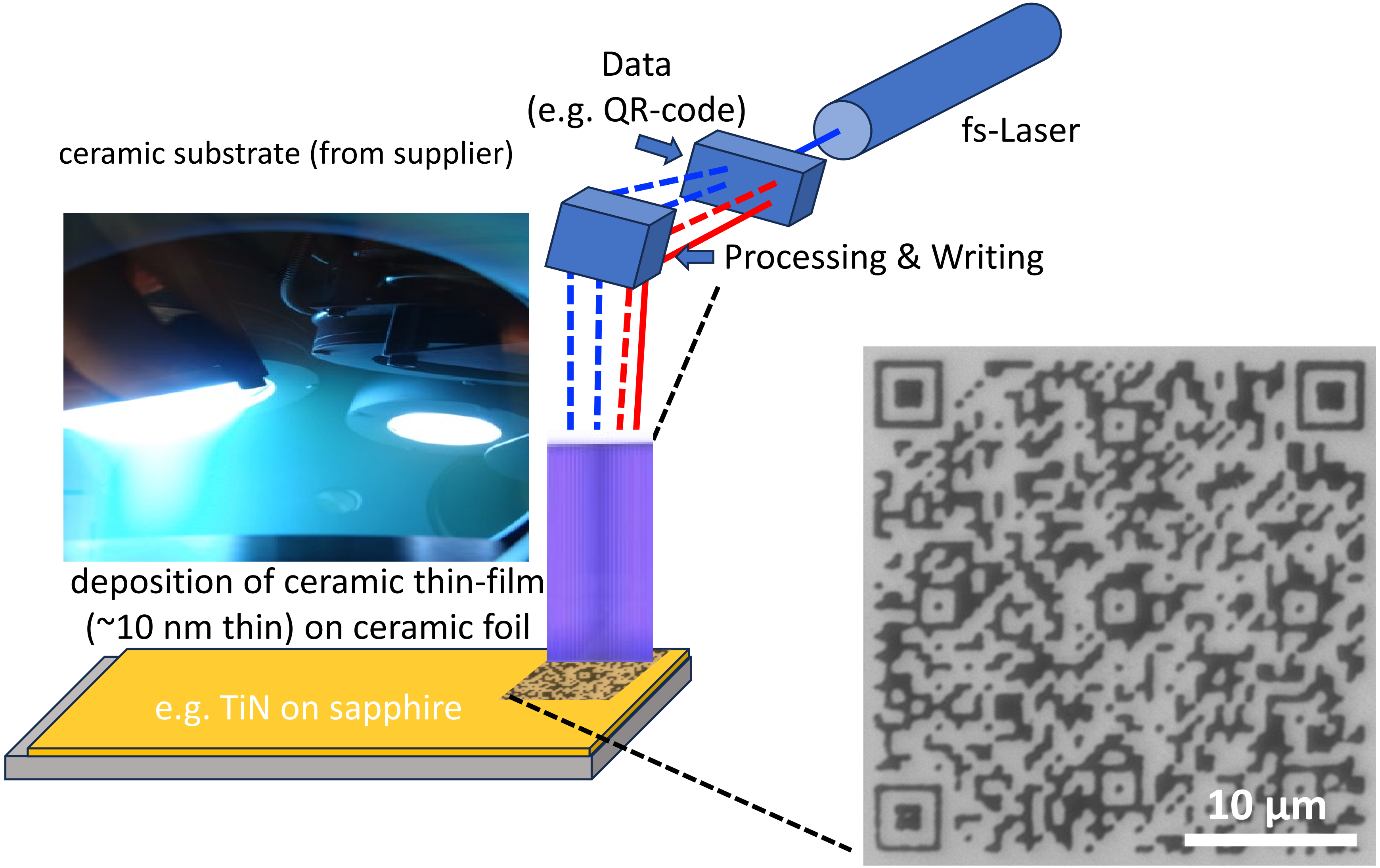


- **70% of all data are cold data**
- Increasing the lifespan of storage media
- Reducing energy consumption
- Sustainable data storage

Idea: Developing ceramic "pages" and writing in these

permanent information
"written in stone"



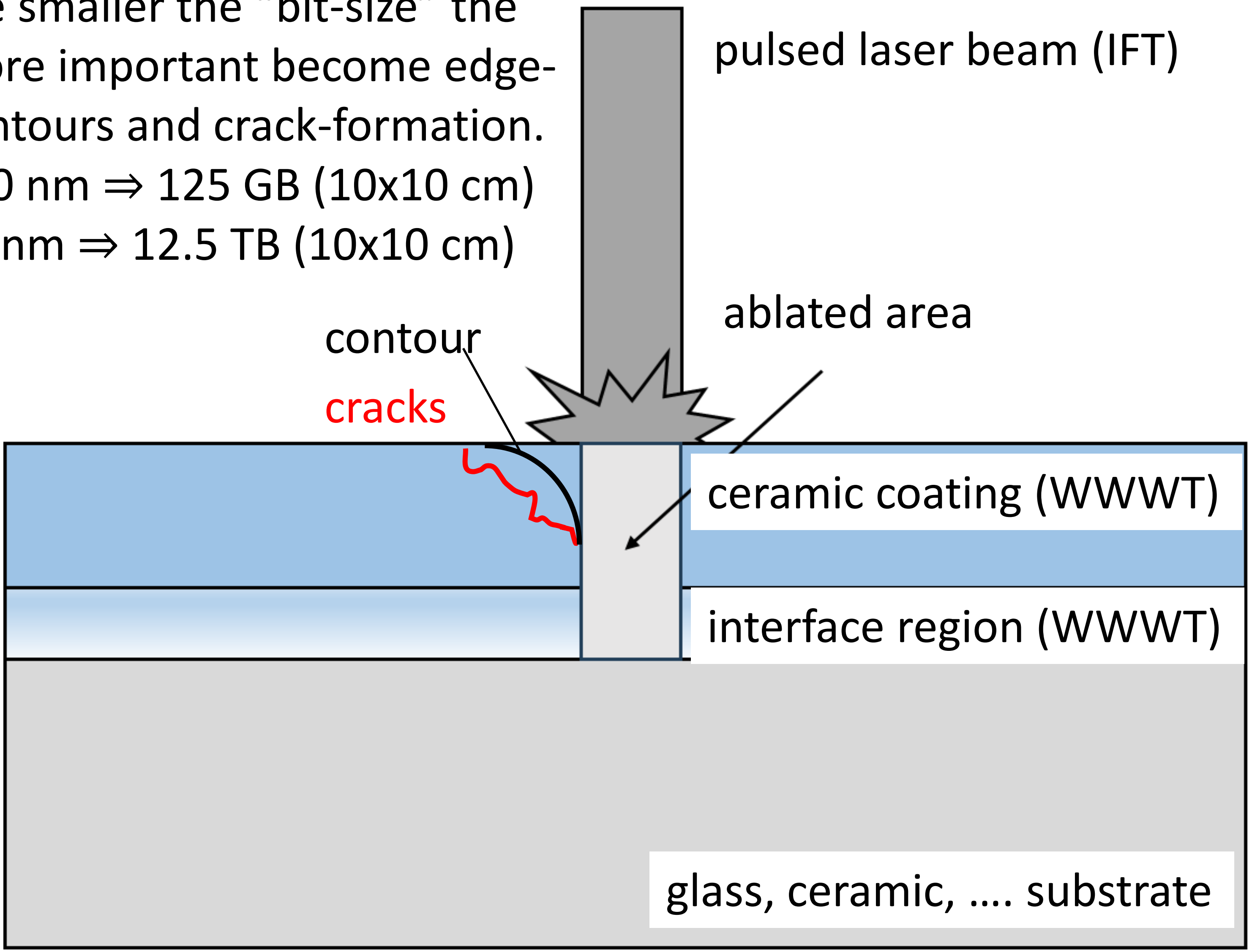


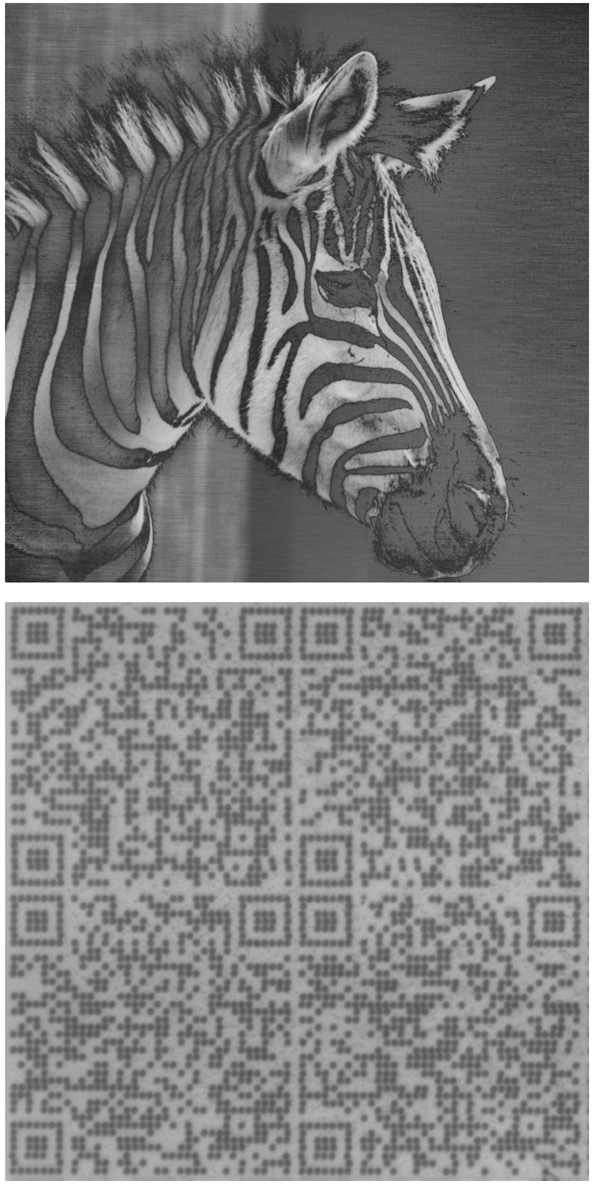
Ideas and targets

the smaller the “bit-size” the more important become edge-contours and crack-formation.

100 nm ⇒ 125 GB (10x10 cm)

10 nm ⇒ 12.5 TB (10x10 cm)





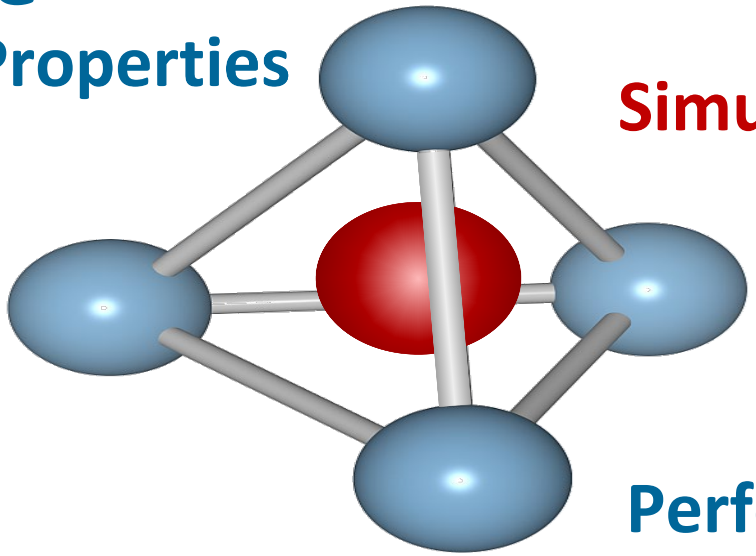
Research Strategy to Develop Innovative High-Tech Materials for a Sustainable Future

- Development and characterization of new materials
- Atomic-level understanding of **Synthesis–Chemistry–Structure–Properties**

Properties

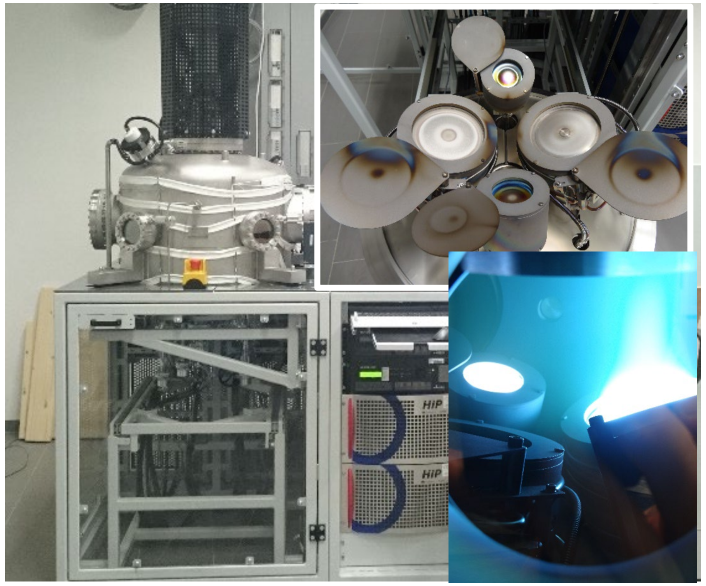
Simulations

Synthesis

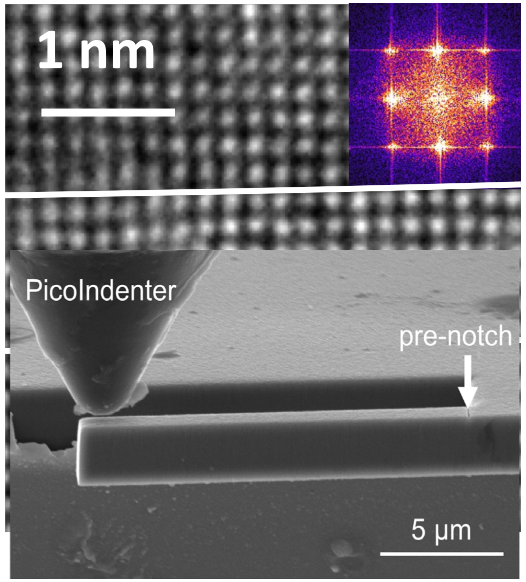


Chemistry-Structure

Performance

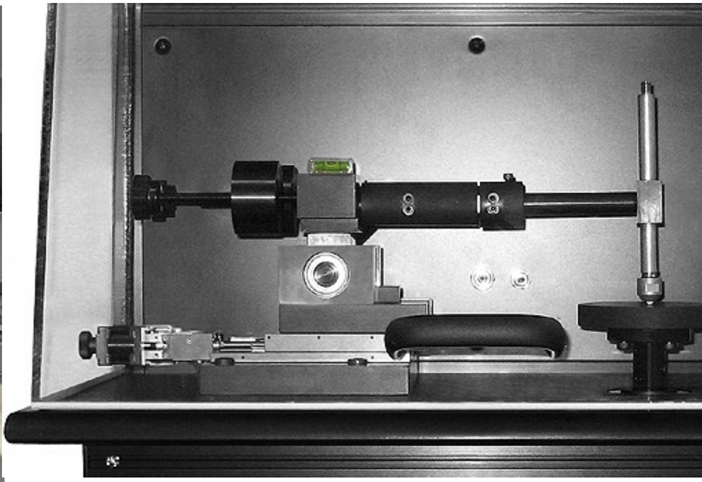


PVD machines



Microstructure and Micromechanics

DSC/TGA to 2400 °C



mechanical and tribological properties

Physical Vapor Deposition to prepare New Materials

From Vapor to Solid

Limited atomic reassembling (low substrate temperature (**$T/T_m < 0.2$**) high defect density in the prepared coatings.

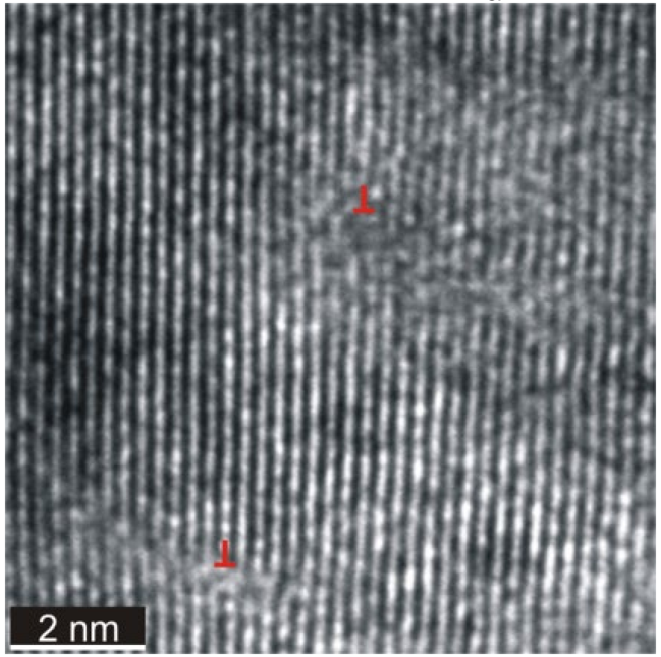
Preparation of **metastable** and/or **supersaturated** phases.

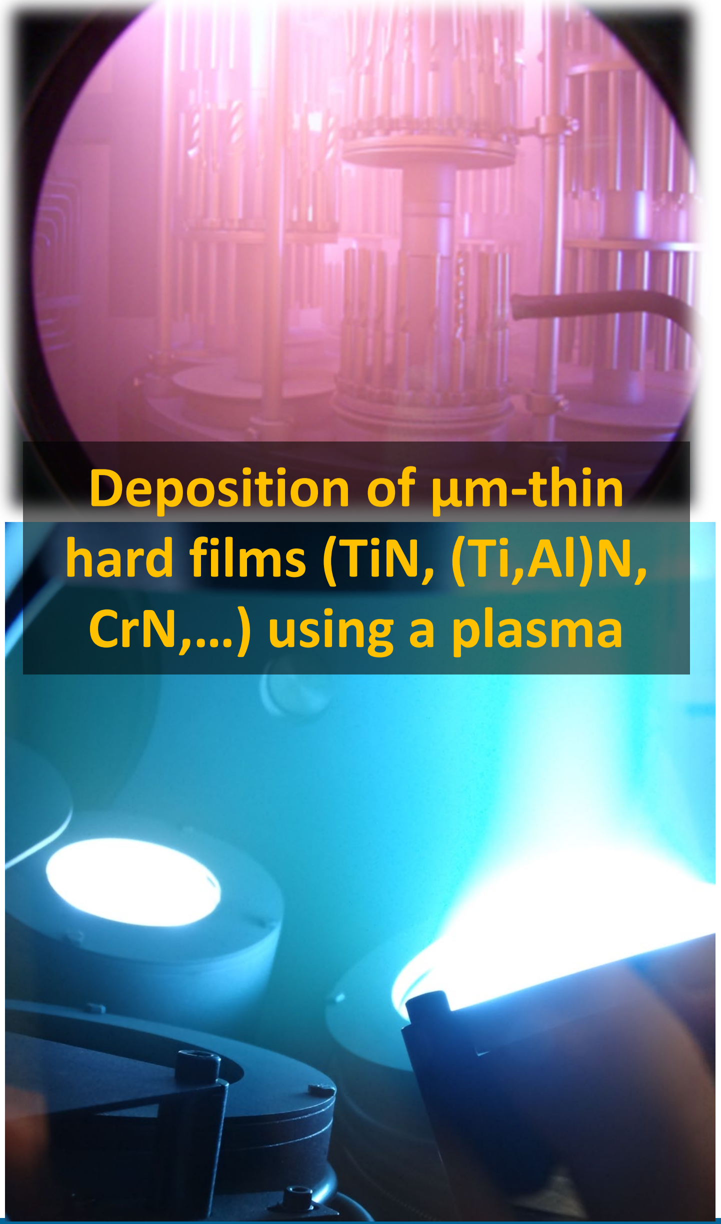
High defect-density

dislocation density for TiN: $\boldsymbol{\rho_d \sim 10^{17}\ 1/m^2}$

heavily deformed steel: $\rho_d \sim 10^{16}\ 1/m^2$

...like people: The defects make them interesting!



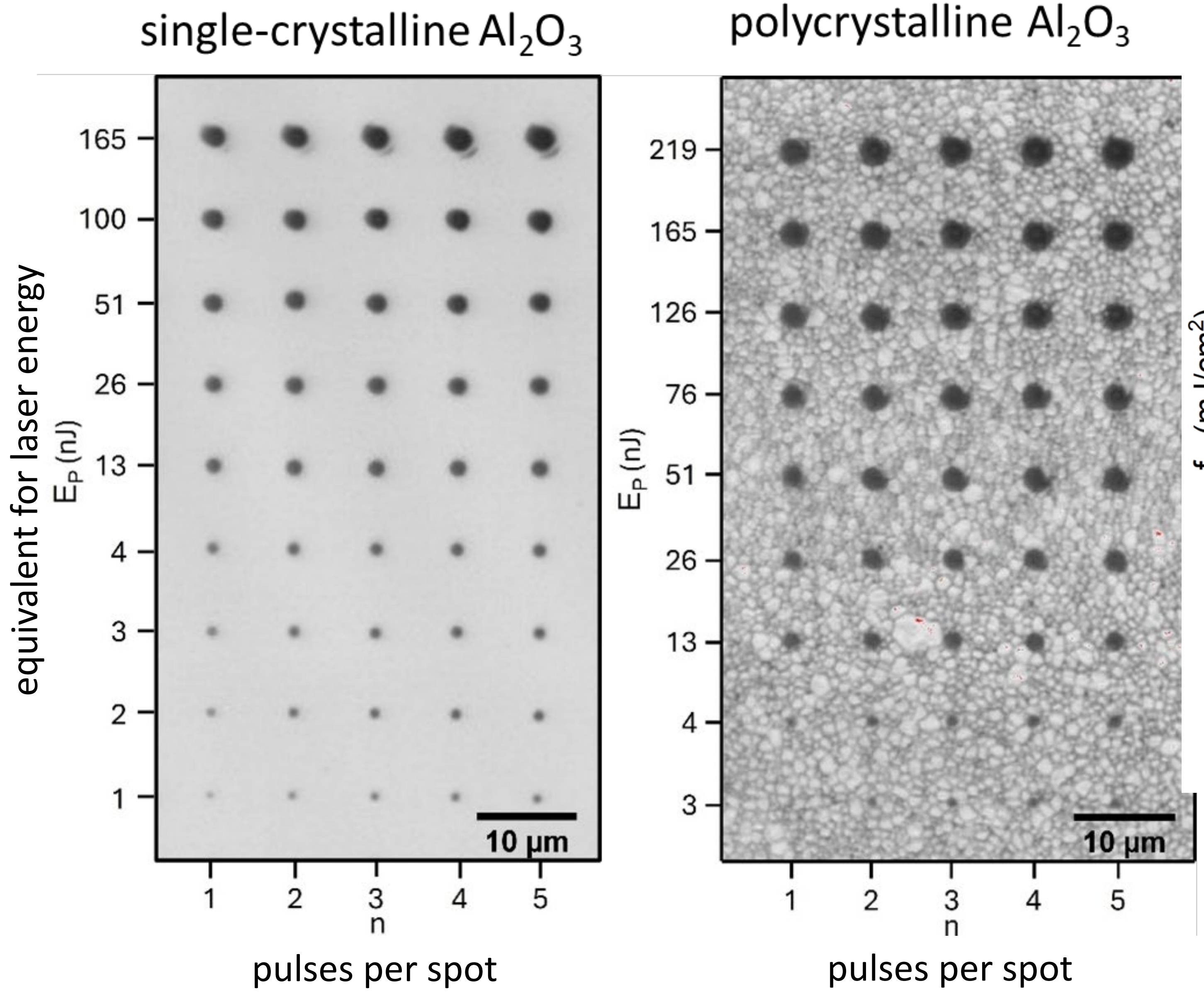


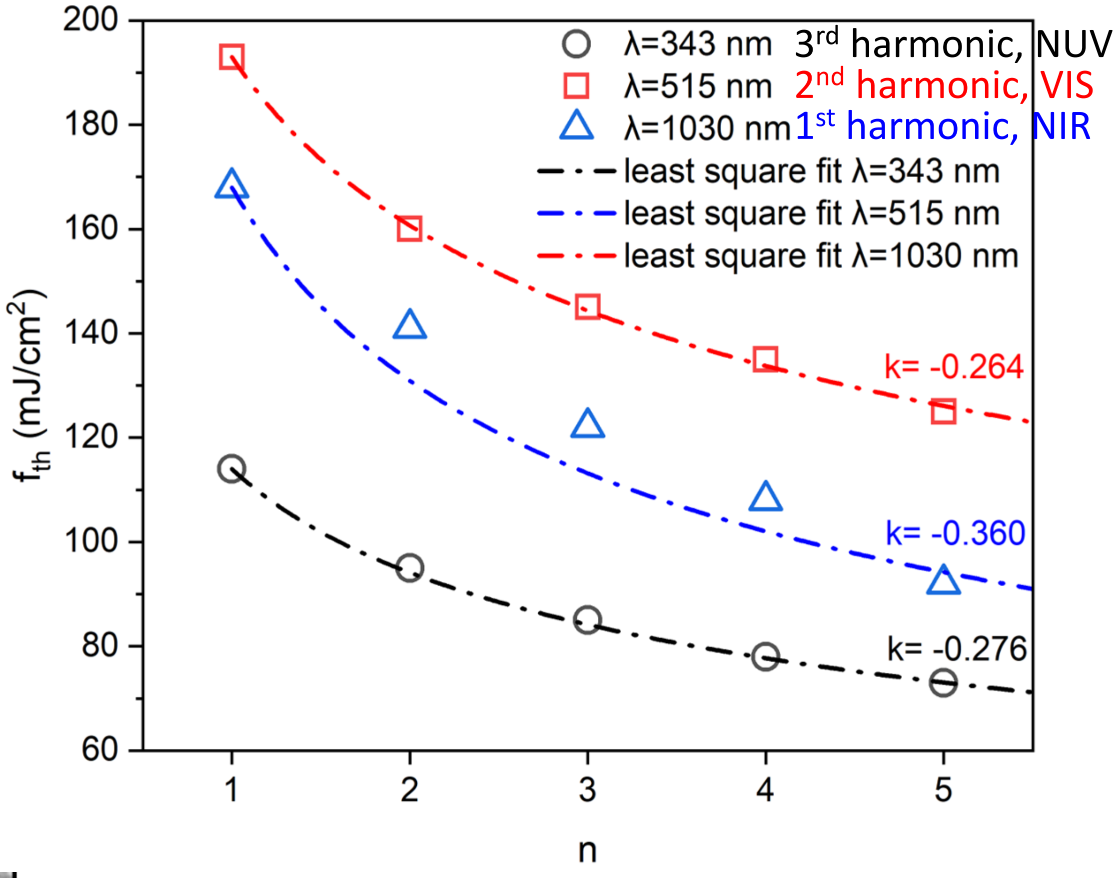
Deposition of µm-thin hard films (TiN, (Ti,Al)N, CrN,...) using a plasma

Huge playground in modifying/developing materials

P.H. Mayrhofer, C. Mitterer, L. Hultman, H. Clemens, *Prog. Mat. Sci. 51 (2006) 1032-1114*

Laser Ablation of a 25-nm-thin CrN on Al_2O_3

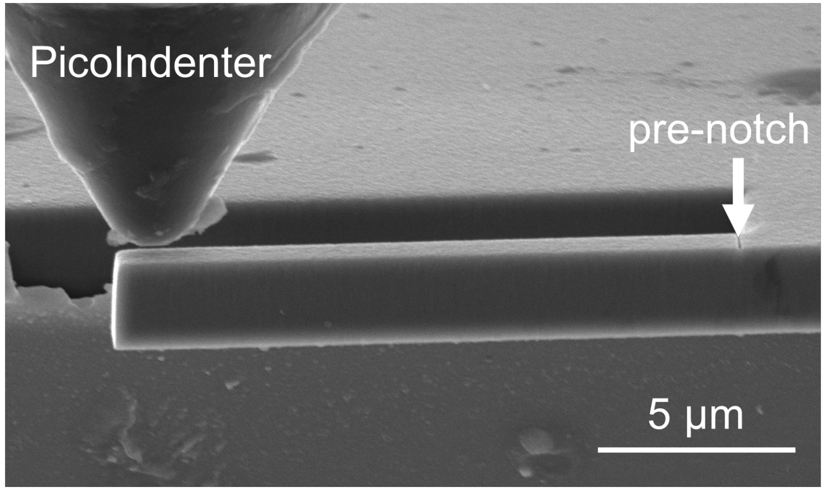


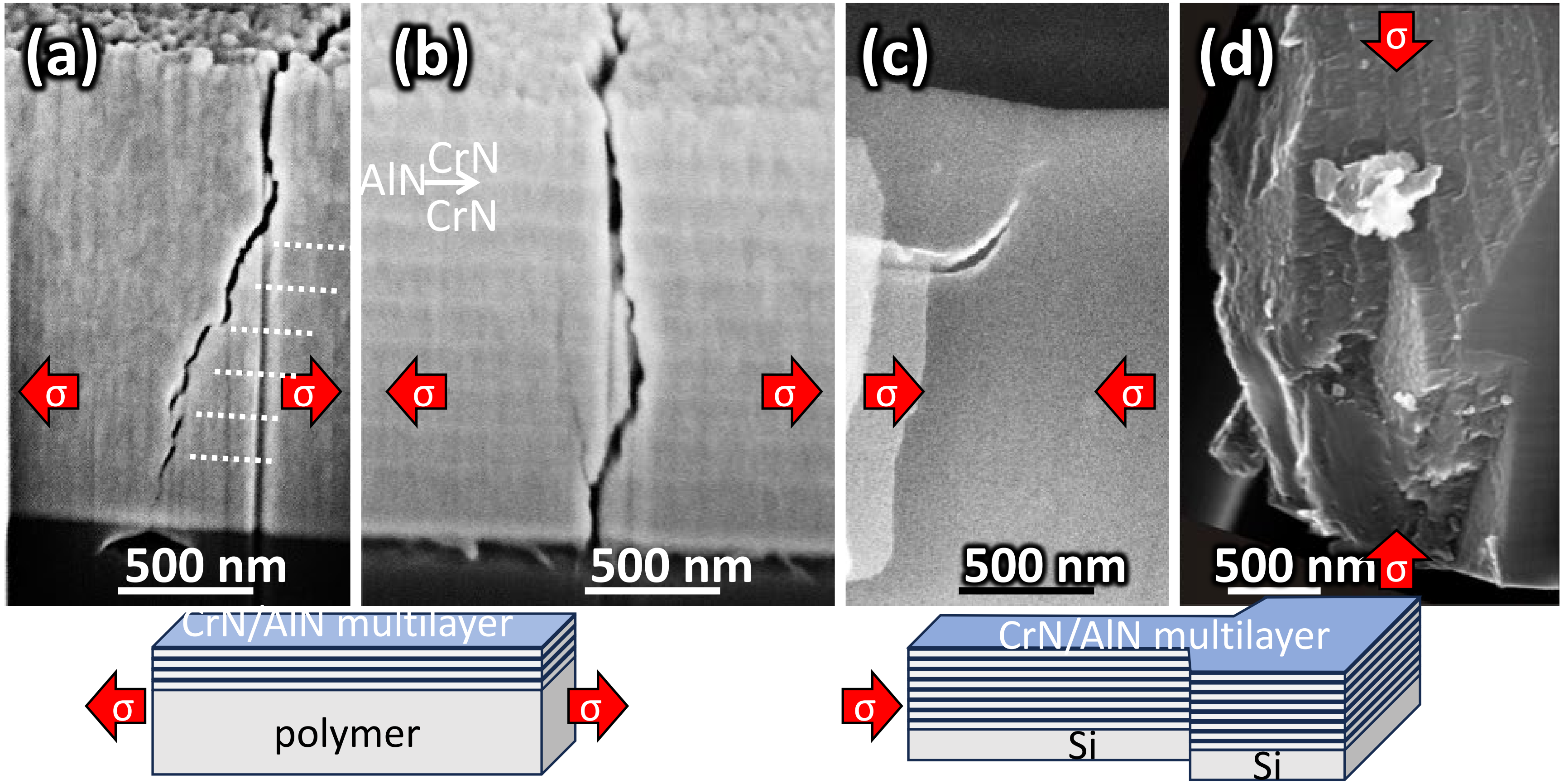


energy consumption depends on coating-material and laser-wavelength and their combination

Mechanical Resilience

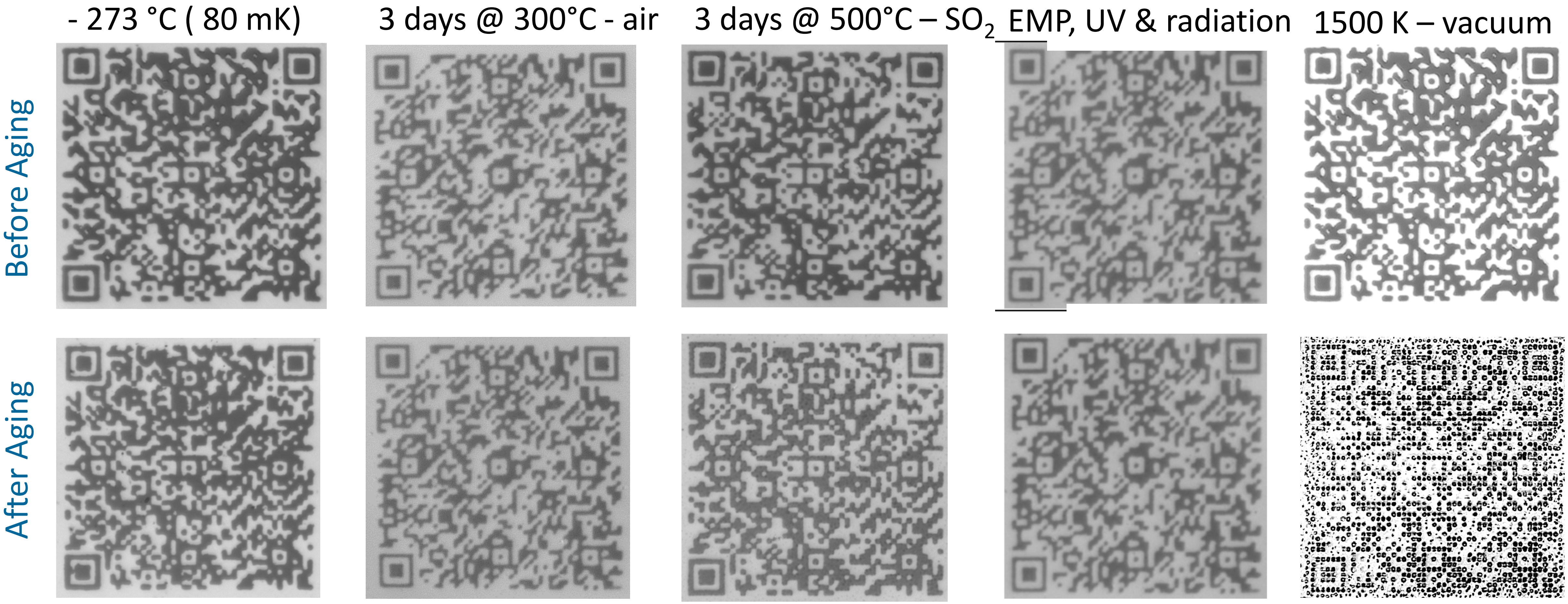
M. Schlögl et al. *Scr Mat* 68 (2013) 917-920
C. Wang et al. *SCT* 257 (2014) 206
R. Hahn et al. *Scr Mat* 124 (2016) 67–70
Z. Zhang et al. *PRB* 95 (2017) 155305
W.M. Seidl et al. *Vacuum* 150 (2018) 24–28
M. Bartosik et al. *IJRMHM* 72 (2018) 78–82
J.S.K.-L. Gibson, ..S. Korte-Kertzel, *MRL 6* (2018) 142
C. Fuger et al. J All Comp 864 (2021) 158121
…





Mayrhofer PH, Clemens H, Fischer FD. *Prog. Mat. Sci. 146 (2024) 101323 1–57*

Corrosive and Thermal Resilience of the “Data” Carriers

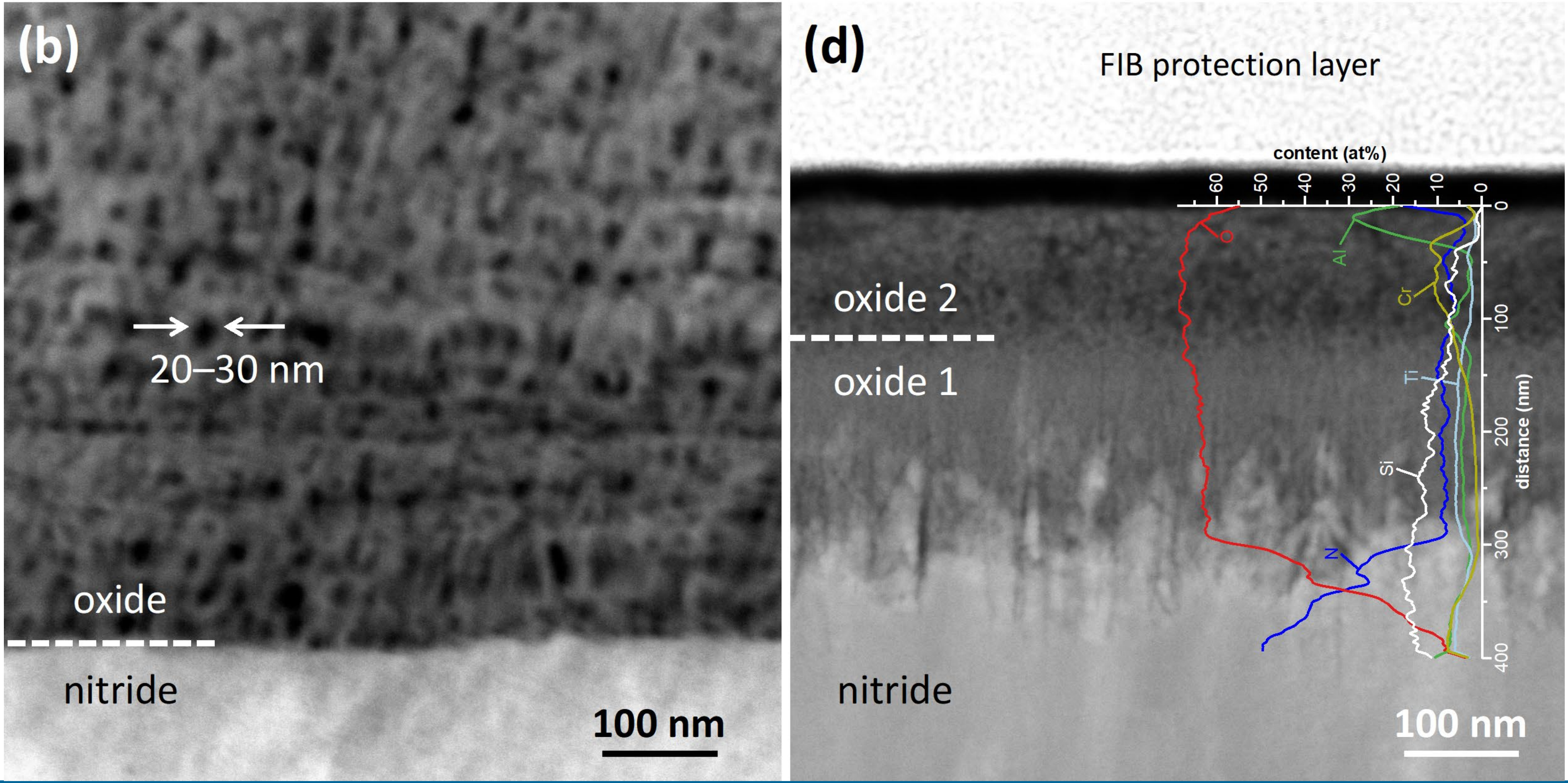


50 µm × 50 µm QR code with 1 µm pixel size on glass substrates and a 10 nm CrN coating.

The reading error remains below 5% after testing.

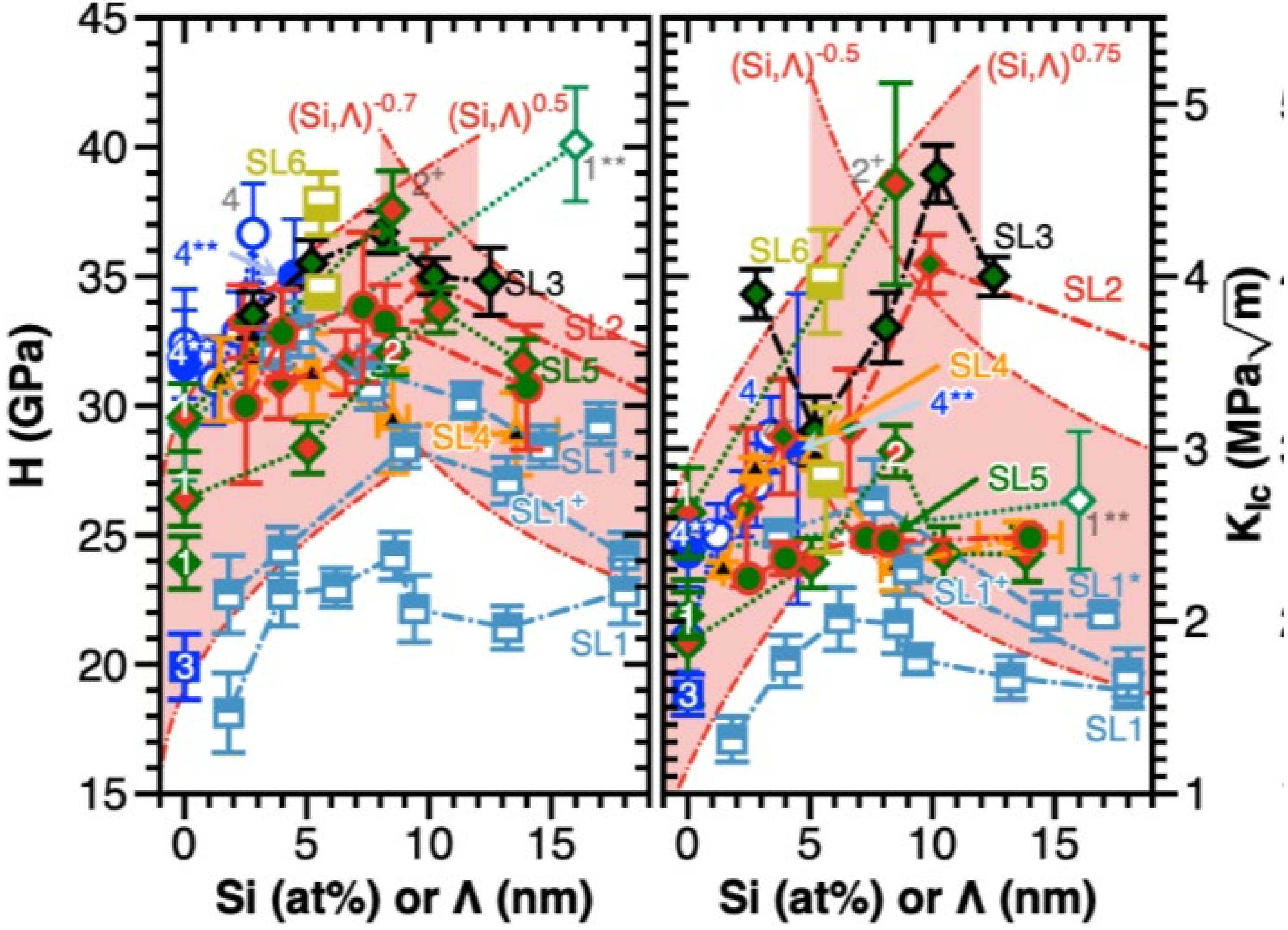
Oxidation resistance

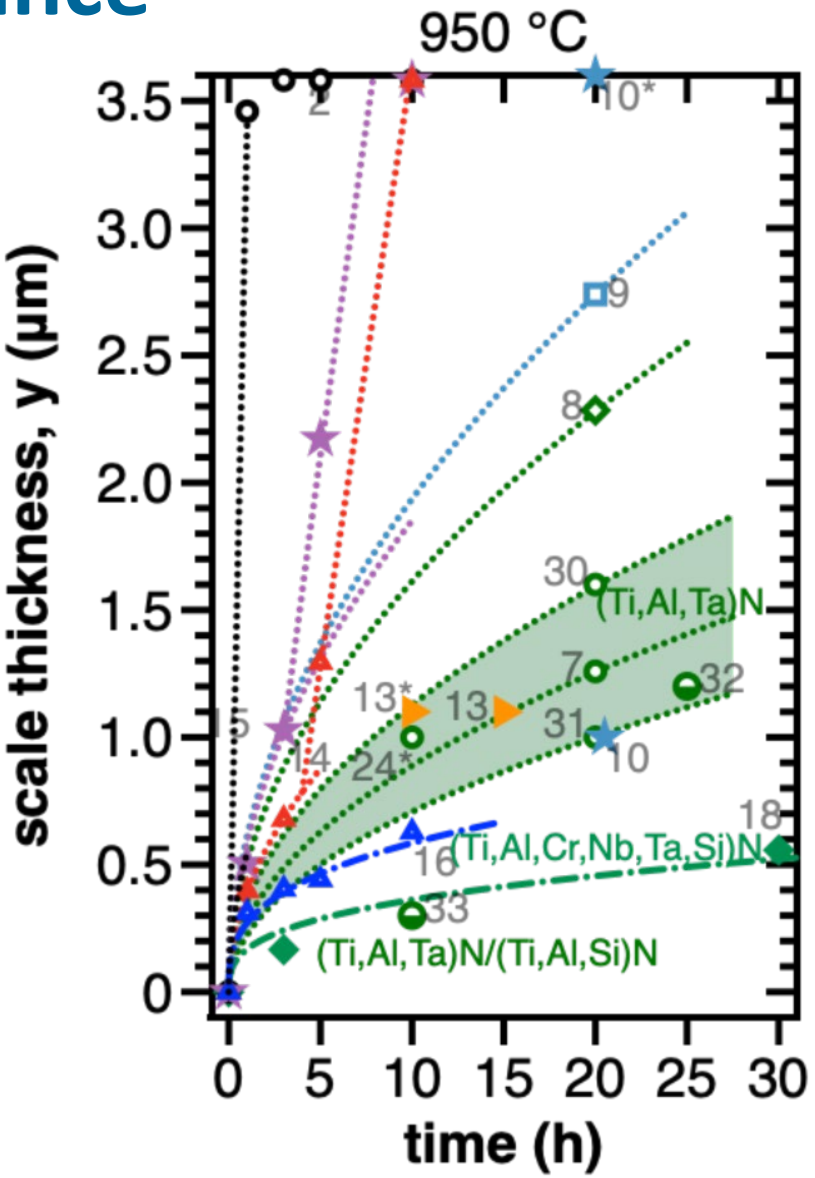
$Ti_{0.21}Al_{0.21}Cr_{0.26}Nb_{0.16}Ta_{0.16}N$ **100 h @ 850 °C** $Ti_{0.21}Al_{0.21}Cr_{0.26}Nb_{0.16}Ta_{0.16}N$+6%Si



A. Kretschmer, A. Kirnbauer, V. Moraes, D. Primetzhofer, K. Yalamanchili, H. Rudigier, P.H. Mayrhofer, SCT 416 (2021) 127162

Combining strength, toughness, resistance



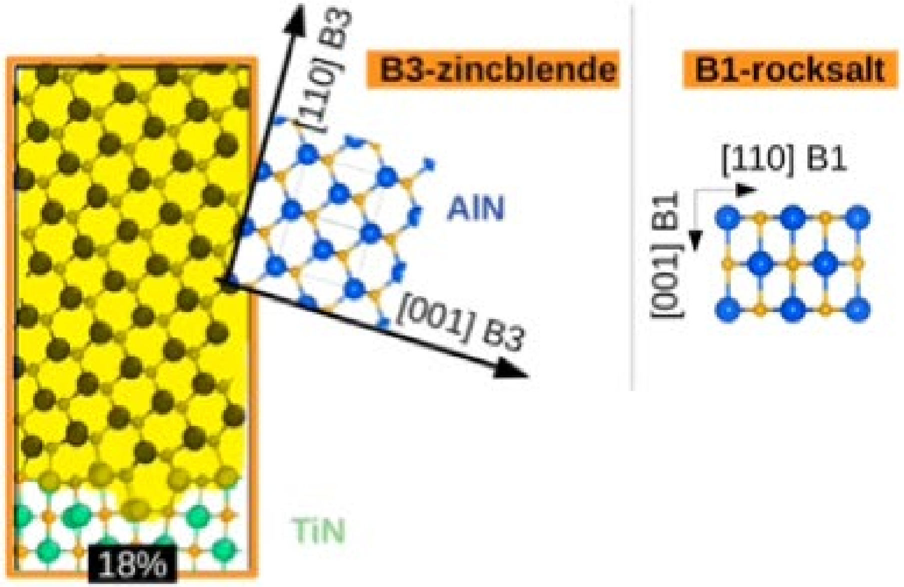


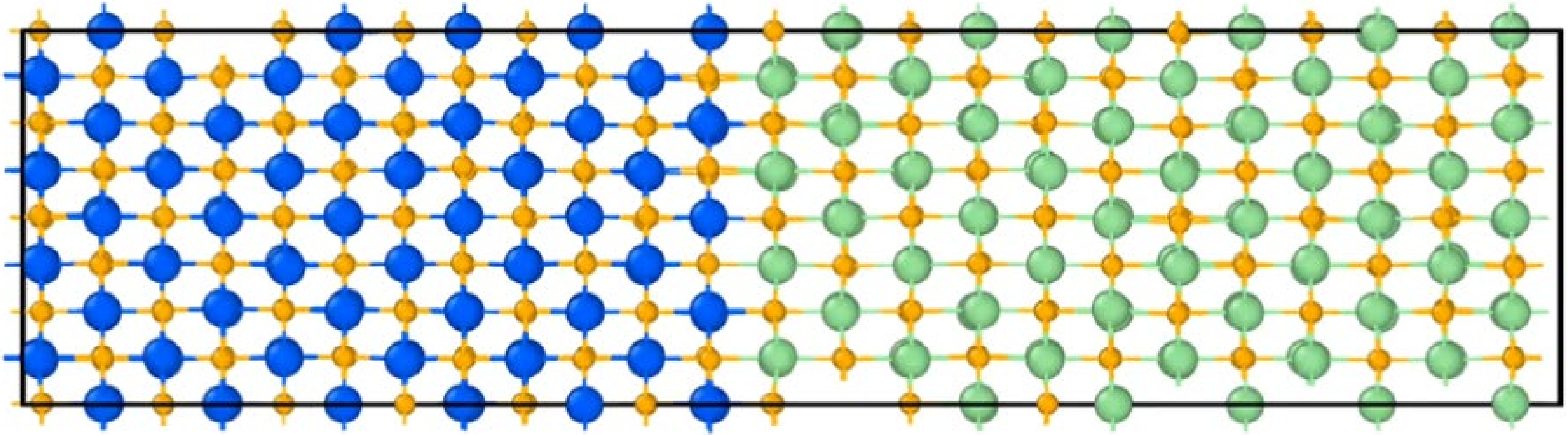
dislocation gliding across the interfaces for small Λ (opposing forces that can act on dislocations); a bit similar to Kelly–Fine:

$\Delta\tau_{SL} \cong \sqrt{\Lambda}$ (replacing r_p with Λ)

 Mayrhofer PH, Clemens H, Fischer FD. *Prog. Mat. Sci. 146 (2024) 101323 1–57*

Outlook – Phase Change Materials





 N. Koutná, et al., *Atomistic mechanisms…plasticity…of AlN/TiN SLs*, Acta Mat. 229 (2022) 117809

Conclusions

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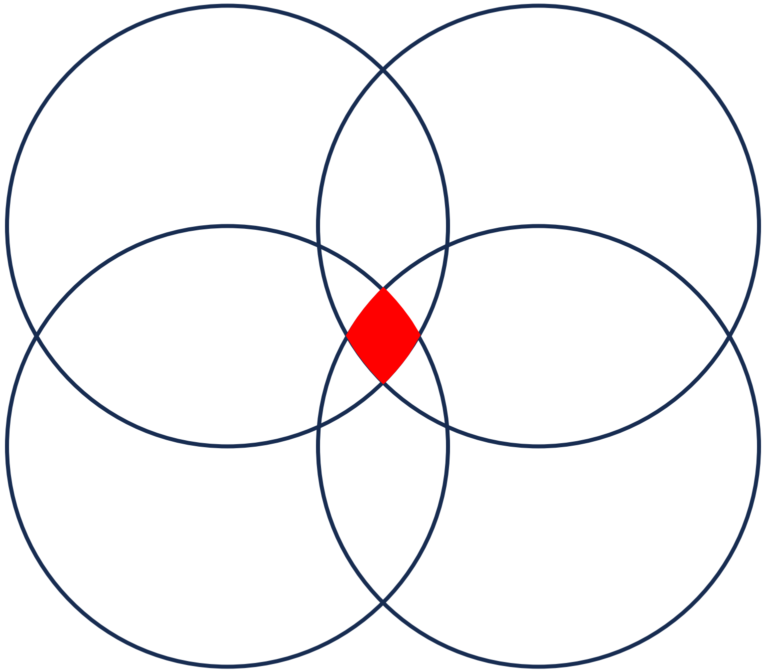
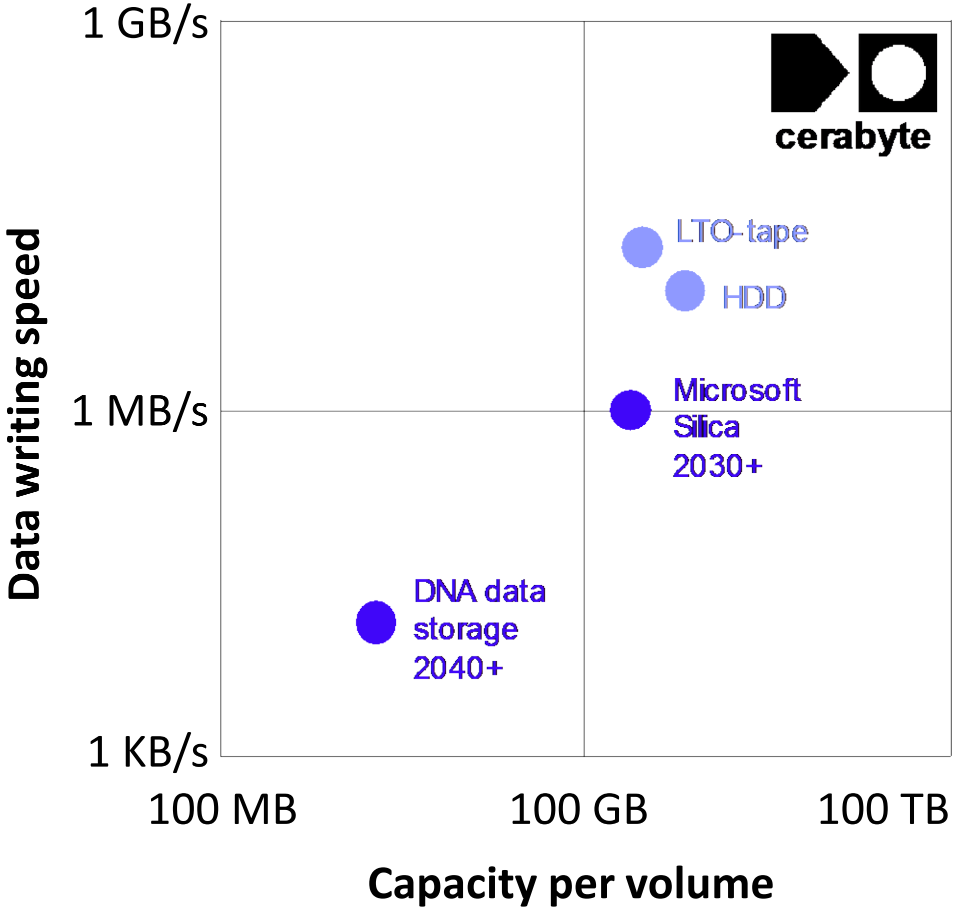
- CrN and (Al,Cr)N: lowest ablation threshold (so far)
- The interface affects the ablation behavior
- PVD allows for tuning structure and phases
- **Identify materials and structures that allow to combine strength, toughness, stability, resistance & minimum energy to ablate!**

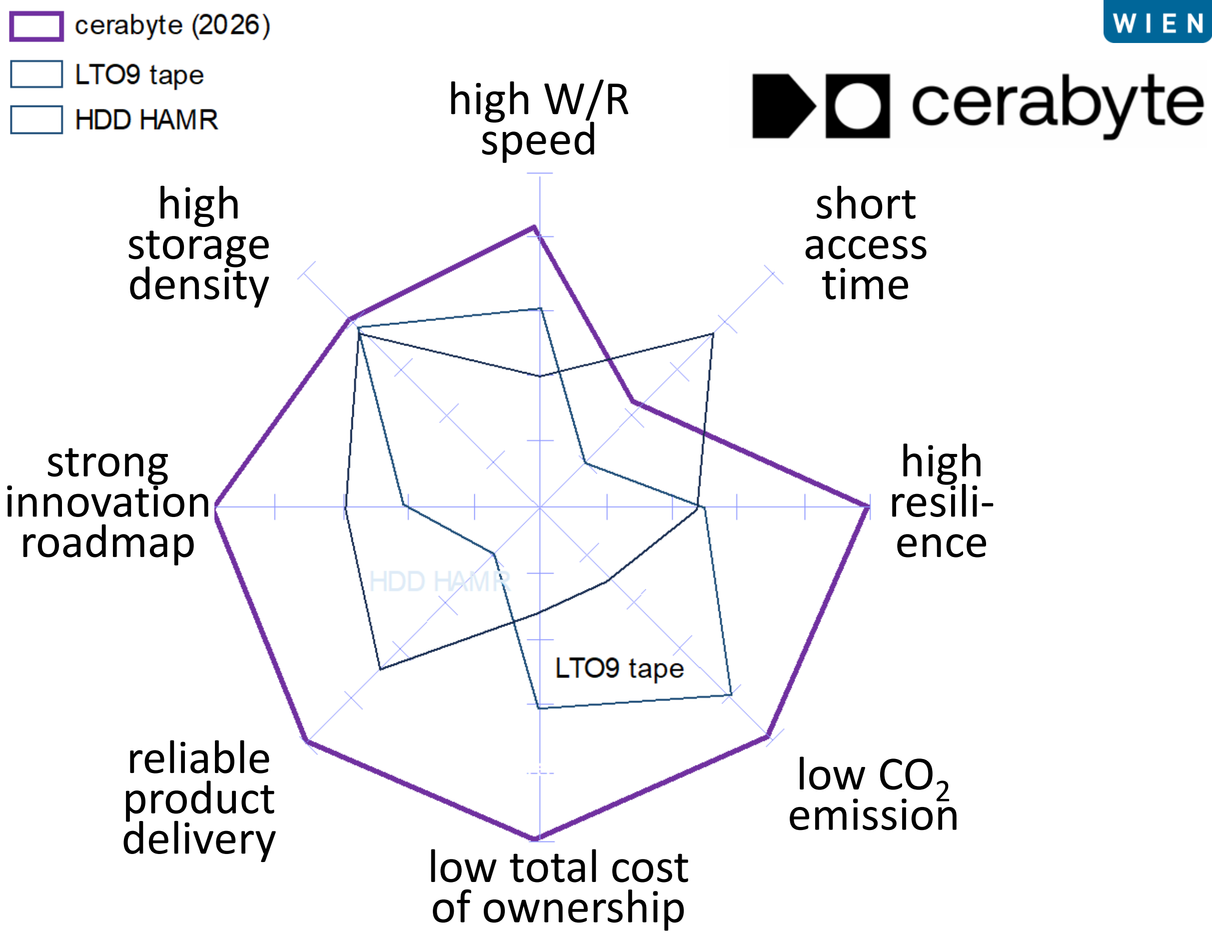
FFG Promoting Innovation.
Bridge

Acknowledgments to scientific and financial support



Comparison





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