The Hotter, the Better – Mikrometer Schichten für maximale Leistungsfähigkeit

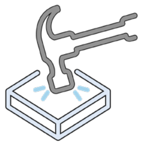
Assoc. Prof. Dr. Helmut Riedl-Tragenreif

The Hotter, the better?

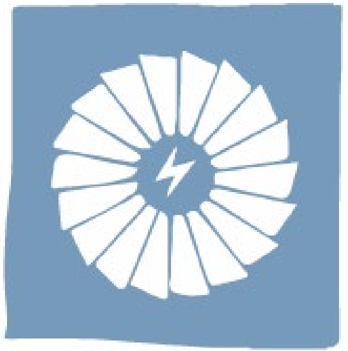
Gas power station
Mellach (838 MW)

A320neo Austrian
Airlines, PW1100G-JM

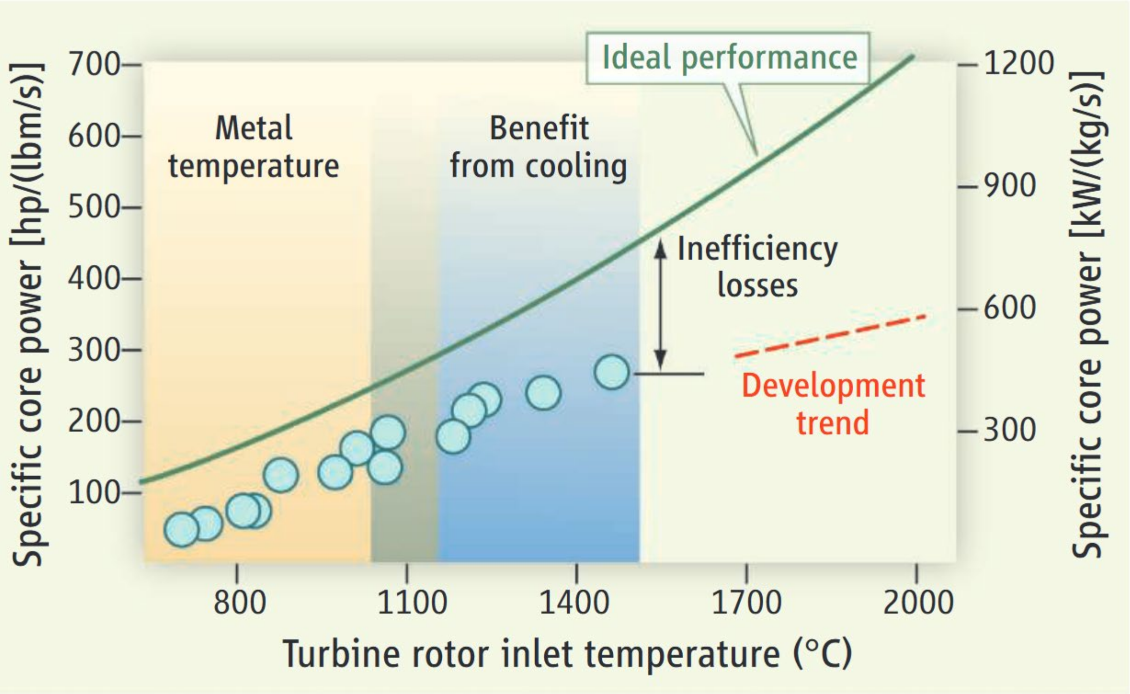
Thermal
loads



Mechanical
impact



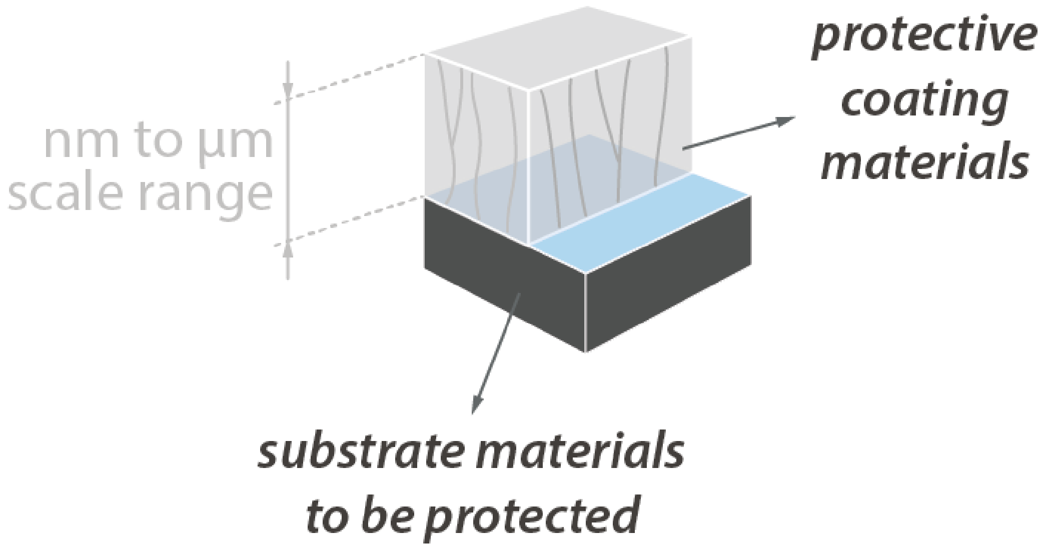
Stationary and flying
gas turbines



J.H. Perepezko, The hotter the engine, the better, Science 326 (2009).

Materials withstanding extreme conditions

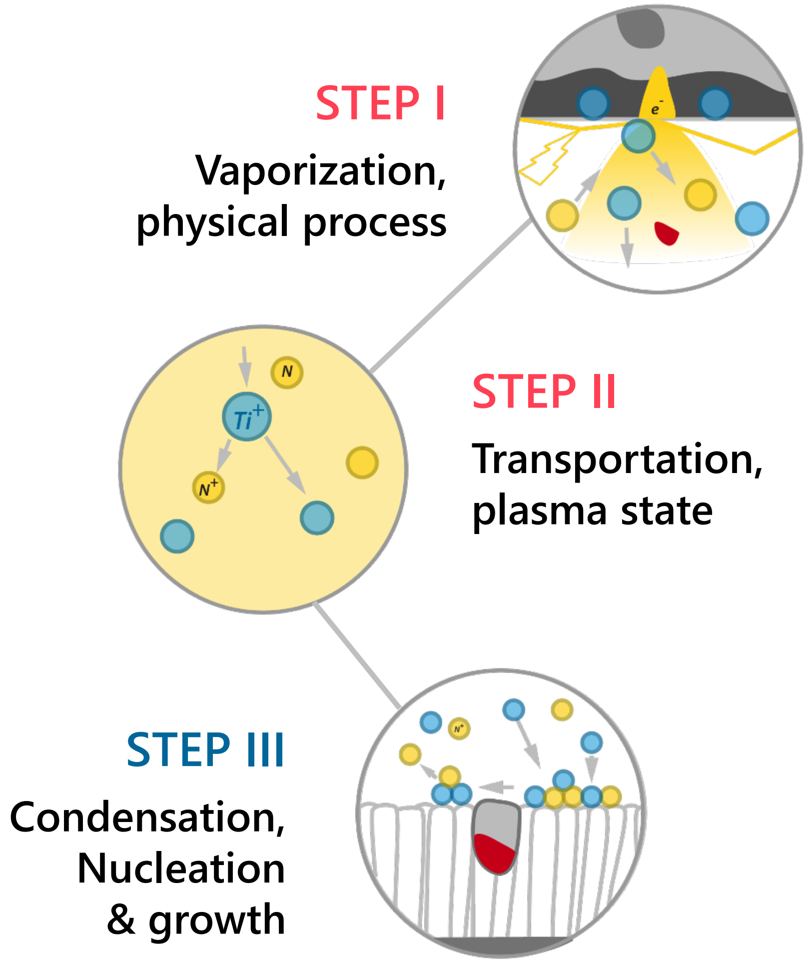
Sustainable Surface Engineering



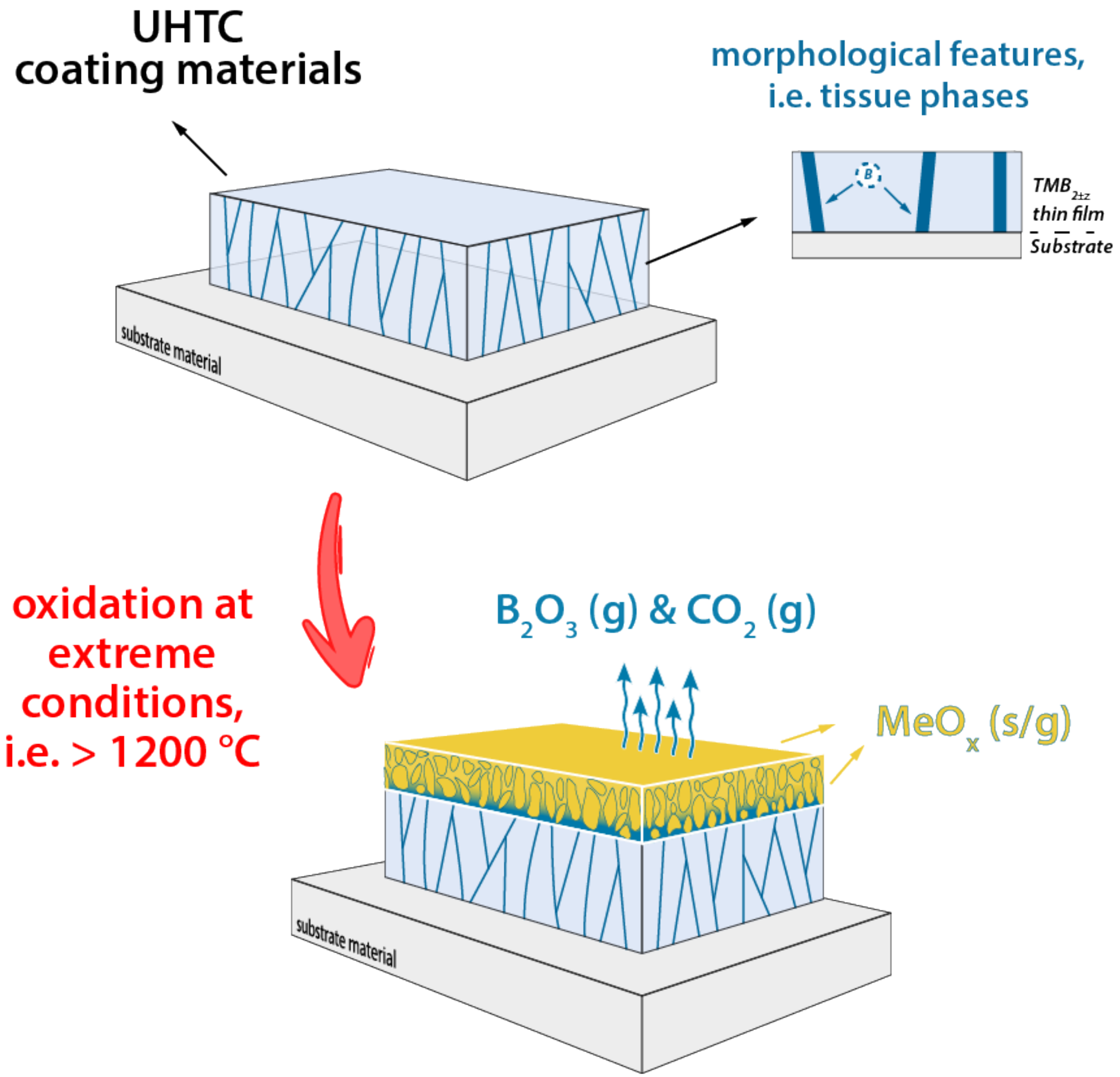
Protective and functional coatings

› Withstand harsh environmental conditions to enhance applicable operating ranges (i.e. temperature, mechanical strength, or chemical resilience) & enabling functionality

PVD at a Glance

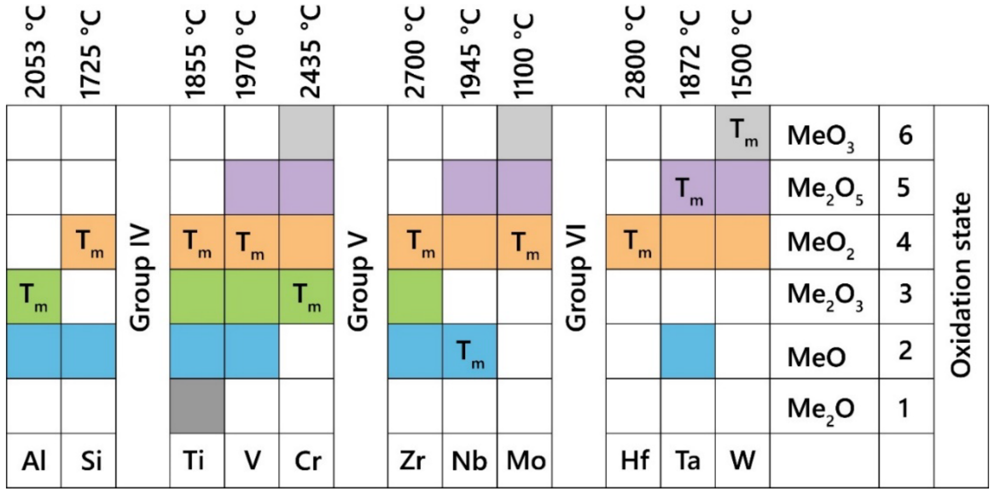


Thermal loads



Challenges above 1200 °C

- **Diffusion kinetic** need to be **extremely low** ➔ Si based scales are preferred (but issues with water vapor)
- **Pore formation** in metastable structure lead to phase separation processes and enhanced diffusion (could be positive & negative)
- **Glassy behavior** for self-healing (i.e. boro-silicates) at some points unavoidable ➔ mechanical impacts



UHT oxidation resistance, ideas?

- › Si alloying via plasma-based routes
- › KEEP it simple ➔ sputtering in pure Ar

Ternary
Ti-Si-$B_{2\pm z}$

Quaternary
Ti-TM-Si-$B_{2\pm z}$

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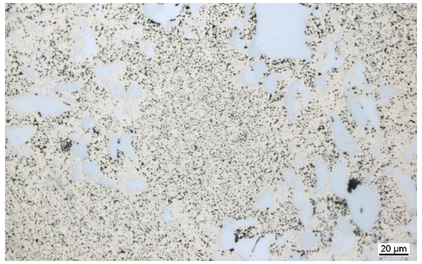
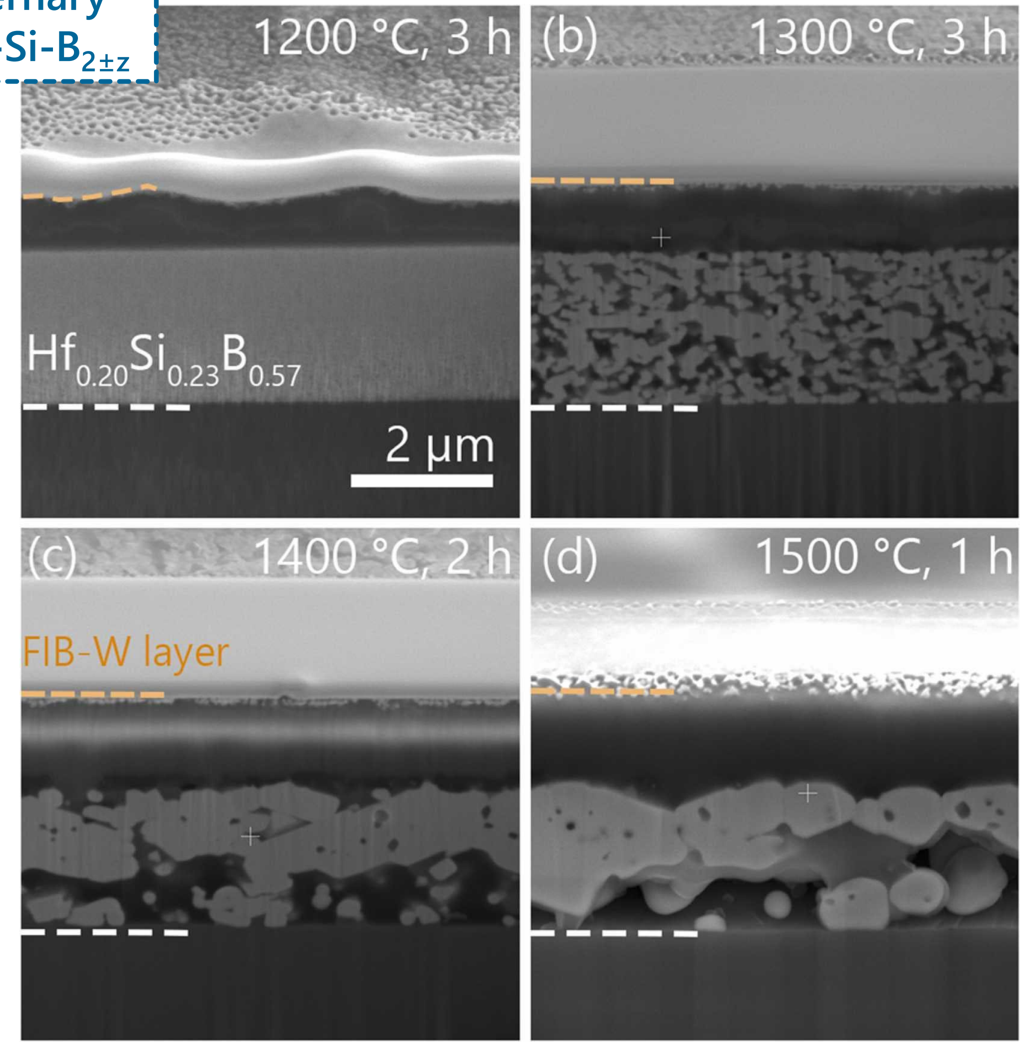


$TiB_2/TaSi_2$ target material

- › Plasma stabilization of single phased structures
- › Improve oxidation resistance
- › Maintain mechanical stability, i.e. super-hardness
- › Screening of novel UHTCs

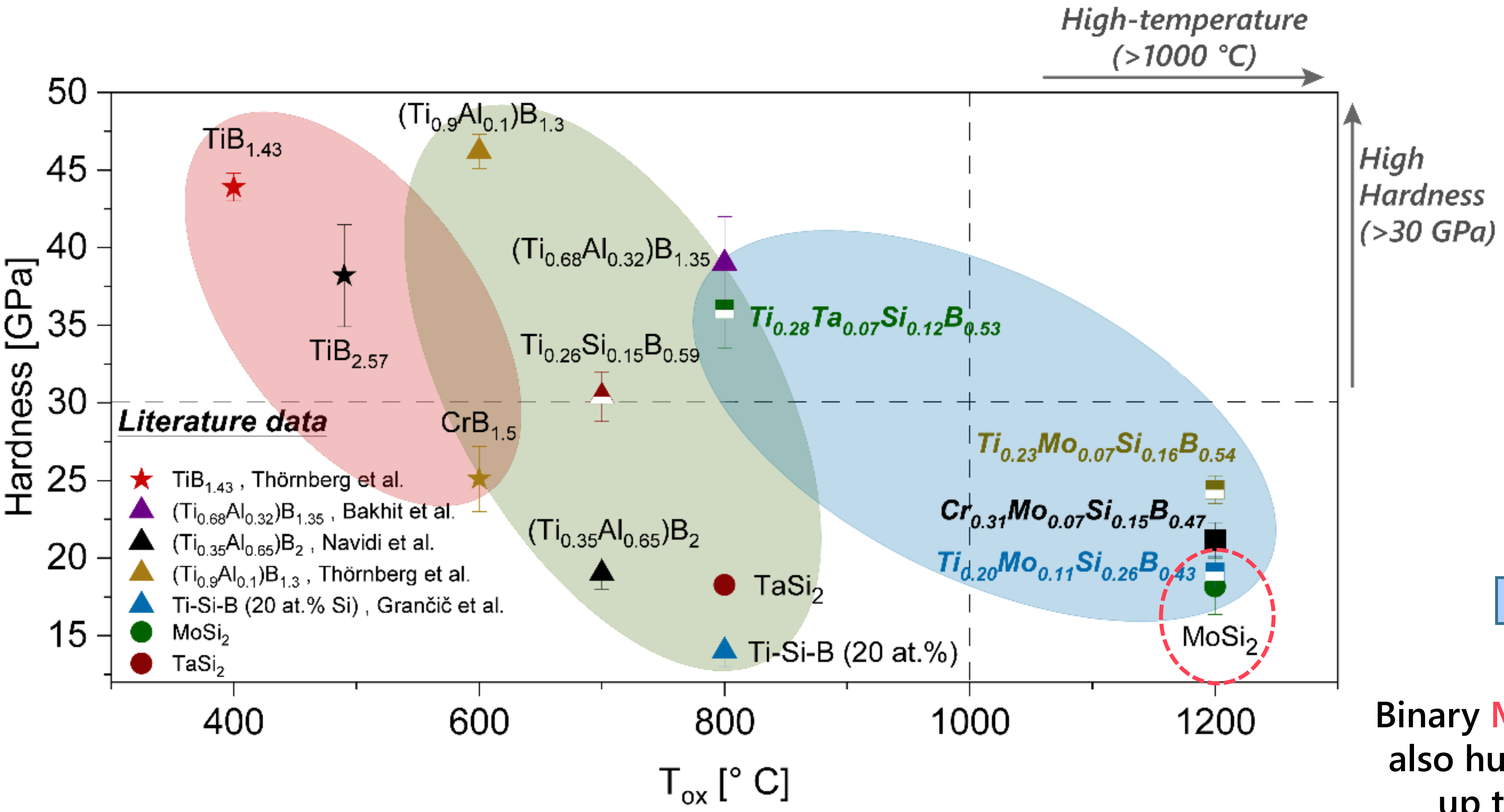
Ternary
Hf-Si-$B_{2\pm z}$



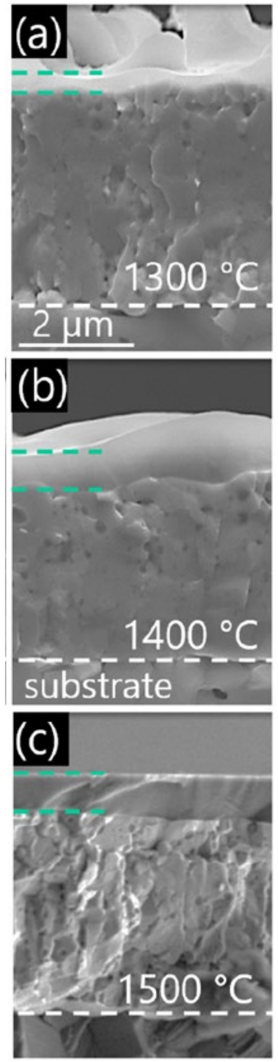
UHT oxidation

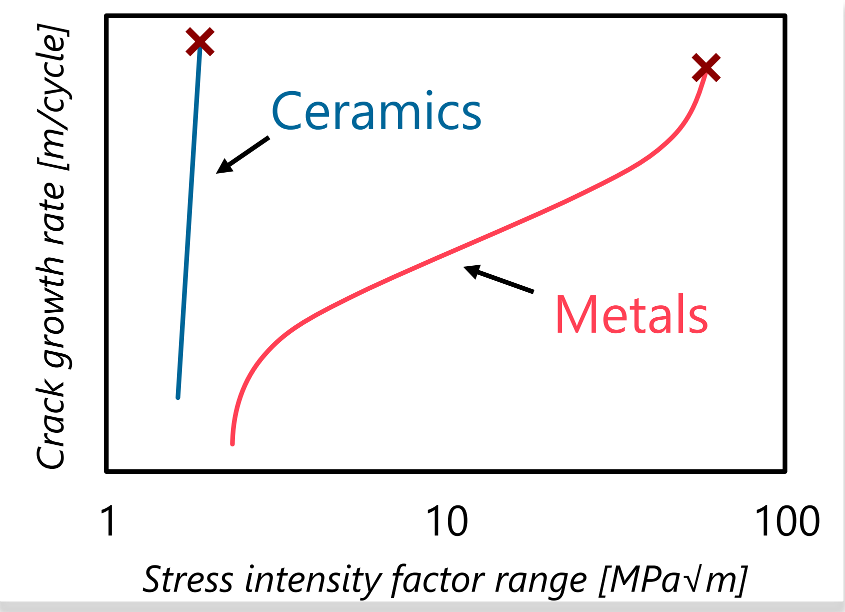
Hexagonal structured quaternary Borides

new interesting group of alloys ➔ also in the world of MAX phases



Binary $MoSi_2$ obtains also huge potential up to 1500 °C

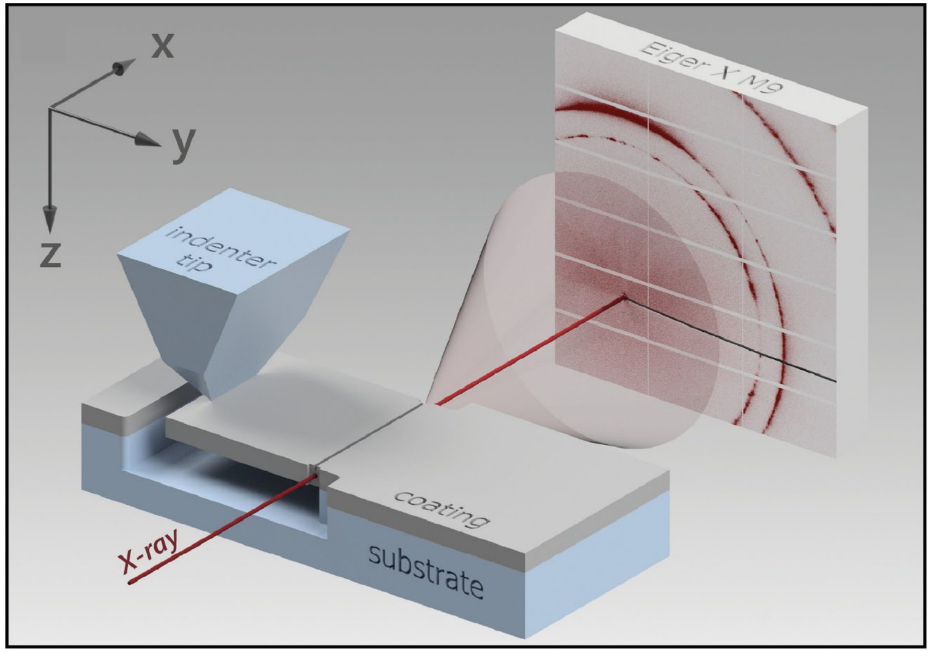




Crack evolution in ductile & brittle materials

- Crack growth rates da/dN for ceramics are extremely sensitive to the stress intensity (brittle failure) in static & dynamic loads

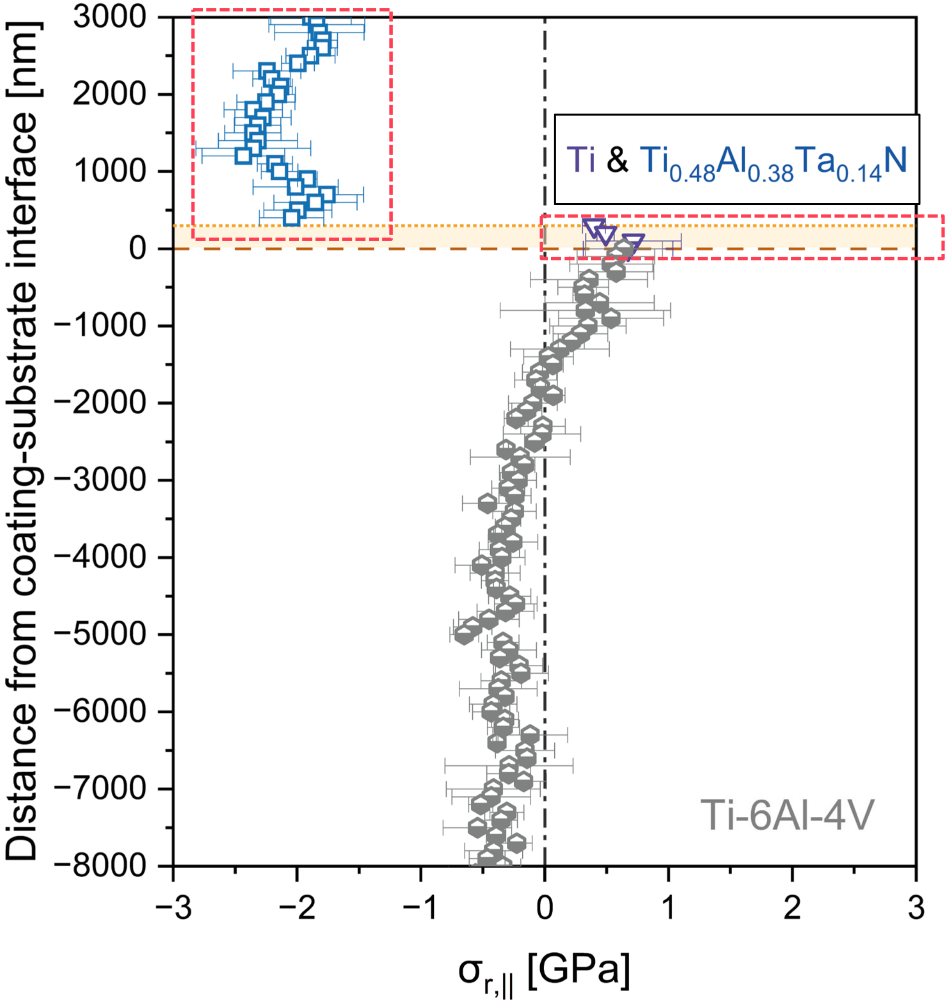
Inspired unique coating design

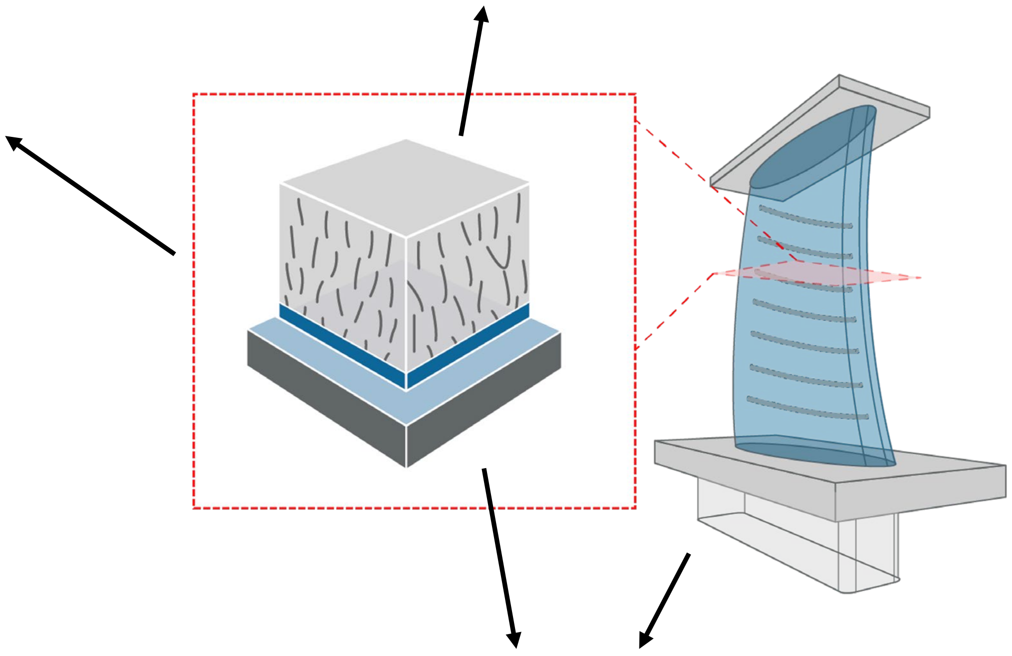


- Novel test set-up at the synchrotron to understand in detail the stress evolution of mechanical loaded coatings

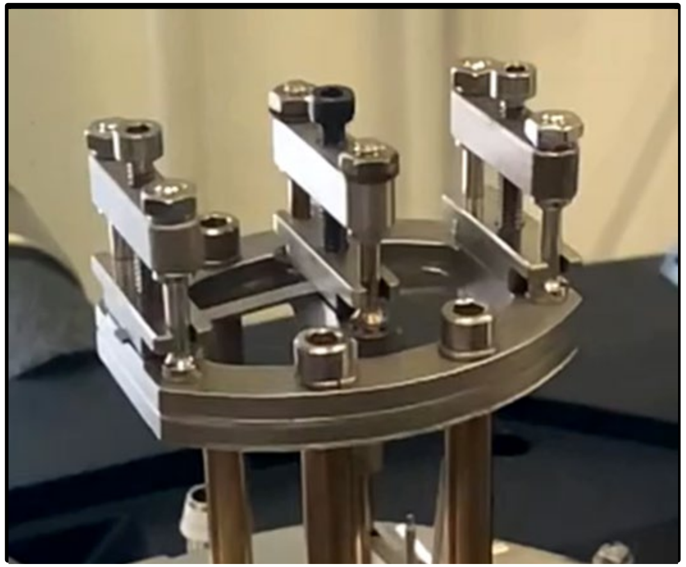
Fatigue resistance

Unique stress design at interface
➔ Ti interlayer in tensile regime + compressive state in Ti-Al-Ta-N

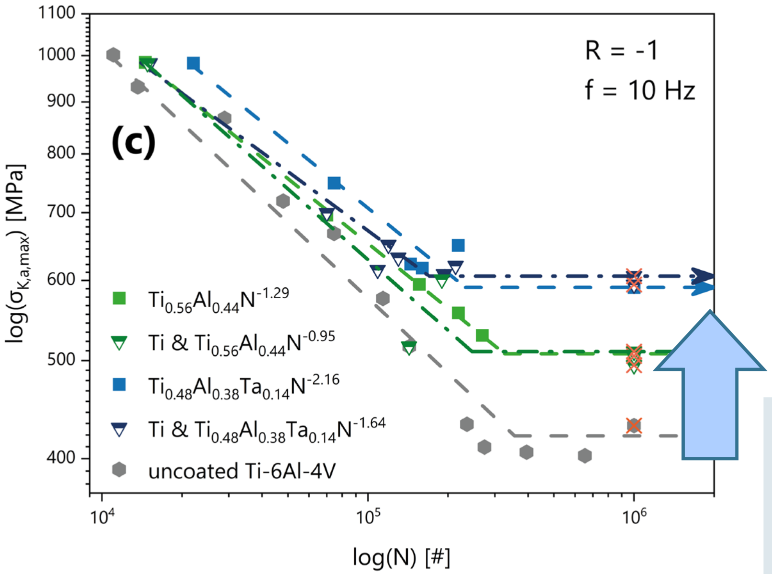




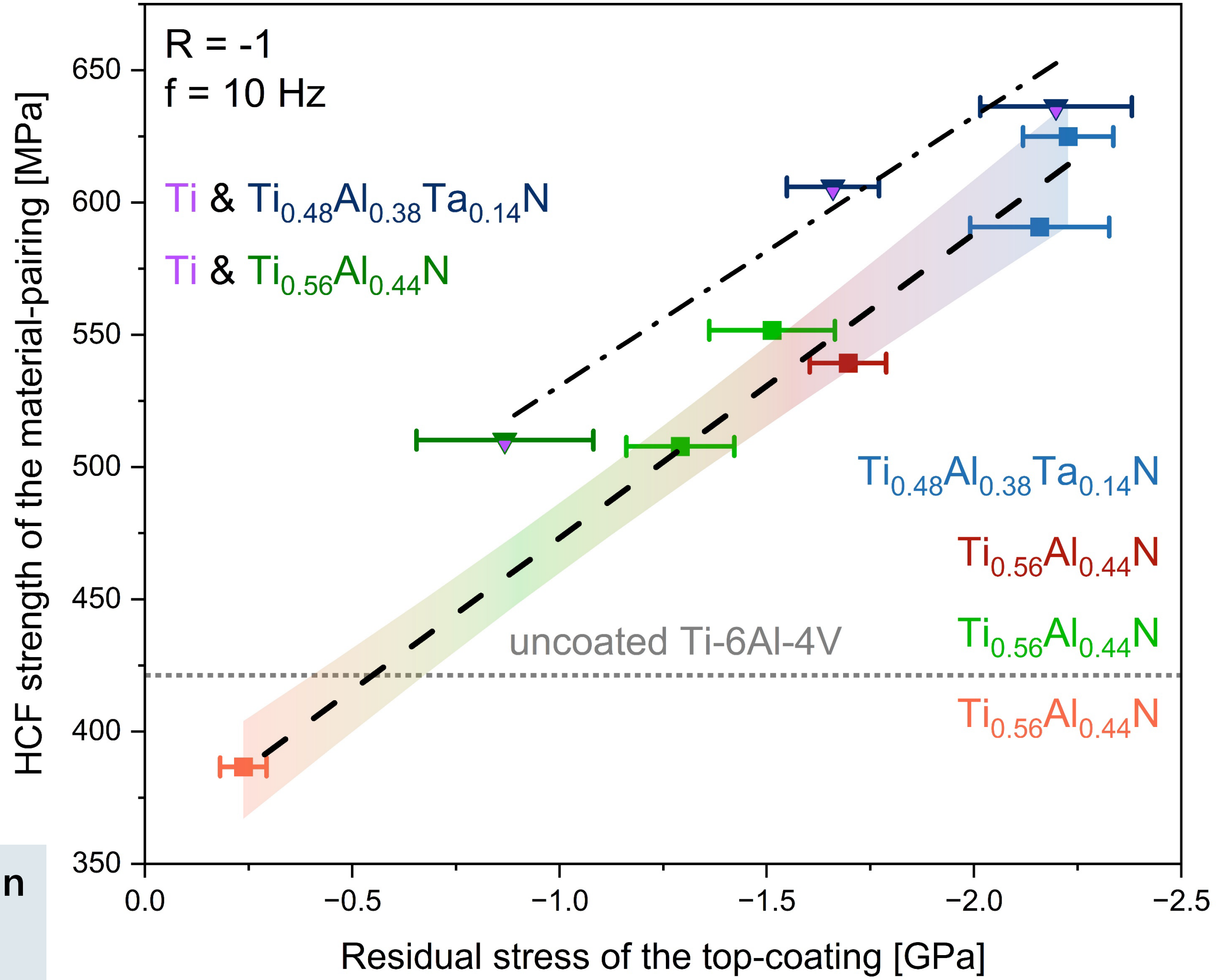
Fatigue resistance



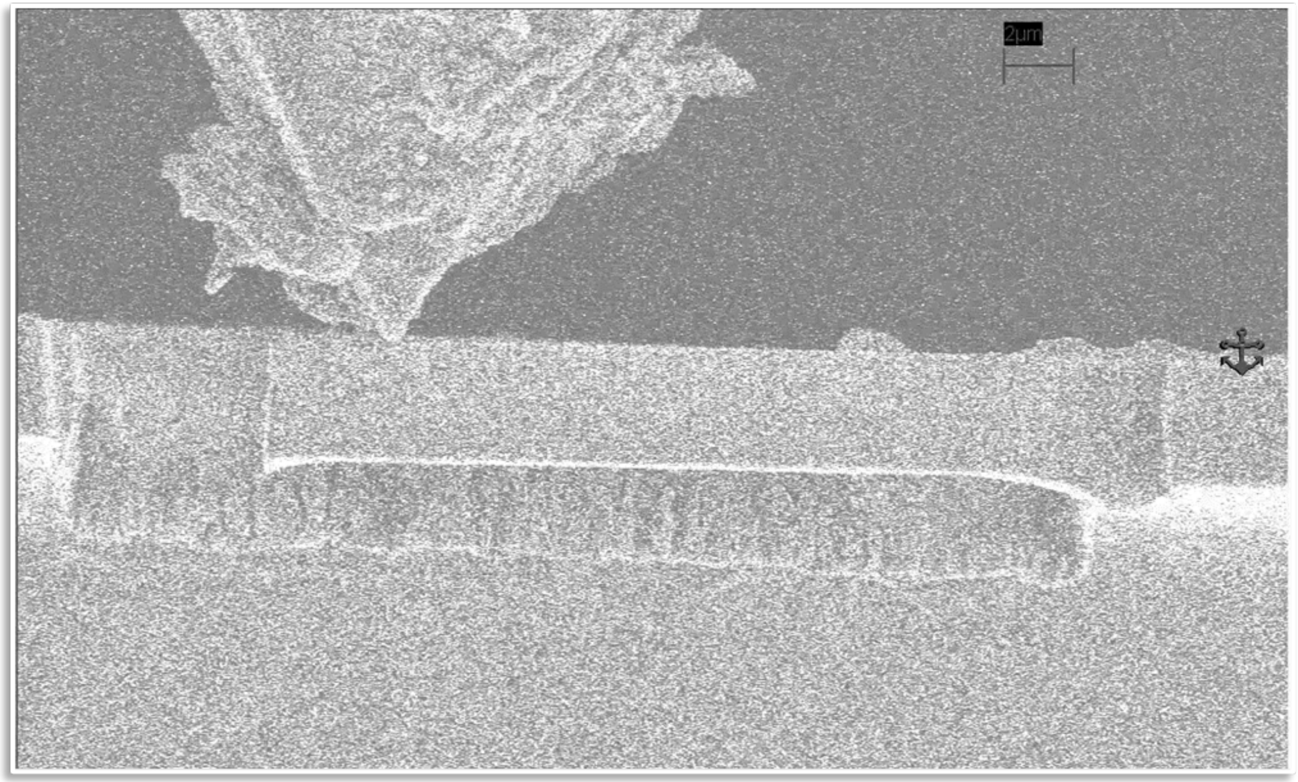
Dynamic mechanical analyzer (DMA)



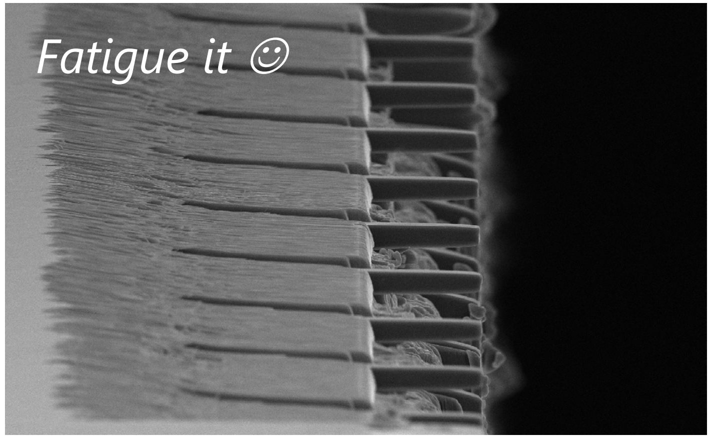
Drastic increase in fatigue life ➔ load amplitude



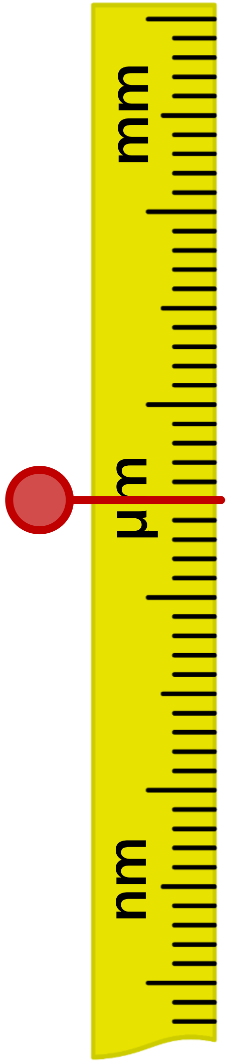
Fatigue resistance



In-situ nano indentation system



FIB prepared cantilevers



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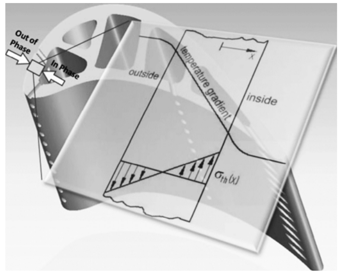
Next generation protective coatings for turbine applications

Take Home Message

In-depth knowledge about UHTC coatings can highly impact use of macroscopic components



Sophie Richter, Theodor Körner Preis 2024

Anna Hirle Best Poster Award Junior EUROMAT

Thomas Glechner, Award of Excellence 2022

Bronze
- Zauner Lukas

DVG

Lukas Zauner, DVG Nachhaltigkeitspreis 2023

Ahmed Bahr, ICMCTF Student Award Gold 2023 San Diego (USA)

Hall of fame

Over 30x SCI-ranked journal papers + 7x invited talks + 2x patent families

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Corrosion Science
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High temperature oxidation resistance of physical vapor deposited Hf-Si-$B_{2\pm z}$ thin films

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Influence of Si on the oxidation behavior of TM-Si-$B_{2\pm z}$ coatings (TM = Ti, Cr, Hf, Ta, W)

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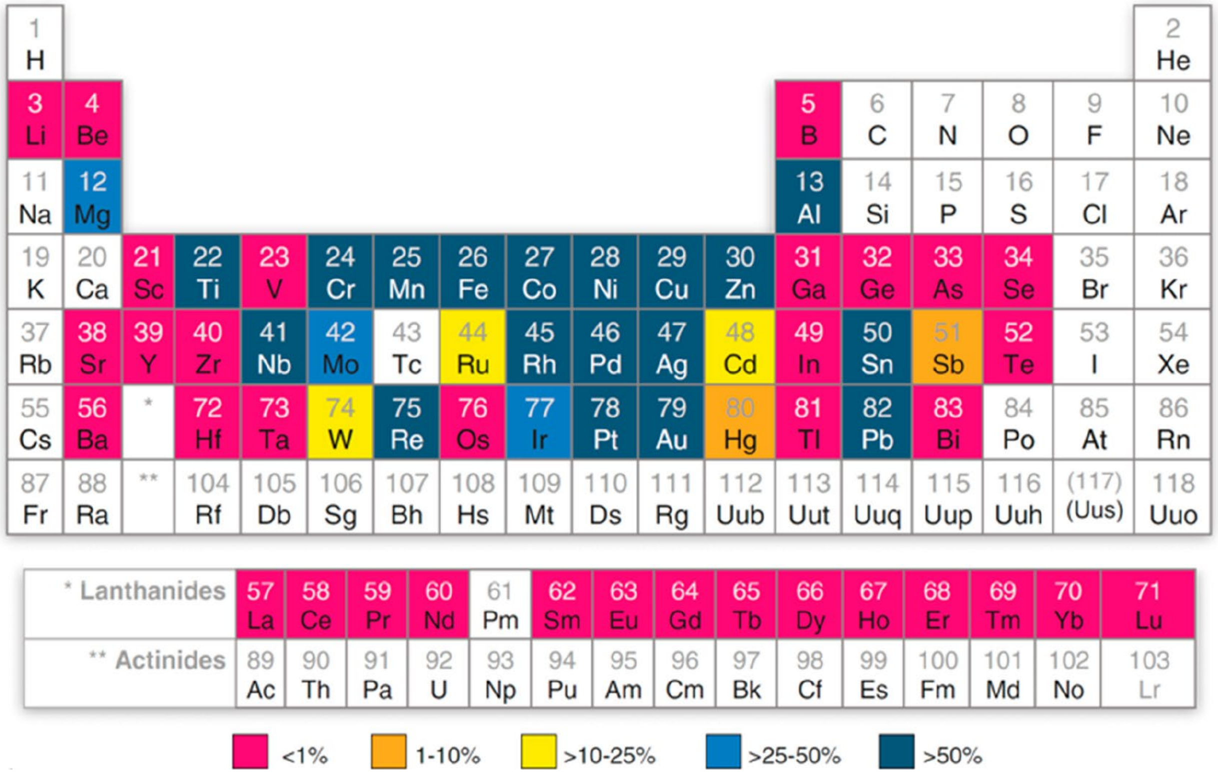
Influence of the non-metal species on the oxidation kinetics of Hf, HfN, HfC, and HfB_2 coatings

T. Glechner[a,*], O.E. Hudak[a], T. Wojcik[a], L. Haager[b], F. Bohrn[b], H. Hutter[b], O. Hunold[c], J. Ramm[c], S. Kolozsvári[d], E. Pitthan[e], D. Primetzhofer[e], H. Riedl[a,f]

Coatings in H_2 technologies

Materials in H_2 technologies

End of life recycling rates (EOL-RR) periodic table



Elements usage

- **Fe & Al + accompanying elements (Cr, Ti, Nb)** in structural materials (steels, Al alloys) used for components / frames for production and transportation

  ➔ not a limiting factor

- Ru, Rh, Pd, Os, Ir, Pt are limited availability and extremely high in price & not good in recycling

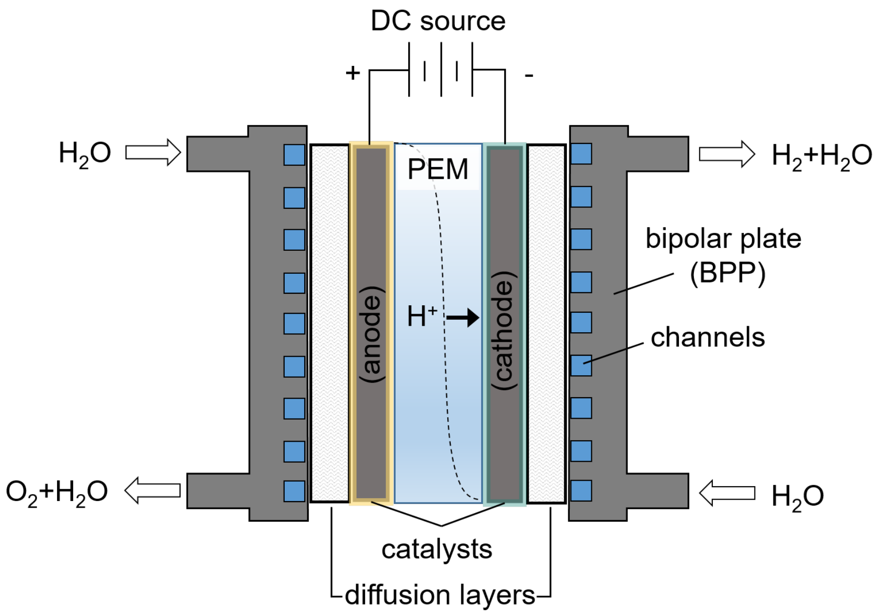
Ir	➔	131.504 €/kg
Au	➔	89.028 €/kg

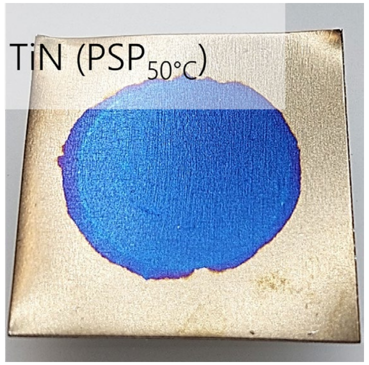
Coating Materials for BPP

I. Noble metals
II. Transition metals
III. TM-nitrides & carbides
IV. MAX phases

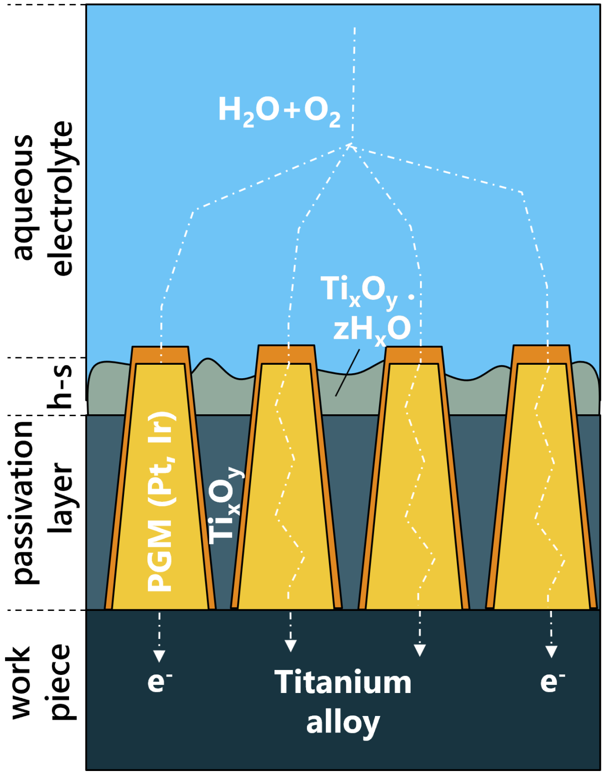
PEM cells

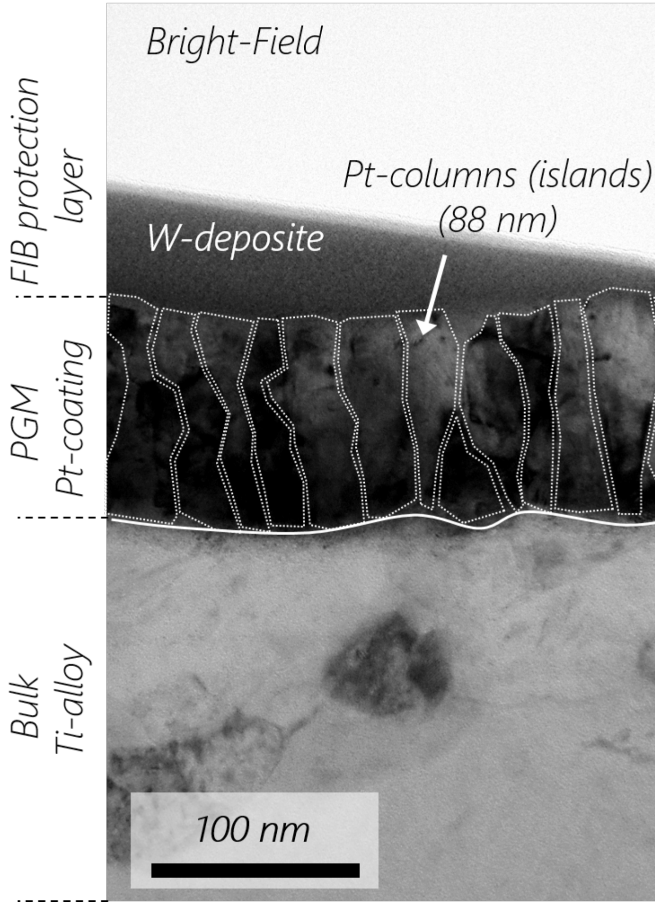
Single-Stack Water PEM-Electrolyzer





State-of-the-Art ➔ „PGM Solution“





Platinum group metals (PGM) heavily used in hydrogen conversion technology

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Christian Doppler Forschungsgesellschaft

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