



TECHNISCHE
UNIVERSITÄT
WIEN

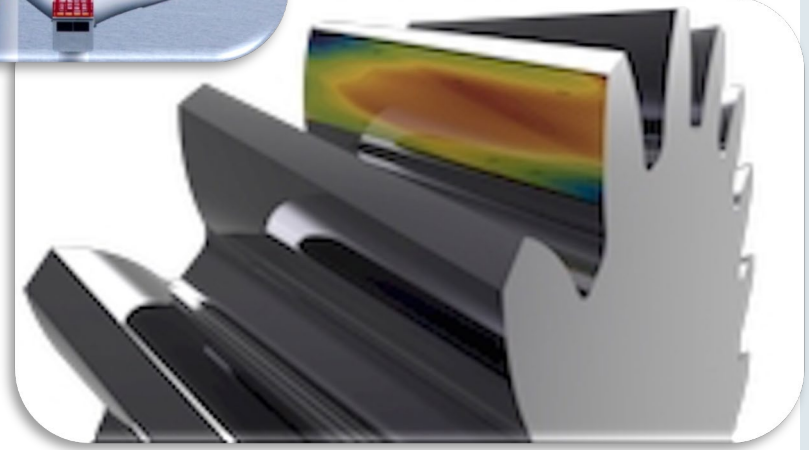
“Tribology in a nutshell: From Helicopters to human implants and beyond “

Univ.- Prof. Dr.-Ing. Carsten Gachot

Head of the Tribology Research Unit @TU Wien, Austria

Advanced Motor Fuels Technology Collaboration Programme (AMF TCP)

28.04.2026



[With Urban Air Mobility Coming into Focus, Two Companies Present Alternative Visions - Aviation Today](https://infra.global/kbr-launches-sustainable-aviation-fuel-technology-in-alliance-with-swedish-biofuels/)

<https://infra.global/kbr-launches-sustainable-aviation-fuel-technology-in-alliance-with-swedish-biofuels/>

[Die zehn größten Offshore-Windparks der Welt \(orsted.de\)](http://orsted.de)

[Biotribology and Biotribocorrosion Properties of Implantable Biomaterials | Frontiers Research Topic \(frontiersin.org\)](https://www.frontiersin.org/research-topics)



I. New Additive Concepts for Helicopter Gearboxes

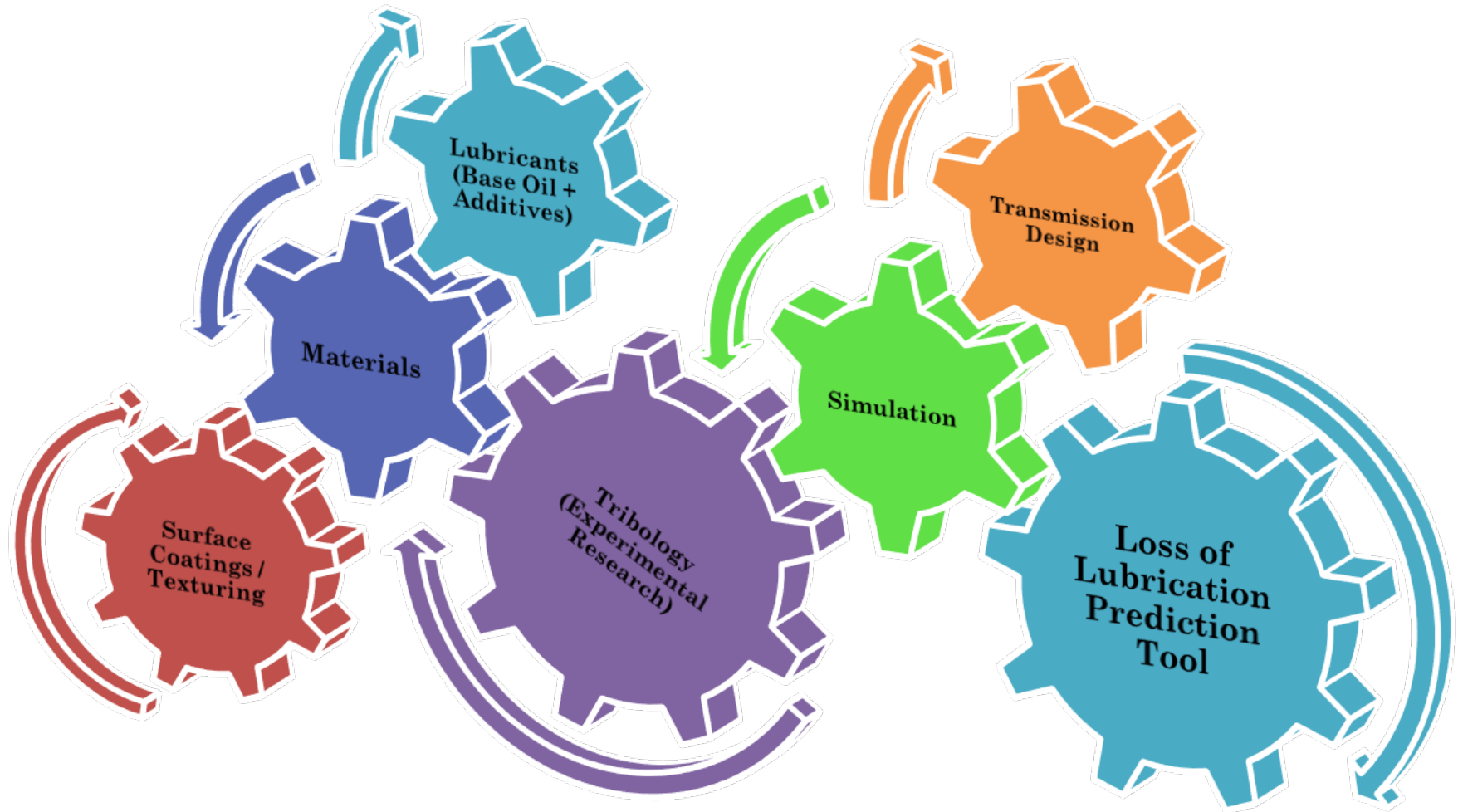


Loss of lubrication of helicopter gears



MIL-HDBK-516C generally states that *“during a loss of the primary lubrication system, the gearboxes shall continue to function and transmit required power until appropriate pilot action can be accomplished”* while JSSG-2009-A (Department of Defence Joint Services Specification Guide) requires that *“the gearboxes shall function for at least 30 minutes after complete loss of the lubricant from the primary lubrication system while maintaining capability of transmitting power and without leading any component to a state of imminent failure”*.





- ✓ Thermal stability
- ✓ Chemical stability
- ✓ Non-flammability
- ✓ Low vapour pressure
- ✓ High heat capacity etc.

Table 1: Molecular name, structure and formula of the two ILs.

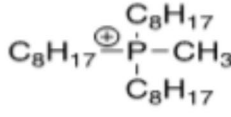
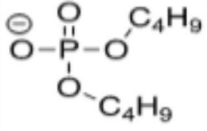
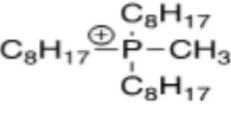
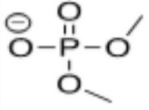
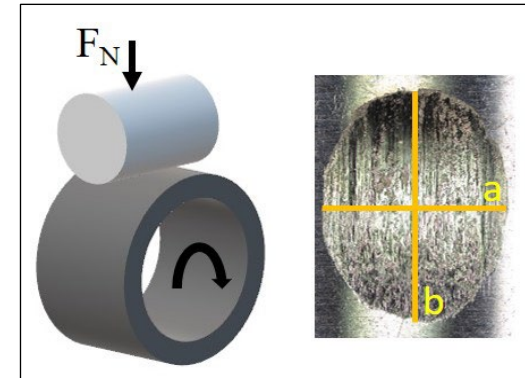
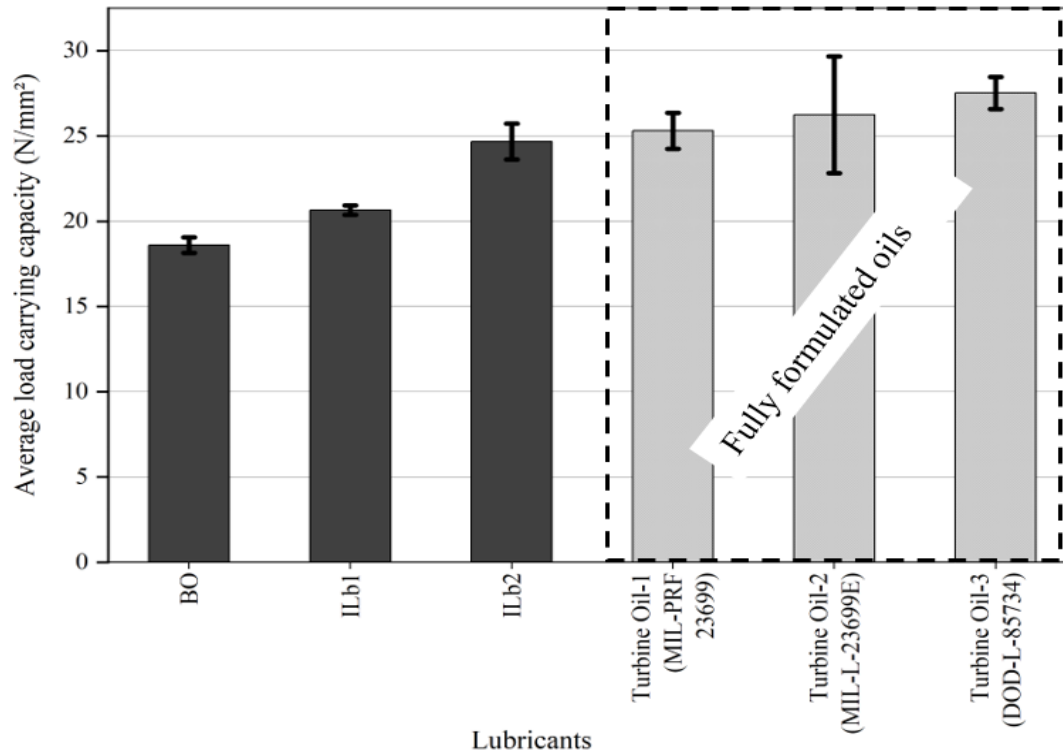
Ionic liquid	Name	Cation	Anion
IL1	<u>Trioctylmethylphosphonium</u> dibutyl phosphate [P ^{SSS1}] [DBP]		
IL2	<u>Trioctylmethylphosphonium</u> dimethyl phosphate [P ^{SSS1}] [DMP]		

Table 2: Blend concentration and viscosities of the BO and IL blends.

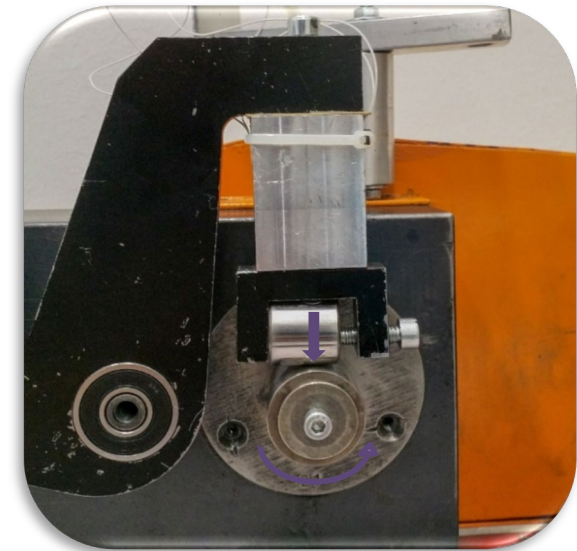
lubricants	notation	blend concentration (wt. %)	viscosities of BO and IL blends (cSt)	
			40 °C	100 °C
FVA2	BO	0	31.0	5.24
FVA2 + [P][DBP]	ILb1	5	33.0	5.72
FVA2 + [OMA][DMP]	ILb2	5	32.6	5.43

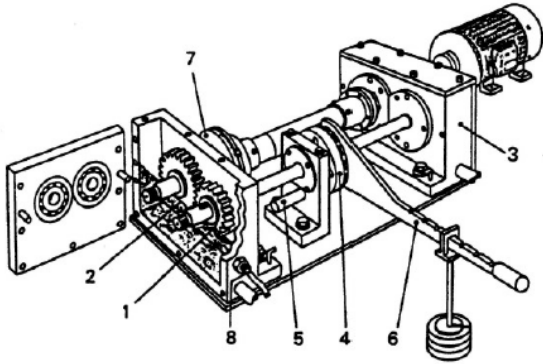
Standard Lubricant tester according to **DIN 51347-1**

Test time [s] : 30
 Oil volume [ml] : 8
 Load [N] : 400
 Contact Pressure [N/mm²] : Load / Area

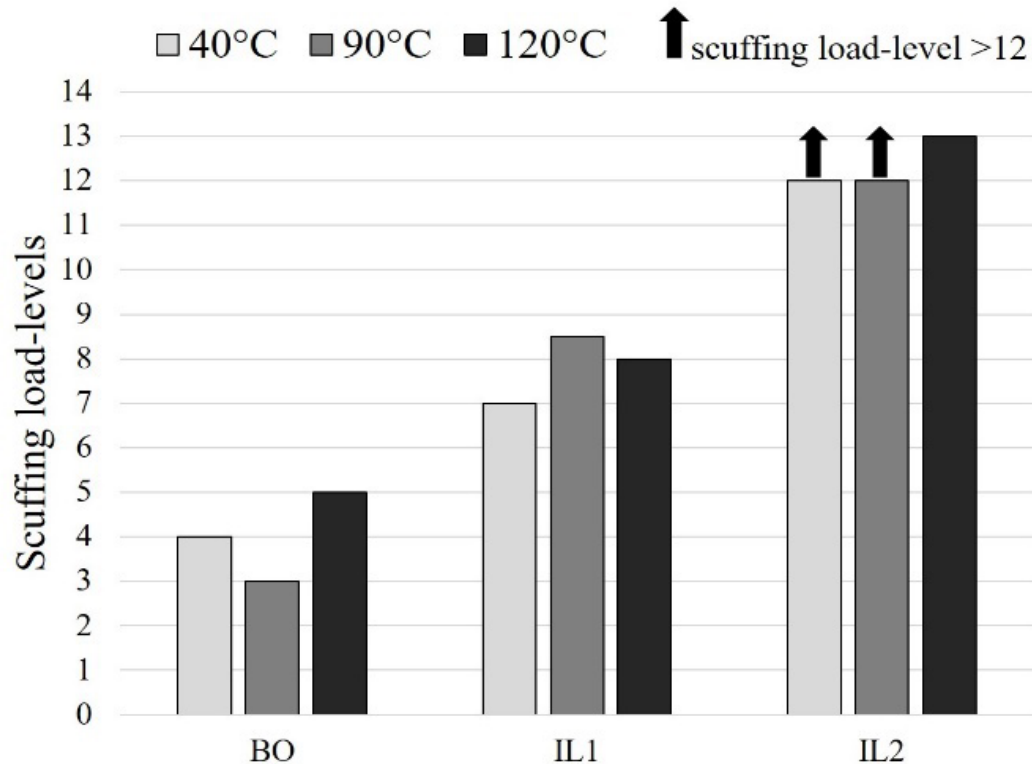
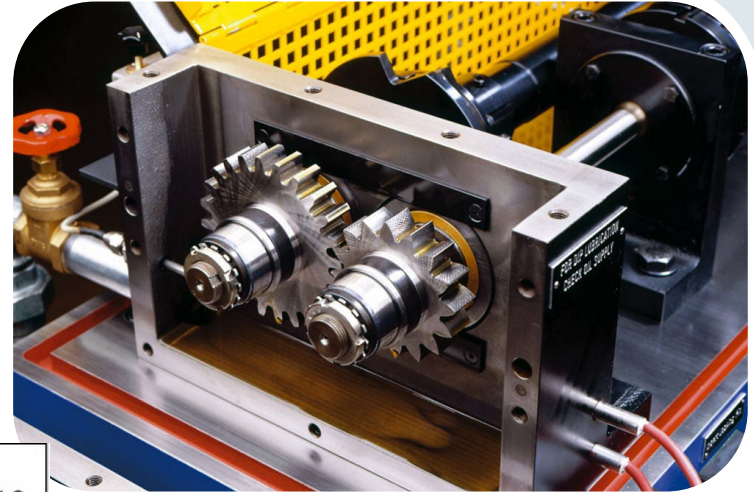


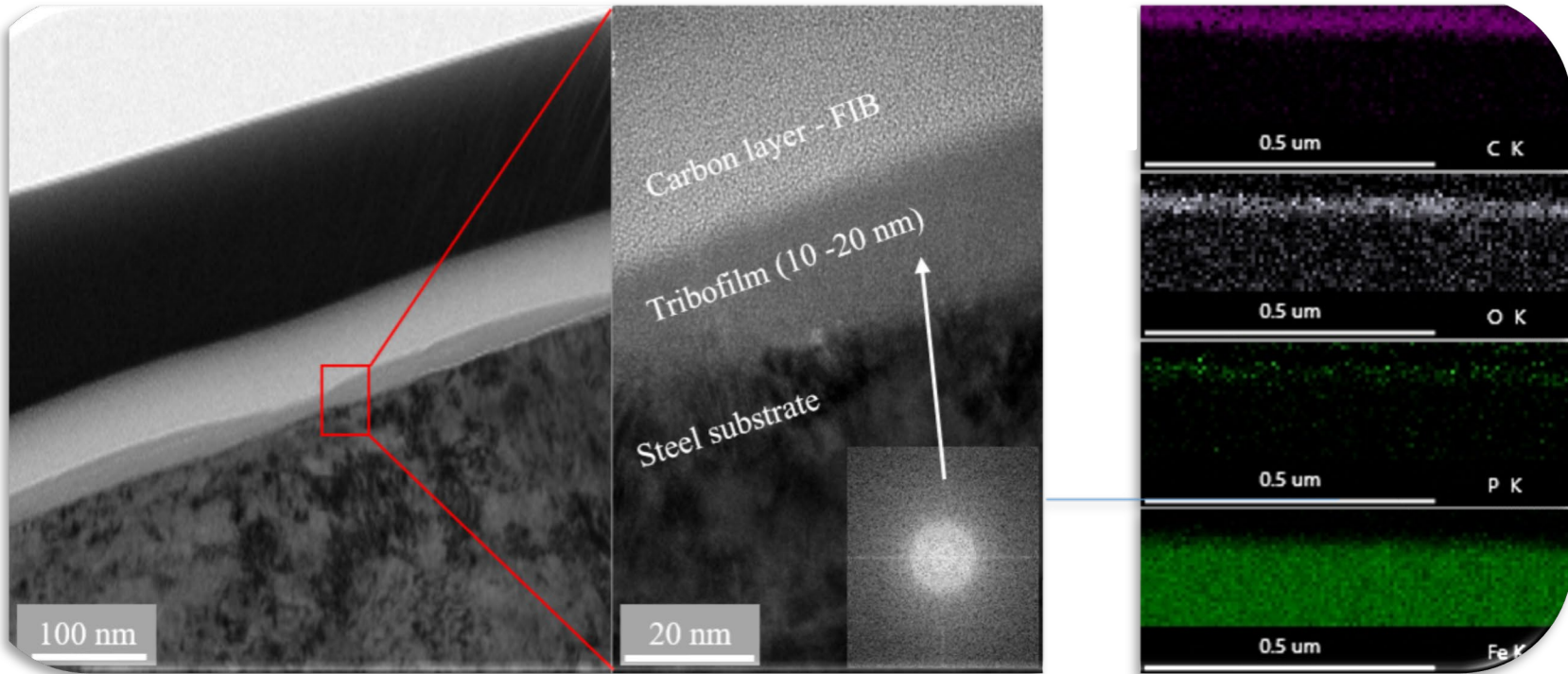
$$B = \frac{4 \cdot F_N}{a \cdot b \cdot \pi}$$





1. Test pinion
2. Test wheel
3. Drive gear case
4. Rotating coupling
5. Locking pin
6. Load lever with weights
7. Torque gauge
8. Temperature sensor



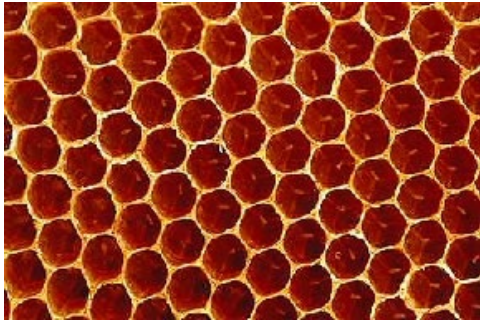


Anifa Mohamed Faruck, A., Grützmaier, P. G., Hsu, C. J., Dworschak, D., Cheng, H. W., Valtiner, M., ... & Gachot, C. (2023). Applying ionic liquids as oil additives for gearboxes: Going beyond the state of the art by bridging the nano-scale and component level. *Friction*, 11(6), 1057-1078.

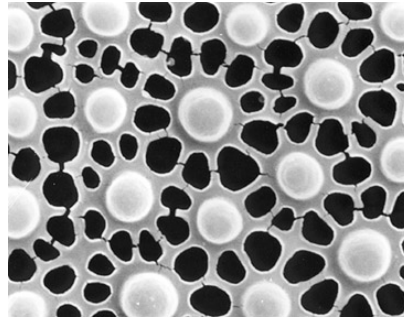


II. Advanced Surface Engineering

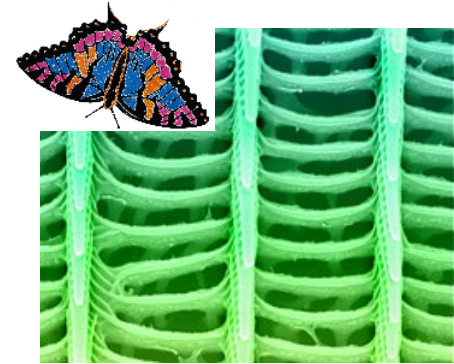




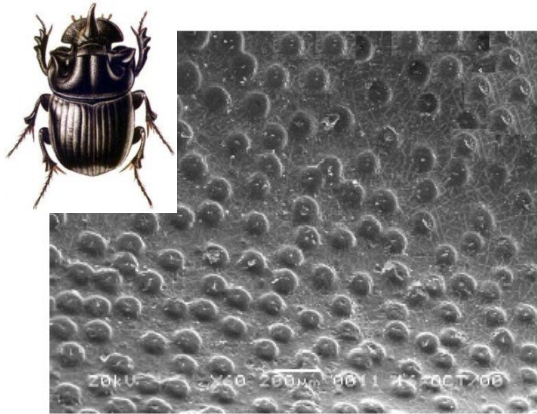
Honey comb



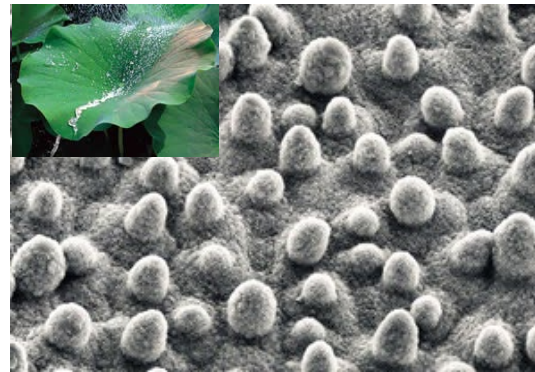
Mosquito egg
surface



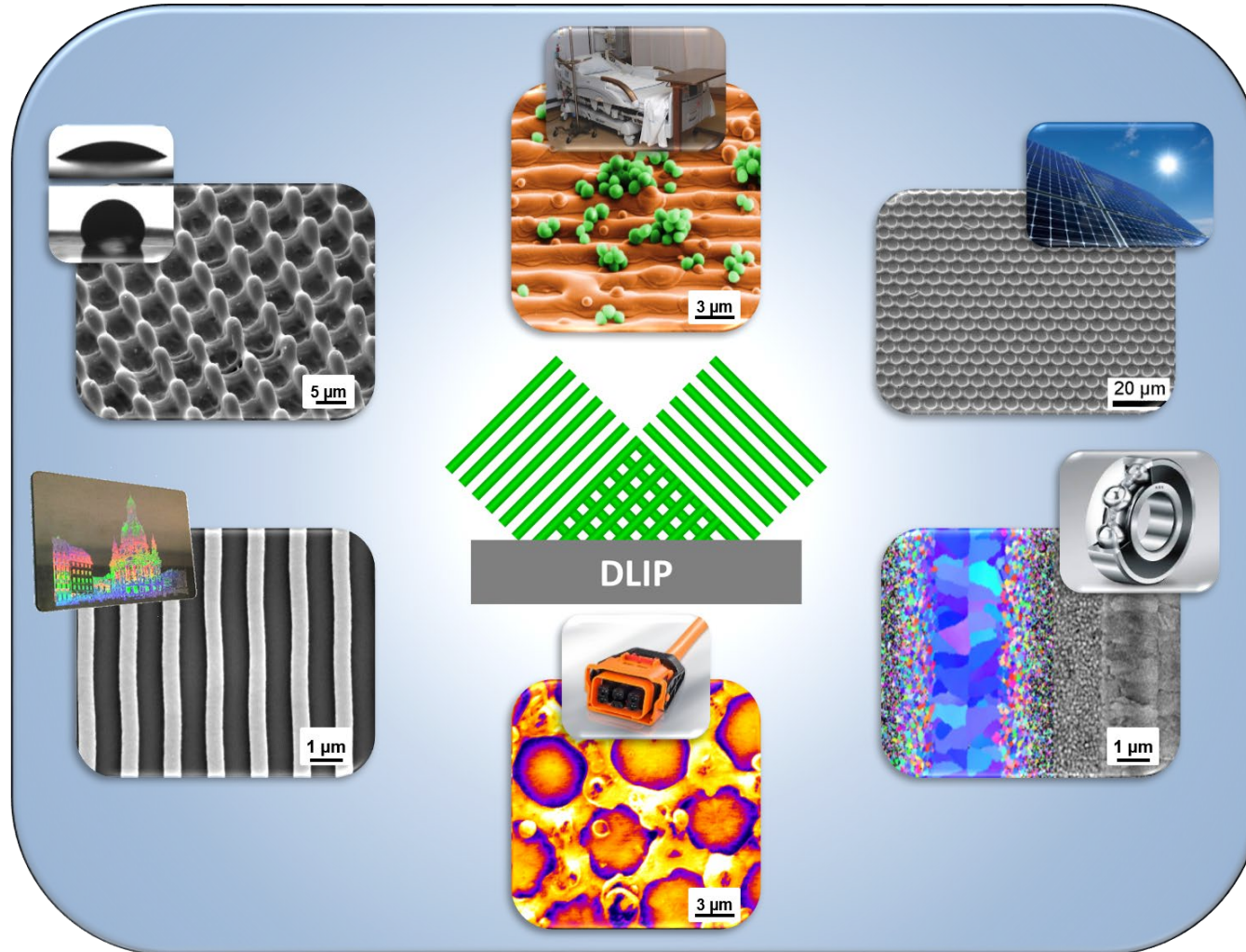
Butterfly scale



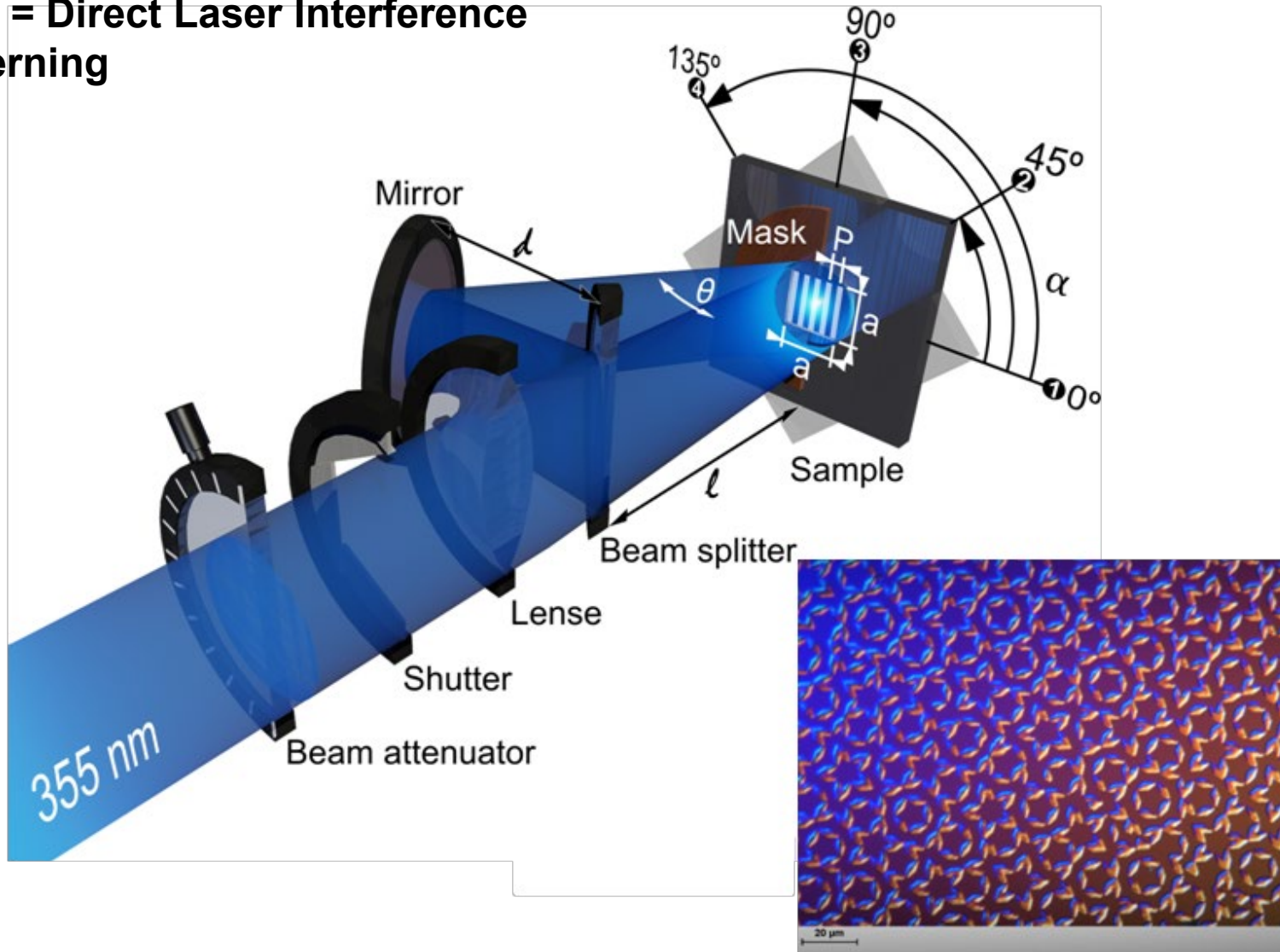
Dung beetle surface



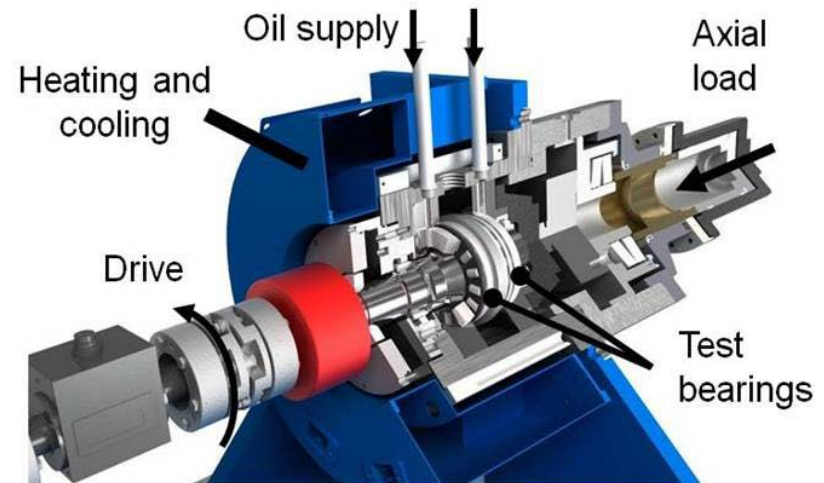
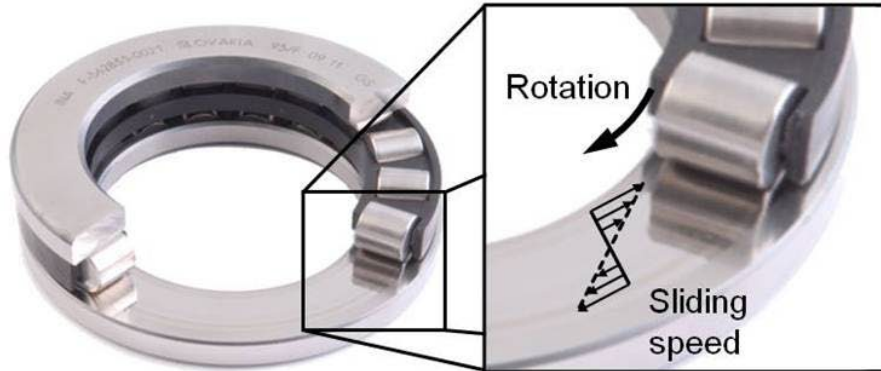
Lotus leaf



DLIP = Direct Laser Interference Patterning



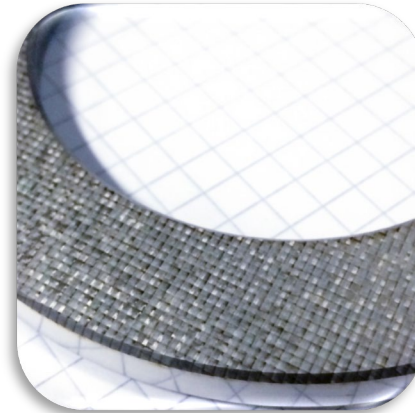
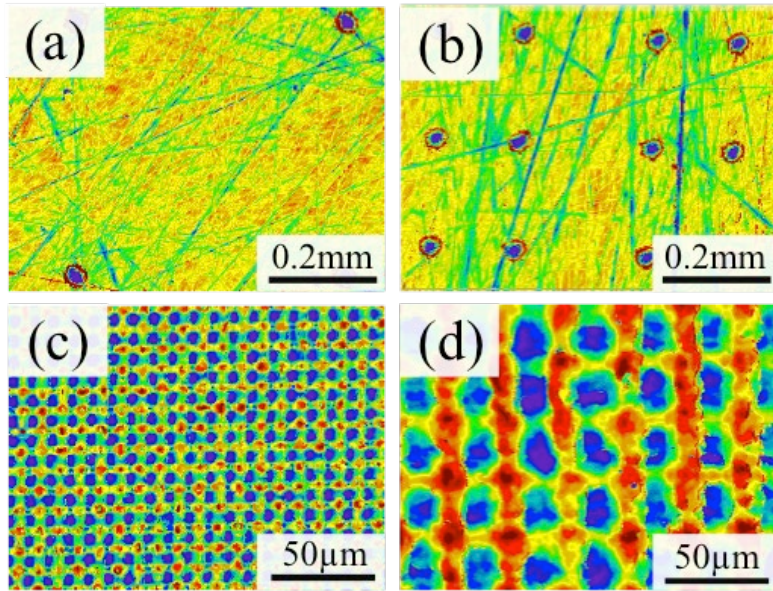
Penrose tiling



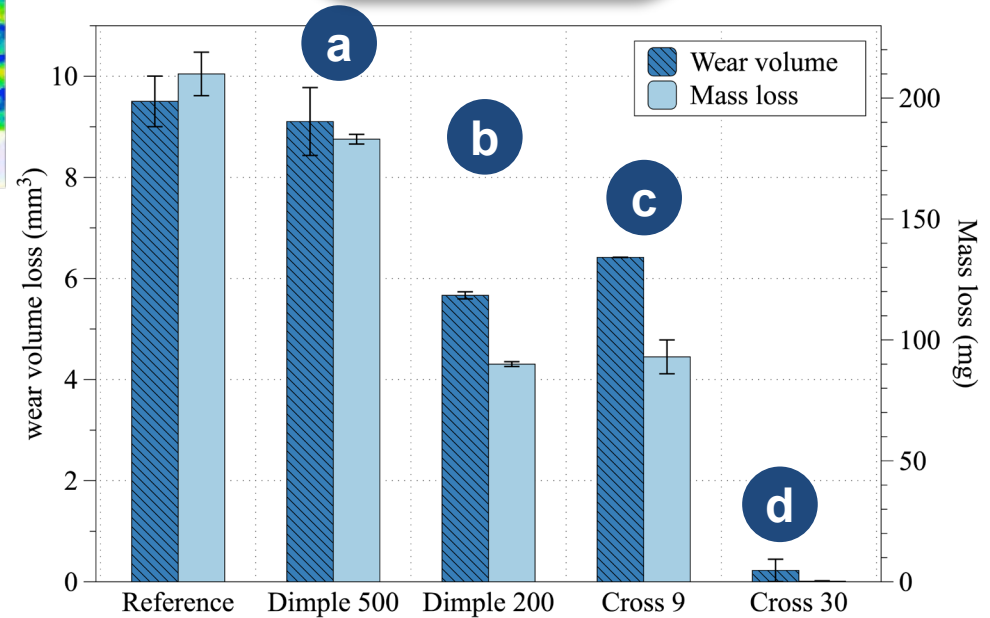
Experimental Parameters

Rotational Speed (rpm)	20
Load (kN)	80
Working Temperature (°C)	60
Duration (Hour)	2
Surface Roughness Ra (μm)	0.2
Bearing Steel	AISI 52100

- The cylinder roller thrust bearing rings were examined by **FE8 test rig according to DIN51819**.
- Mineral oil of class ISO VG 100 mixed with ZDDP additive.



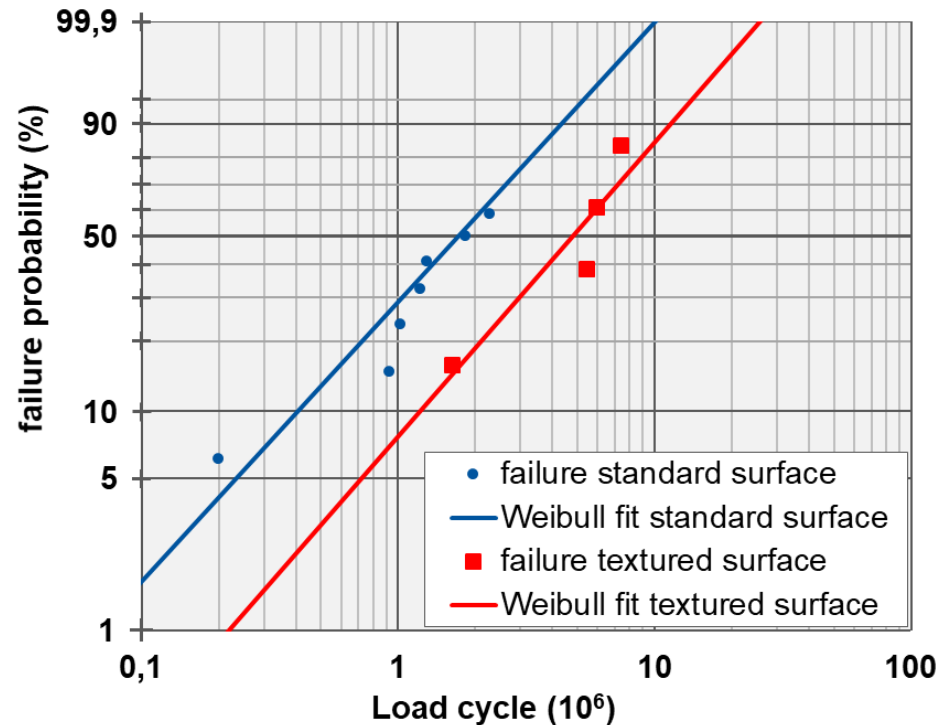
- The wear reduction is due to the formation of a tribolayer and the capability of lubricant storage.



What about the fatigue life-time of textured components?

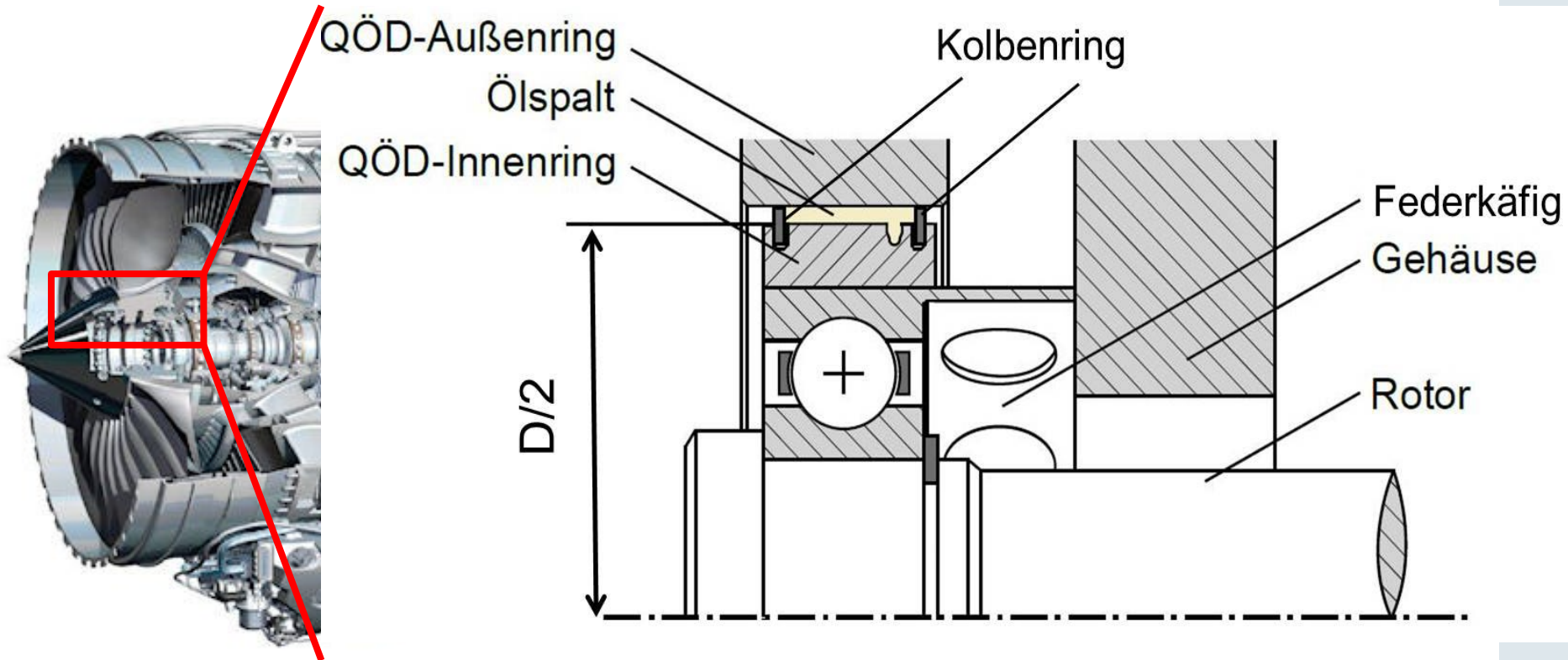
Experimental Parameters

- Bearing Type: 51212
- Rotational Speed: 750 min⁻¹
- Normal Load: 80 kN
- Contact Pressure: 3.6 GPa
- Temperature: 90 °C
- Concentration: 500 ppm P

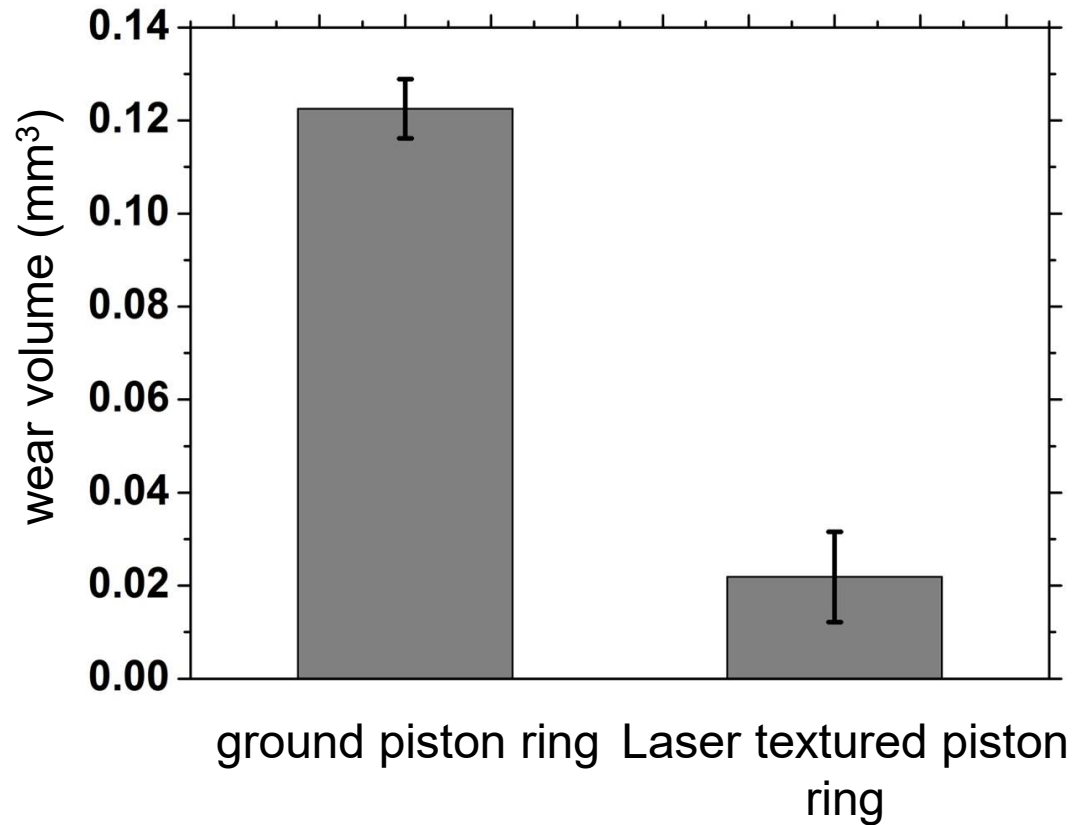
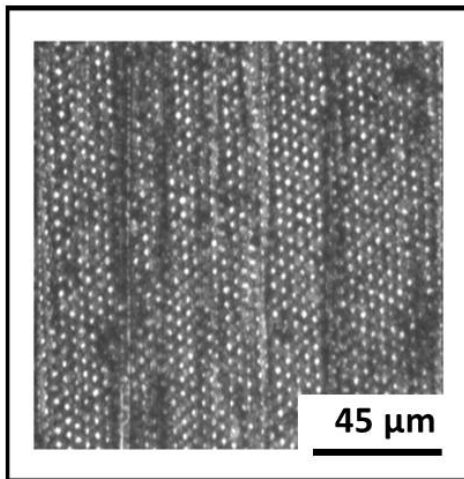
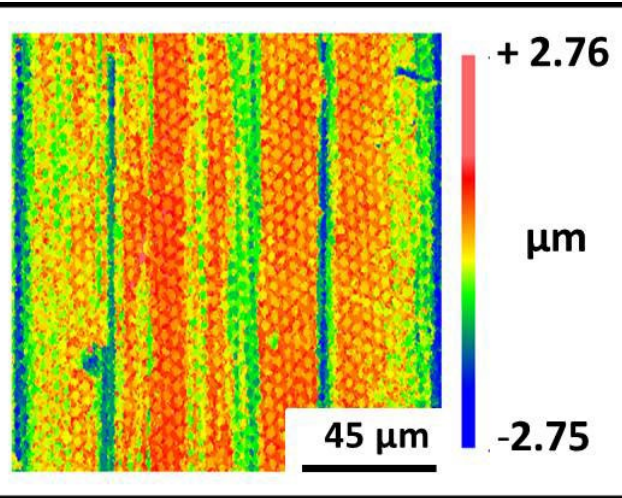


- The fatigue life-time of the laser textured bearings increases by a factor of 3!
- The fatigue mechanism remains the same

Piston rings of squeeze film dampers



Piston rings of squeeze film dampers in turbines



wear reduction by a factor of 6!



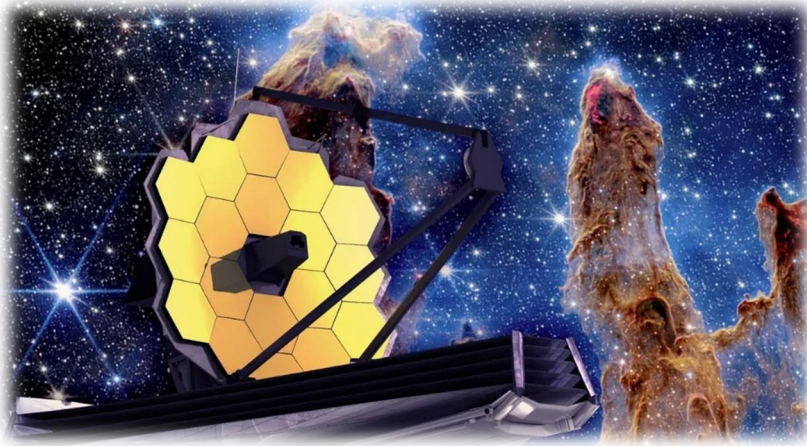
III. High-Performing Solid Lubricants – 2D Materials



TECH

James Webb telescope has a friction drawback that NASA wants to repair

BY BHAGYASHREE SONI — SEPTEMBER 22, 2022 — UPDATED: SEPTEMBER 22, 2022 — NO COMMENTS — 2 MINS READ



- 10 billion dollar project
- Sun-shades as large as tennis courts
- Located in second Lagrange point around 1.5 million km away from the Earth!
- 13.000 pounds weight => one adult African elephant!

James Webb Telescope and Pillars of Creation (Photo illustration by Salon/Getty Images/NASA)
<https://www.designworldonline.com/lubricants-play-critical-role-space-applications/>

Chat GPT 4.0 custom-built



A new “family” of materials – MXenes as 2D materials

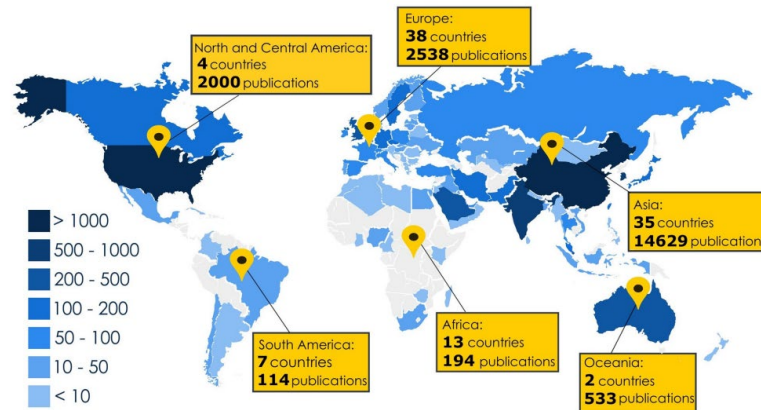
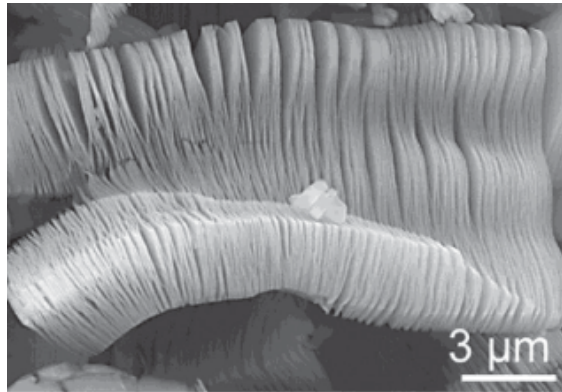


Fig. 1 The number of MXene publications and countries per continent based on the topic search on the word MXene on Web of Science on September 30, 2023 (courtesy of Magdalena Zywołko, Alex Inman and Jamie Banks, Drexel University)

DERSTANDARD › Wissenschaft

SUPPORTER

24 Postings



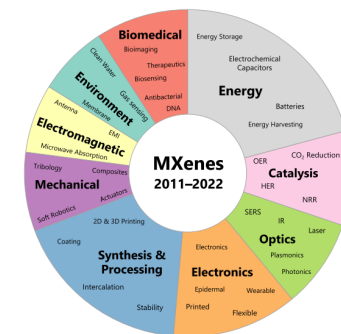
Neues 2D-"Wundermaterial" ist der perfekte Schmierstoff

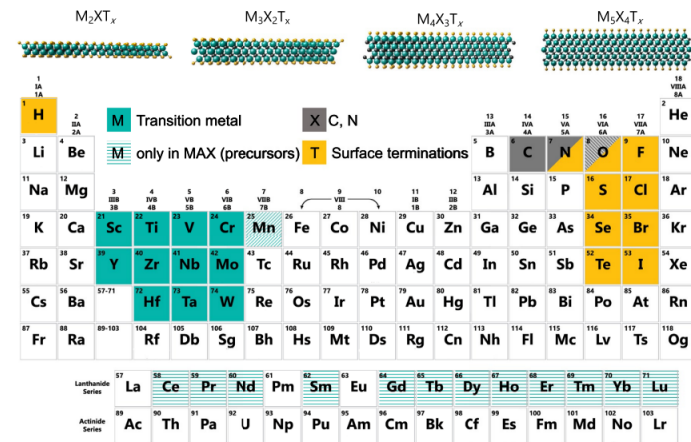
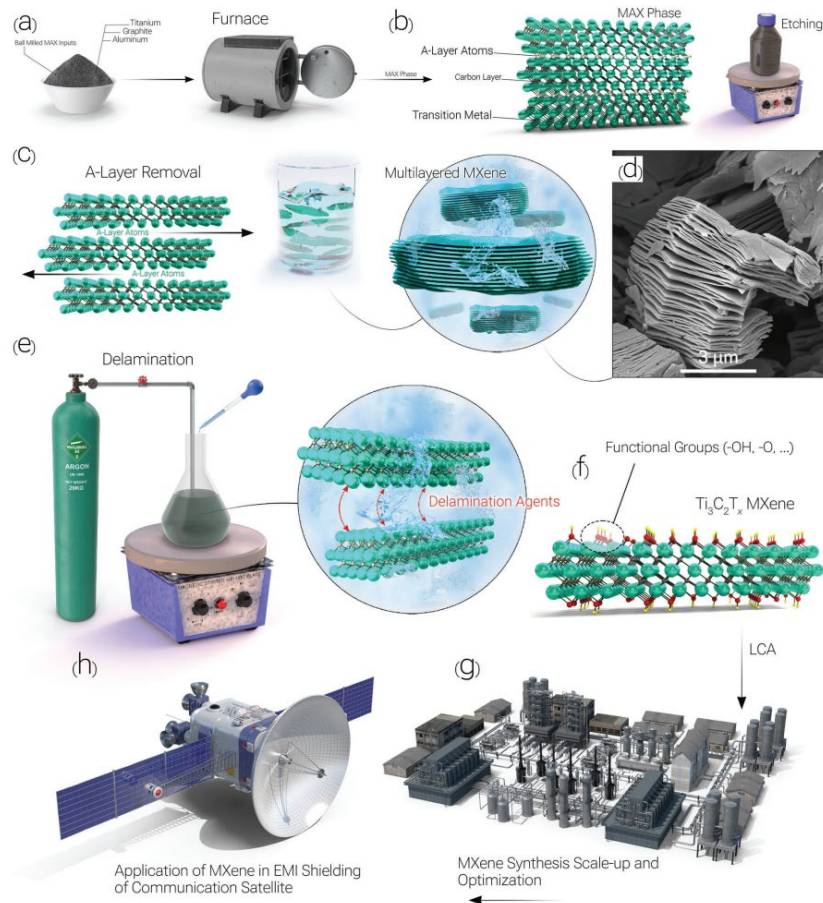
Das Nanomaterial mit vielversprechenden Eigenschaften eignet sich als Festschmiermittel unter extremen Bedingungen

21. April 2021, 08:12 24 Postings

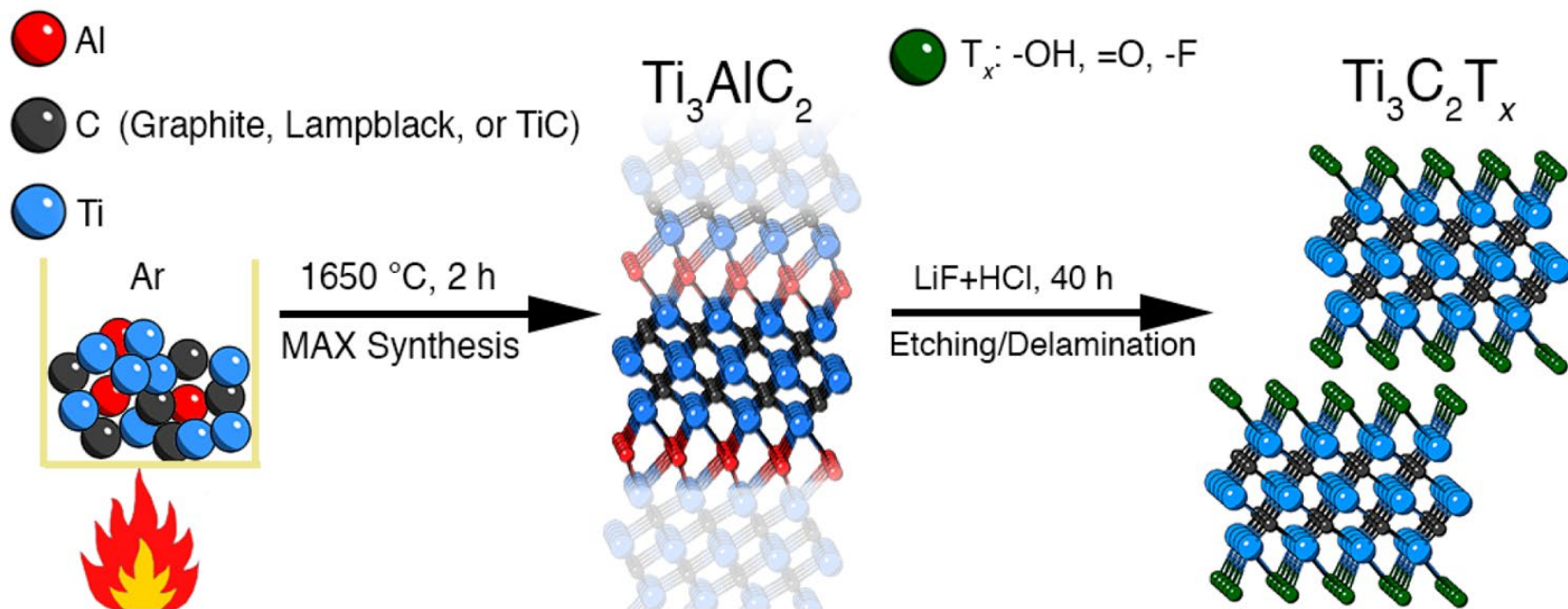
Nicht zuletzt den Errungenschaften der Materialwissenschaft ist es zu verdanken, dass die Bezeichnung „Wundermaterial“ mittlerweile inflationär verwendet wird. Auch die Materialklasse der sogenannten MXene (sprich: Maxene) bekam schon häufig dieses Schild umgehängt. Und tatsächlich zeigt das zweidimensionale Nanomaterial vielversprechende Eigenschaften etwa für den Einsatz in der Energiespeicherung. Wiener Forscher berichten nun im Fachjournal „ACS Nano“, dass sich MXene auch als hervorragende Schmierstoffe erwiesen haben, die extrem haltbar sind und auch unter schwierigsten Bedingungen funktionieren.

Wie das Kohlenstoff-Material Graphen zählen auch die MXene zu den sogenannten 2D-Materialien: Ihre Eigenschaften werden wesentlich dadurch bestimmt, dass es sich um ultradünne Schichten handelt, um einzelne Atomlagen, ohne starke Bindungen nach oben oder unten.

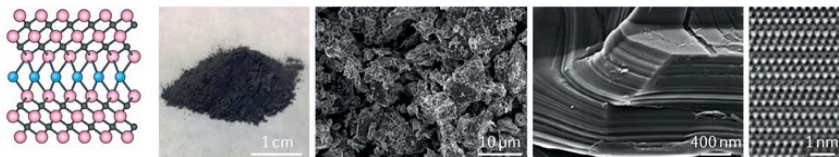




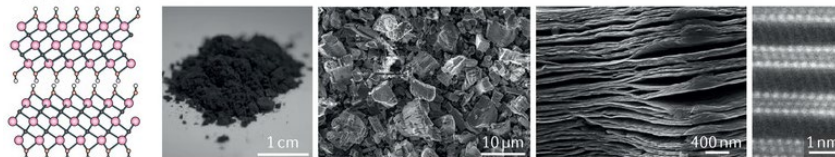
Anasori, B., Gogotsi, Y. MXenes: trends, growth, and future directions. *Graphene and 2D mater* **7**, 75–79 (2022). <https://doi.org/10.1007/s41127-022-00053-z>

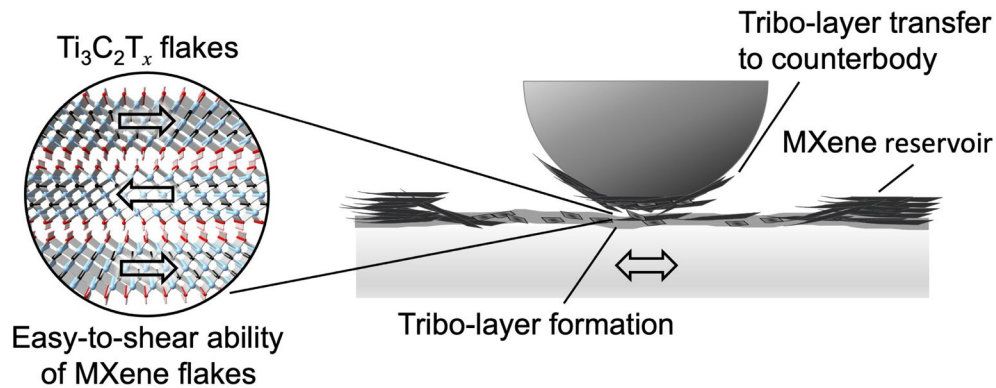
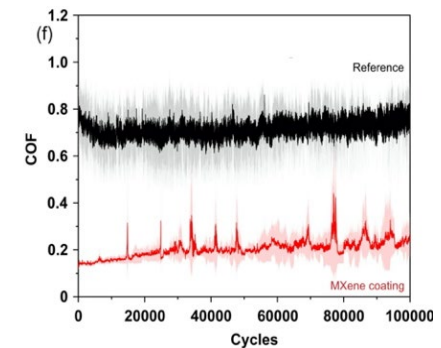
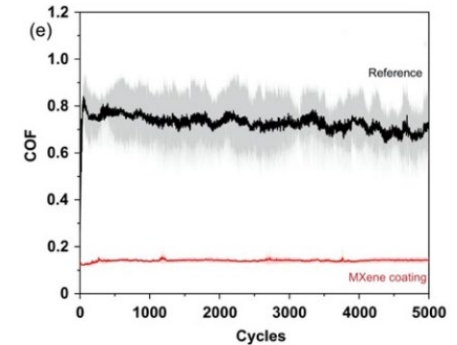
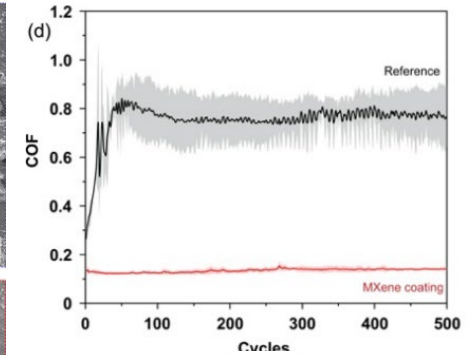
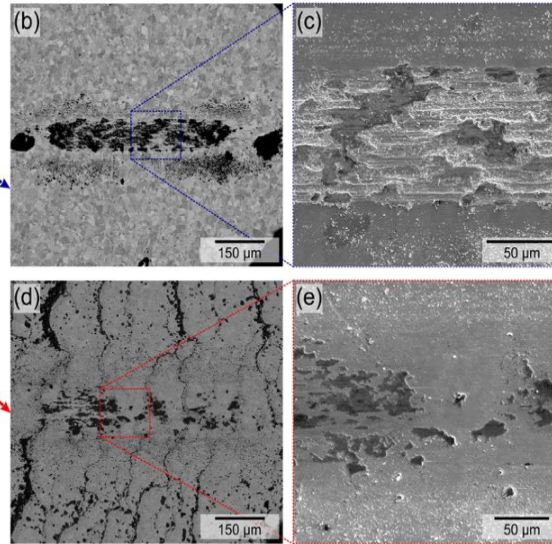
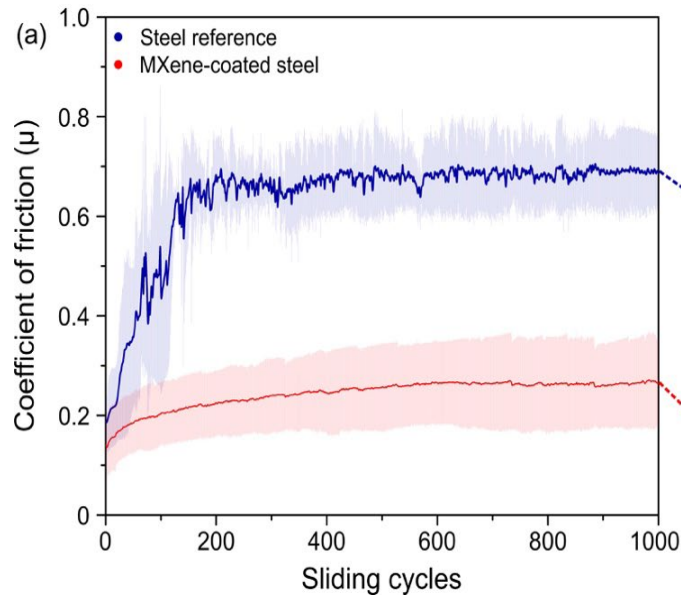


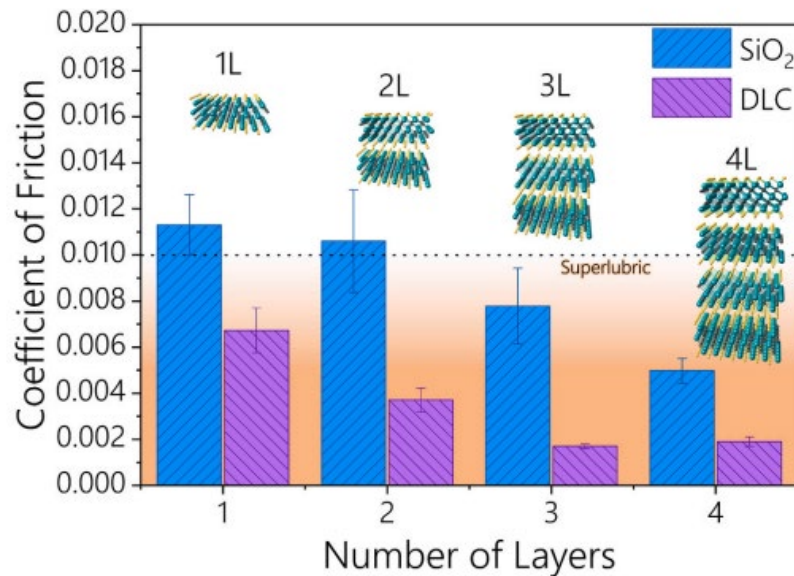
M_3AC_2 powder (precursor)



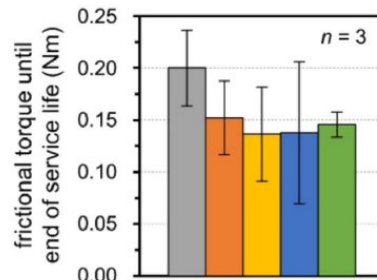
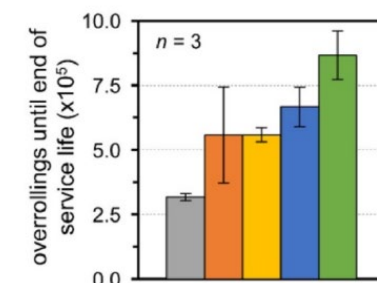
$\text{M}_3\text{C}_2\text{T}_x$ powder (multilayer)



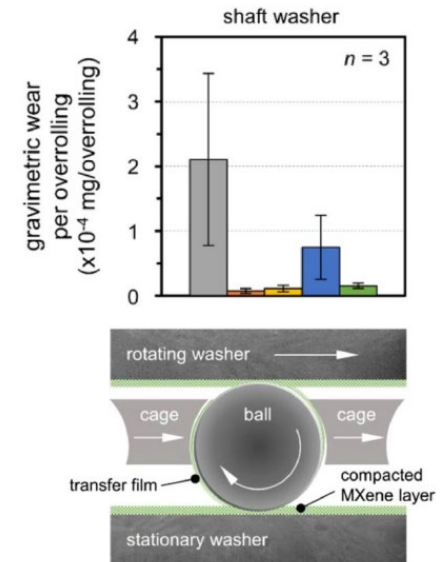




Wait, J., Josephson, G., Wyatt, B. C., Anasori, B., & Çolak, A. (2023). Environmentally stable nanoscale superlubricity of multi-layered Ti₃C₂T_x MXene. **Carbon**, 213, 118284.

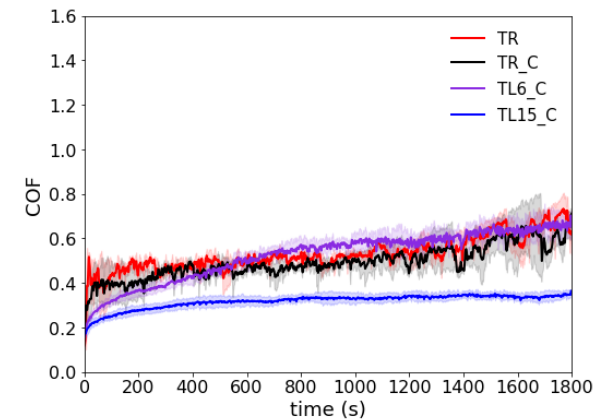
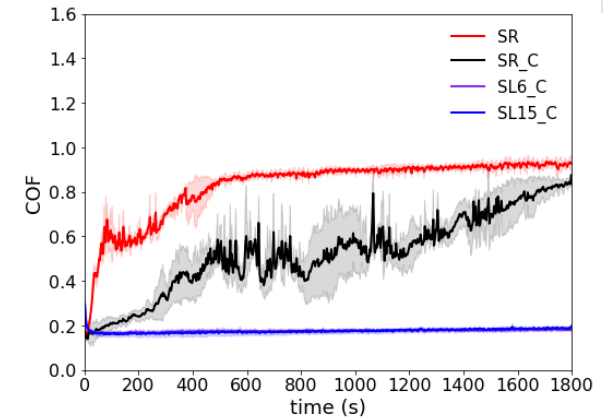
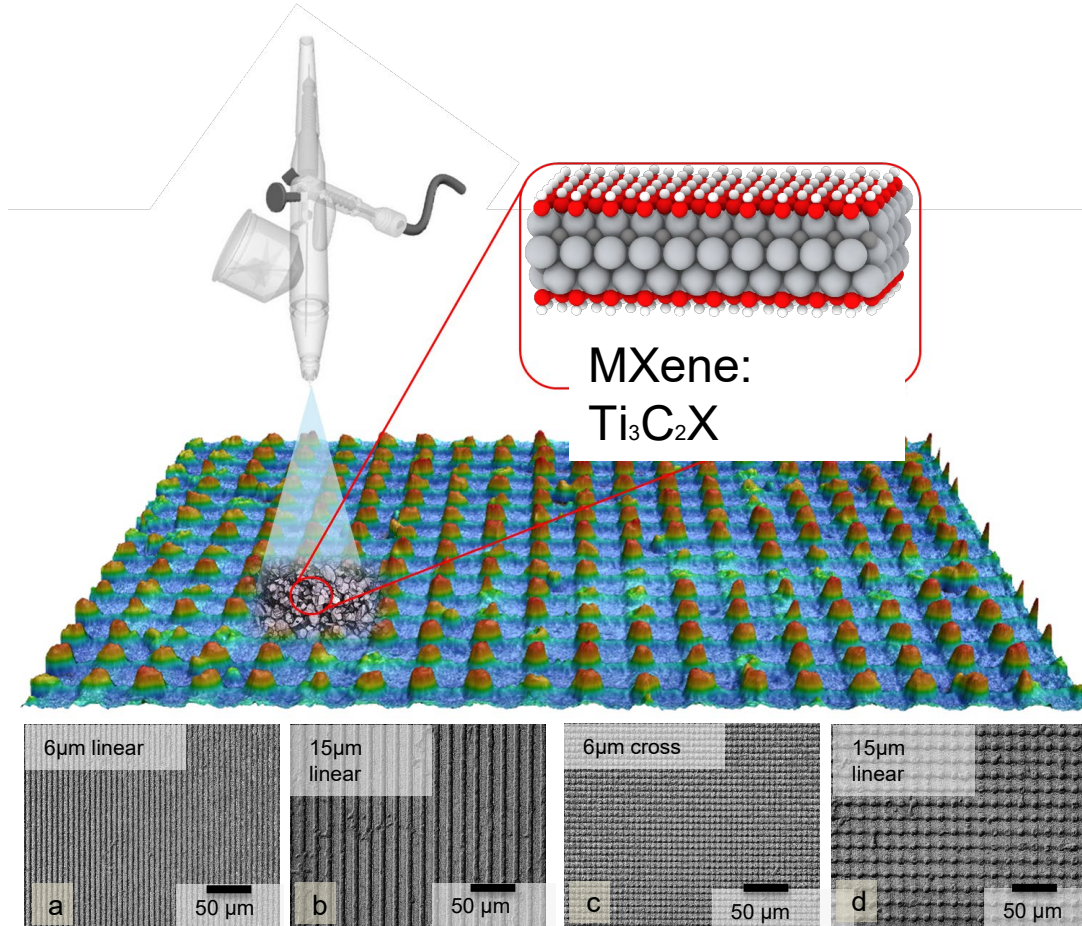


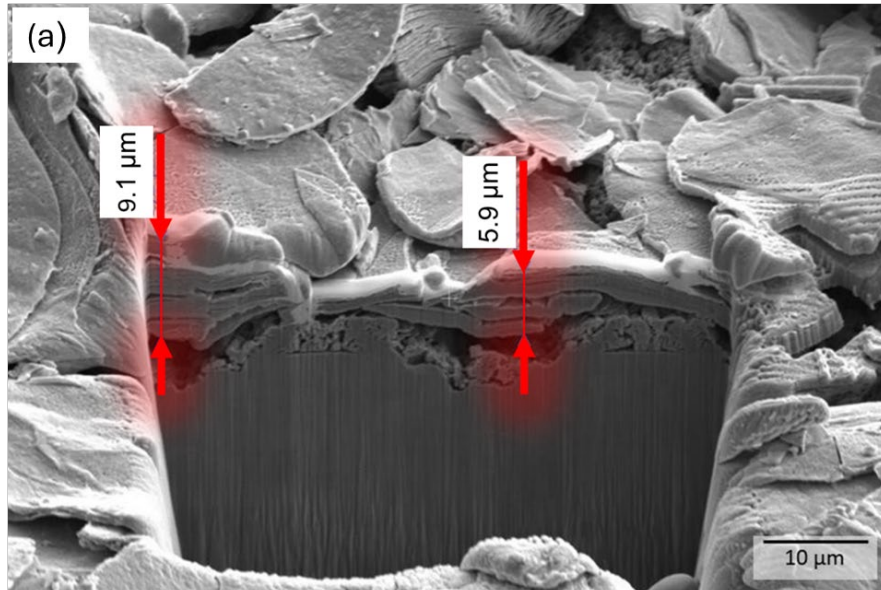
■ uncoated reference ■ MoS₂-coated
 ■ a-C:H:W-coated ■ Ti₃C₂T_x-coated
 ■ a-C-coated



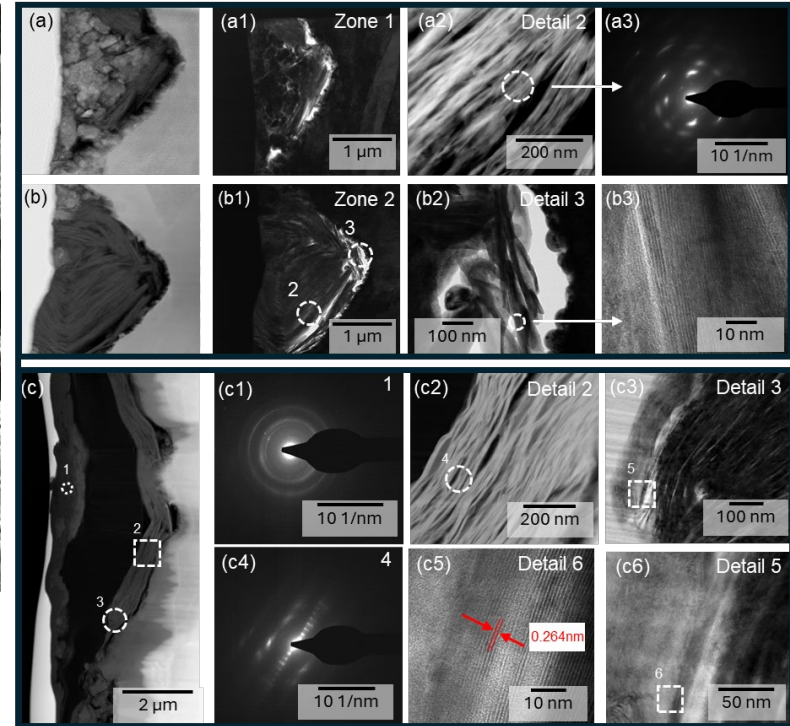
Marian, M. et al. *Appl. Mater. Today* 25, 101202 (2021)

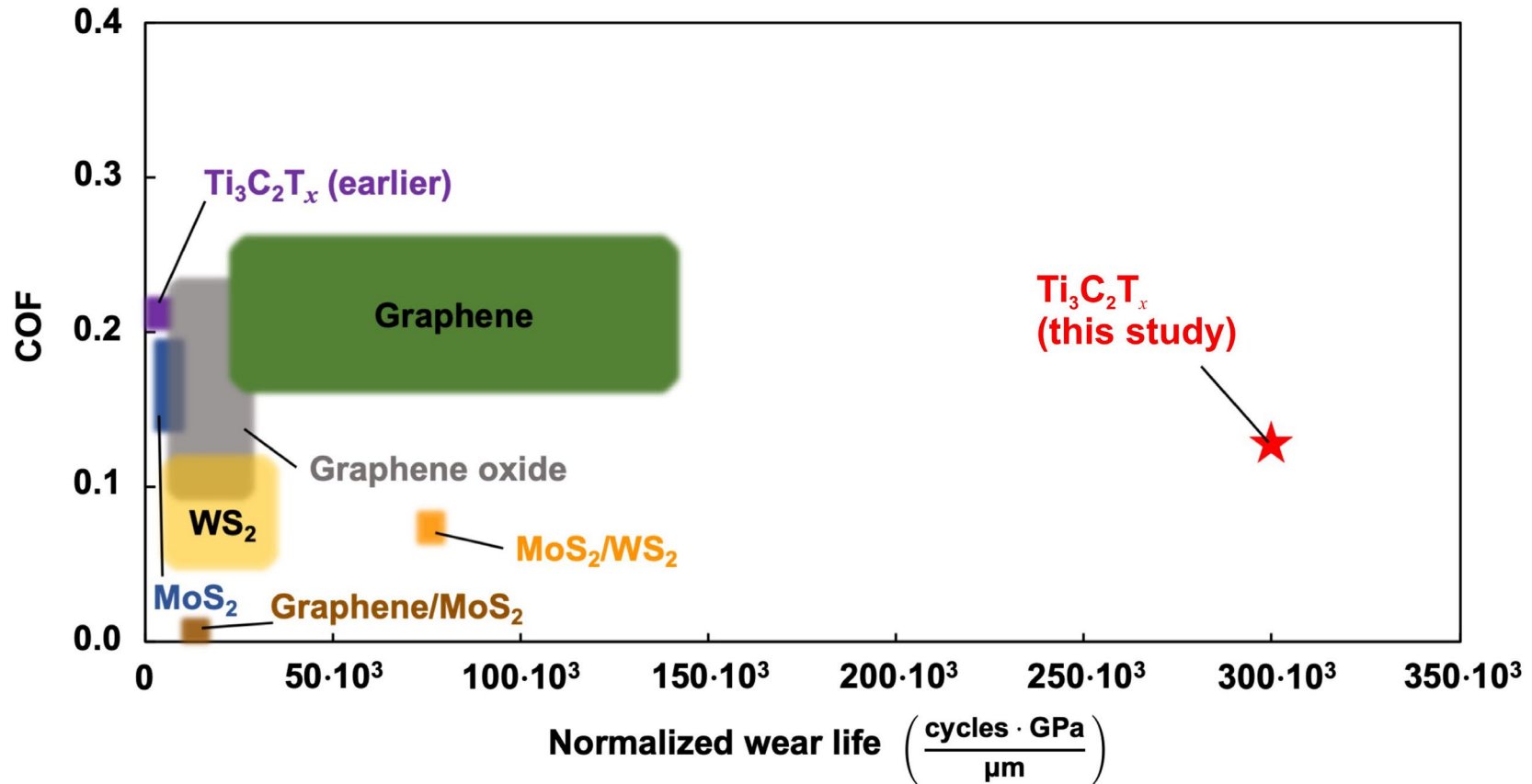
Marian, M., Feile, K., Rothhammer, B., Bartz, M., Wartzack, S., Seynstahl, A., ... & Rosenkranz, A. (2021). Ti₃C₂T_x solid lubricant coatings in rolling bearings with remarkable performance beyond state-of-the-art materials. **Applied Materials Today**, 25, 101202.





=> MXene flakes replicate well the laser textures and can be found in recessions of the textures!



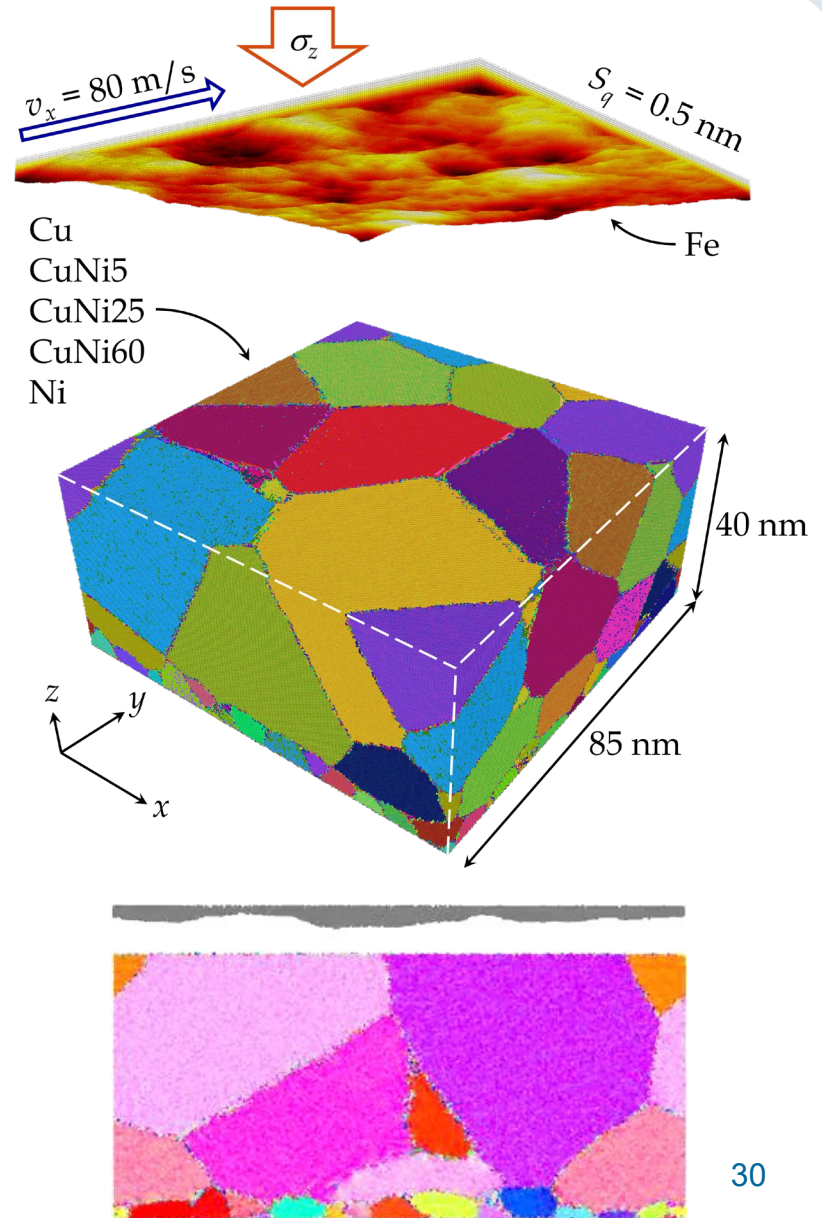




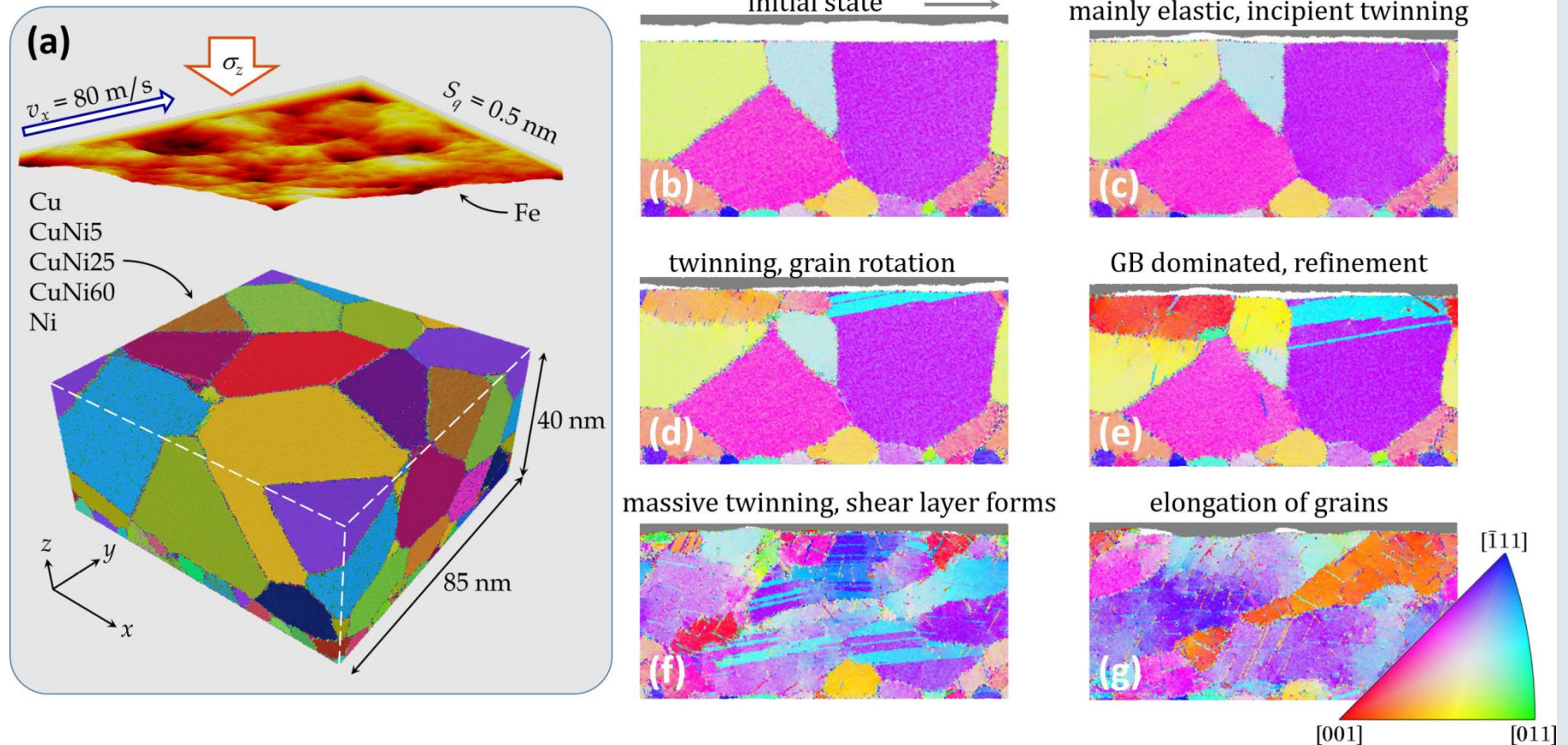
IV. Computational Materials Tribology



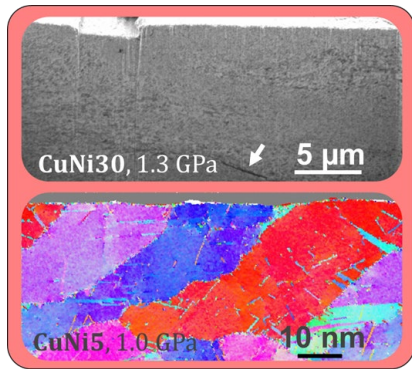
- Polycrystalline MD model of CuNi alloys with 25 Mio atoms
- Mean grain size: 40 nm → plasticity not dominated by grain boundary sliding
- Rough rigid counterbody
- 5-8 normal pressures / composition
- ~ 8 million core hours



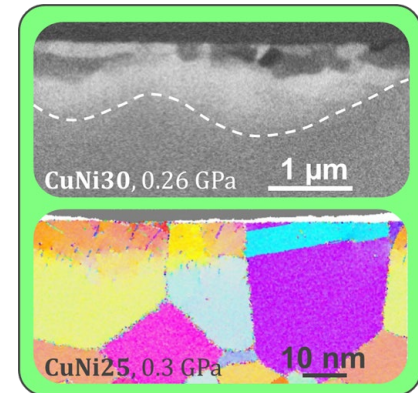
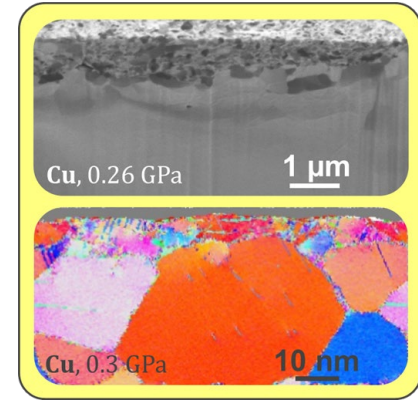
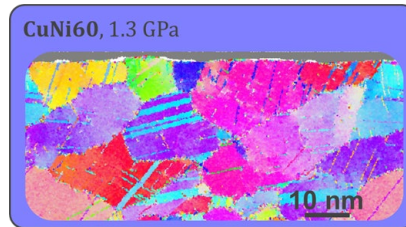
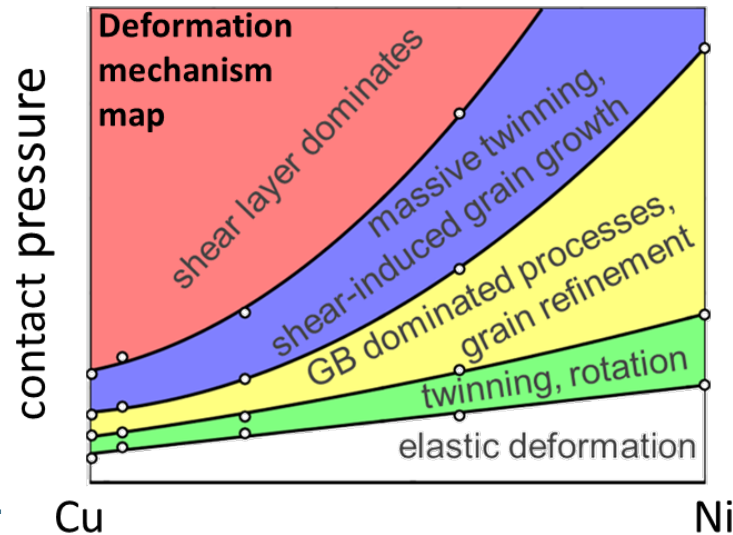
Getting a deeper understanding of the materials' microstructure!



Deformation mechanism map - Experimental validation attempt



That's nice, but it's all for room temperature...



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2D MaT

2D Materials in Tribology