Karlsruher Institut für Technologie

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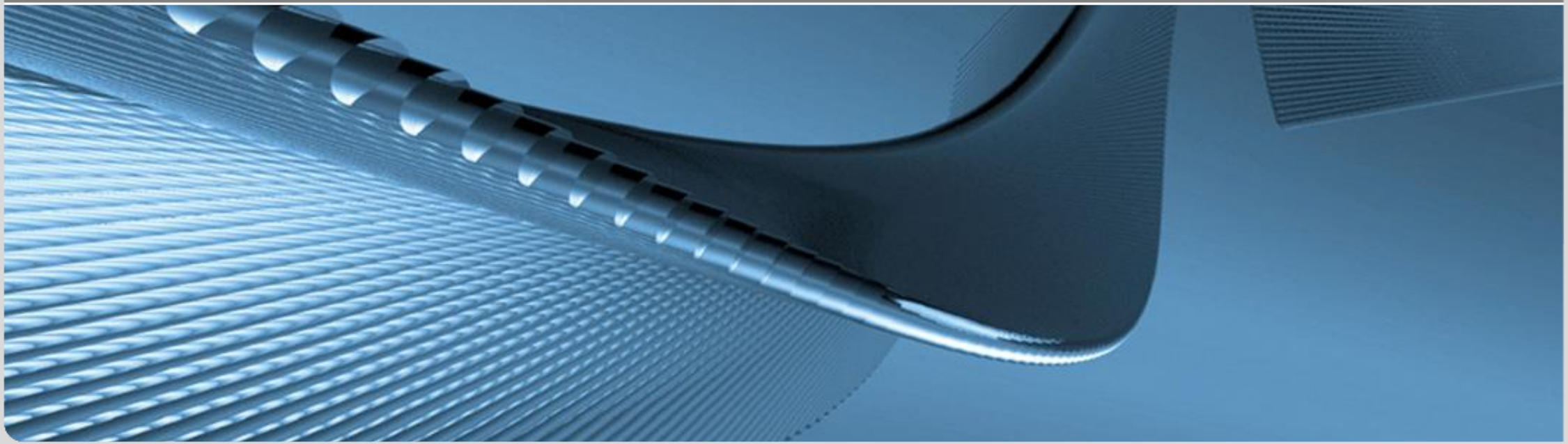
UNIVERSITY OF OXFORD

Fracture behavior of tungsten materials and the impact on the divertor design in nuclear fusion power plants

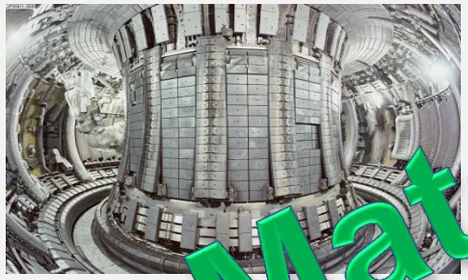
M. Rieth, A. Hoffmann, J. Reiser, D.E.J. Armstrong

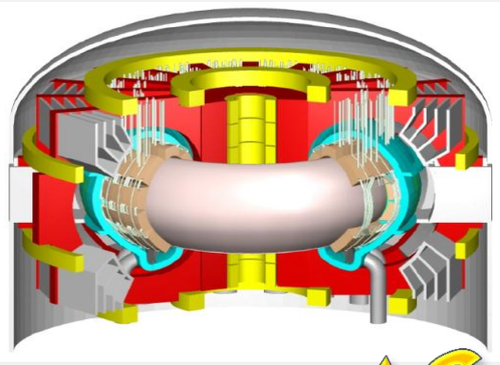
INSTITUTE FOR MATERIALS RESEARCH



Components and Applications

fusion devices:





ASDEX-U JET ITER DEMO

Standard Materials

heat removal:

passively cooled PFCs

actively cooled PFCs

water helium liquid metal

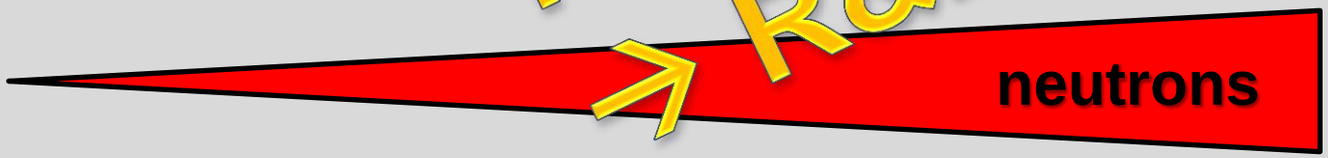
New Concepts

New Materials

tritium fuel:

- increased T inventory
- n-induced material degradation

R&D

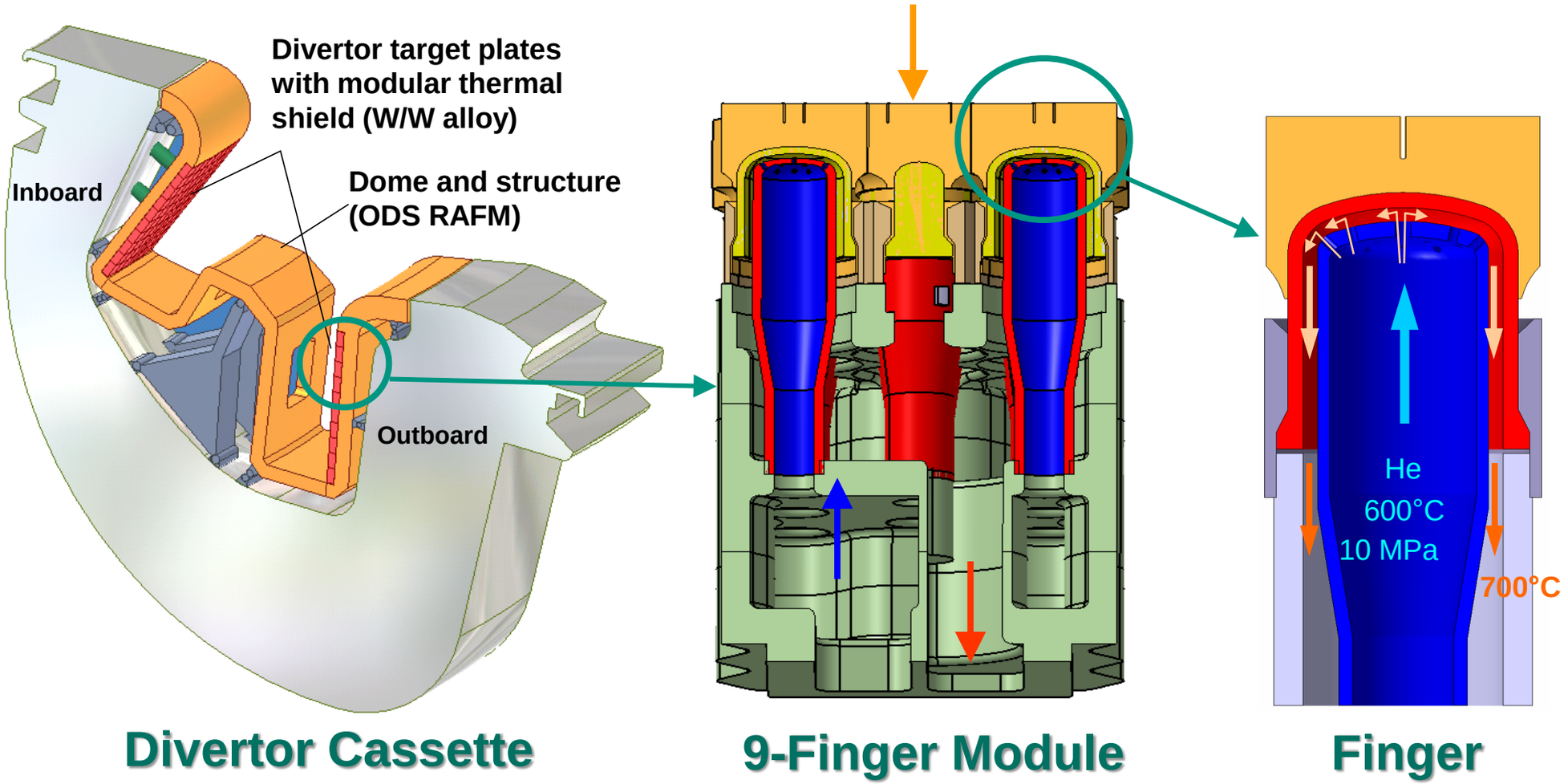


life time fluence:

0 dpa 10^{-9} dpa 1 dpa 100 dpa

He-cooled Divertor Concepts

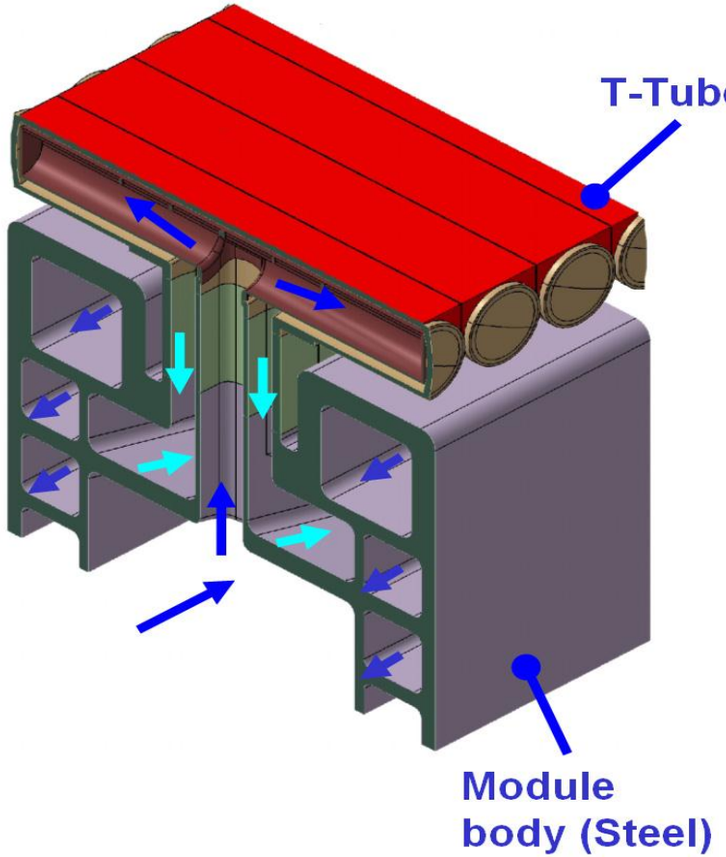
Current Case Study: Possible heat flux up to 15 MW/m²

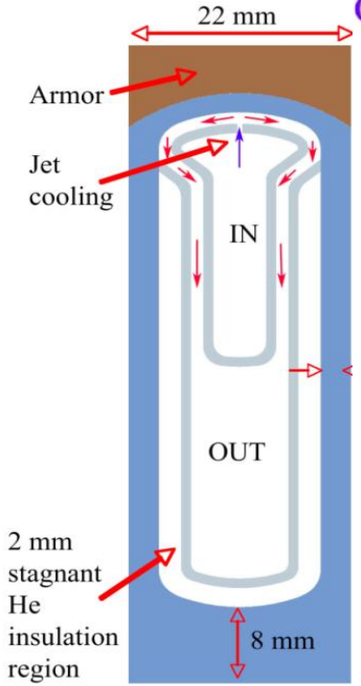


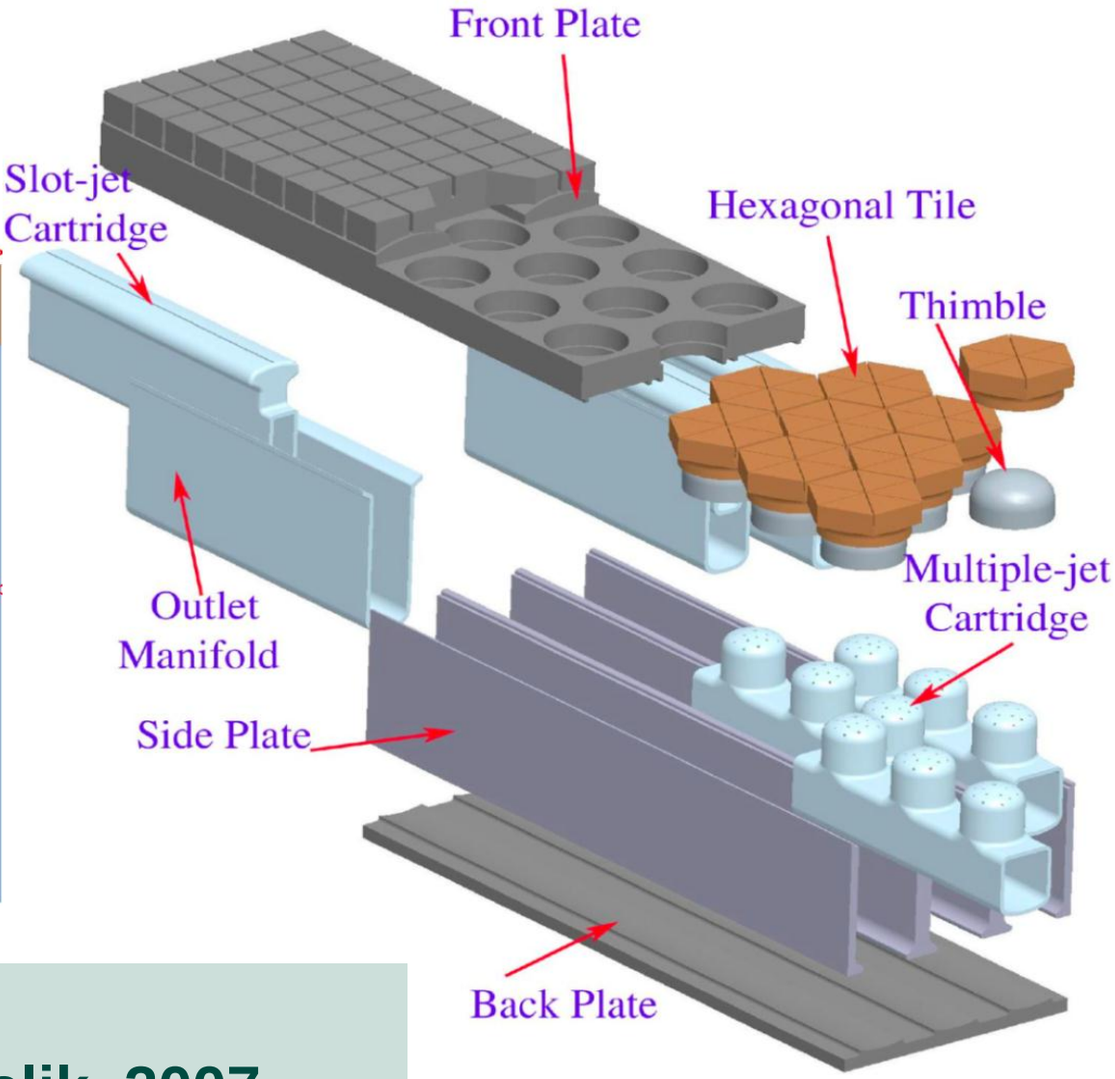
Divertor Cassette **9-Finger Module** **Finger**

P. Norajitra *et al.*, KIT, 2003-2010

Divertor Concepts, 5-10 MW/m²

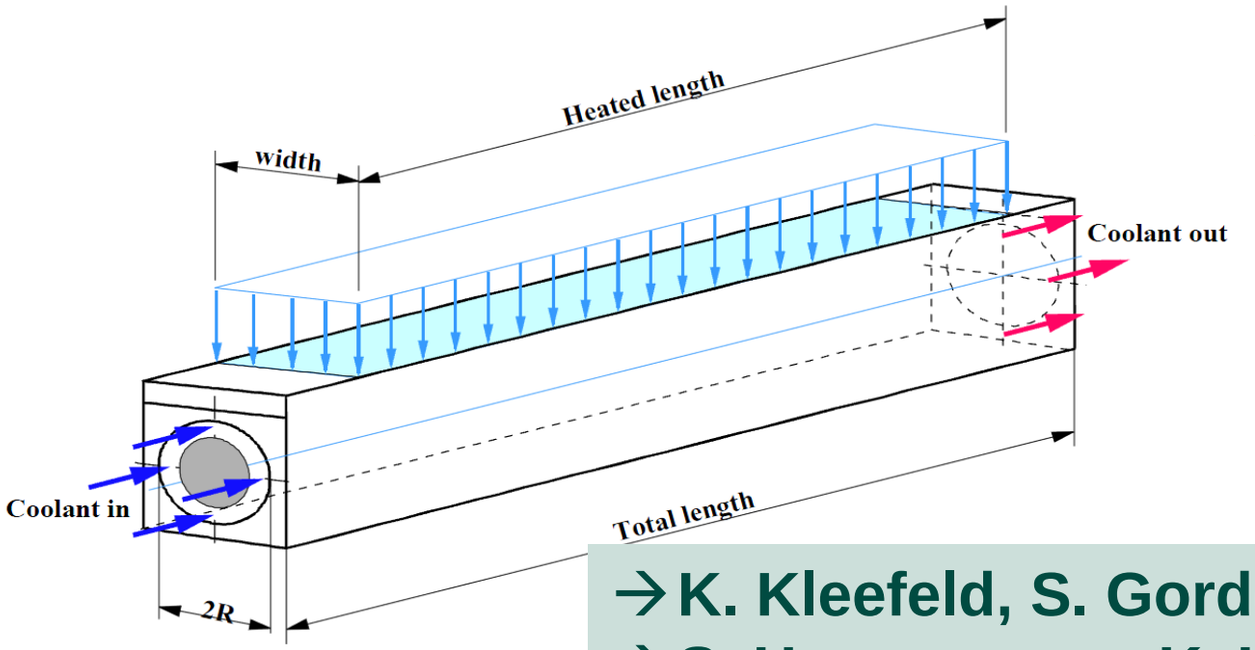


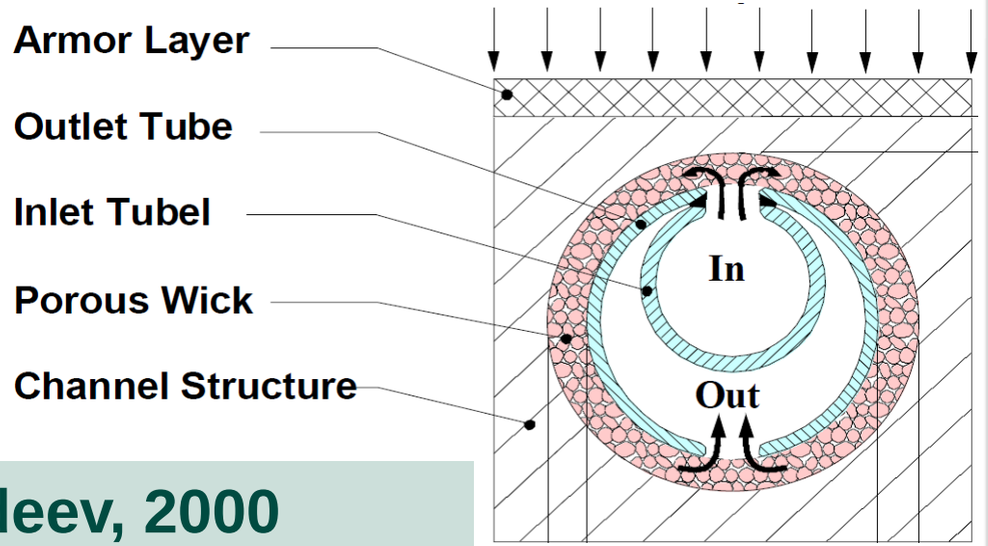




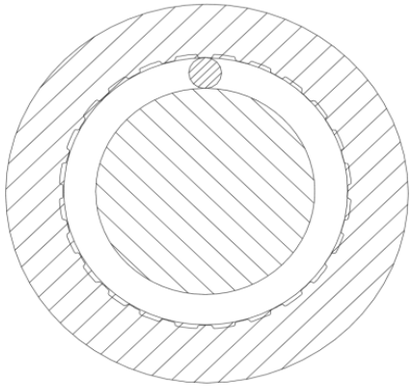
→ S. Hermsmeyer, S. Malang, 2002
→ T. Ihli, A. R. Raffrey, S. I. Abdel-Khalik, 2007
→ A. R. Raffrey, S. Malang et al., 2008

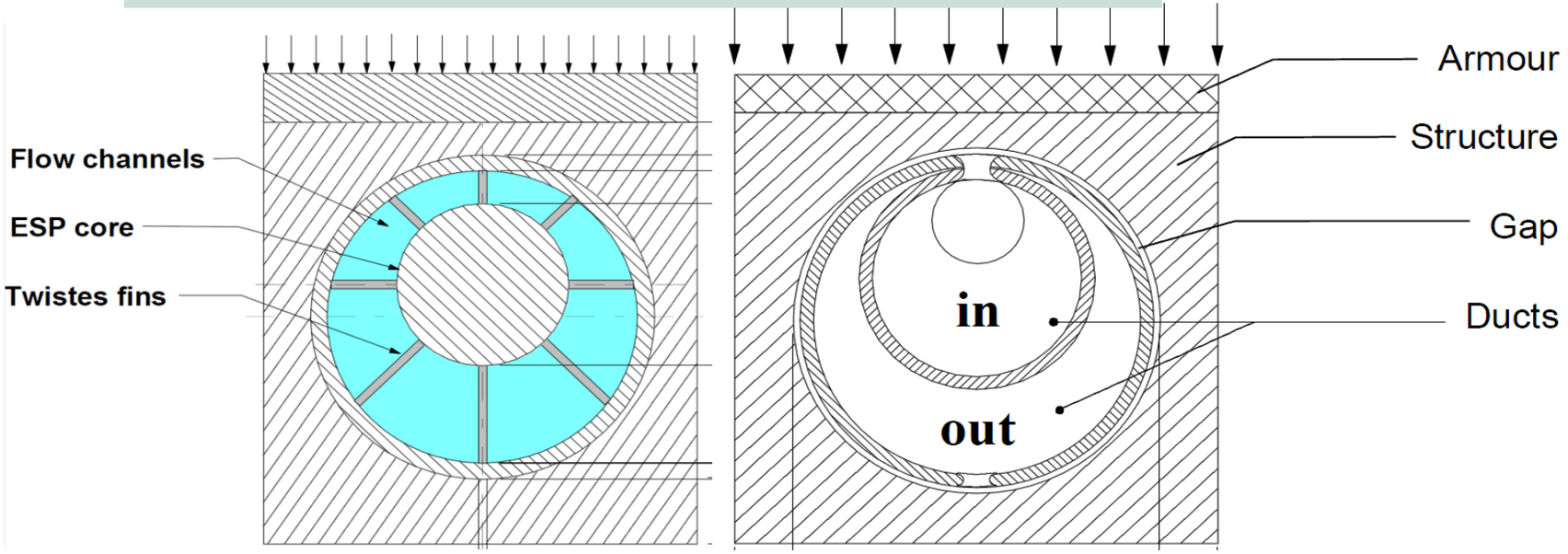
Divertor Concepts, 5 MW/m²



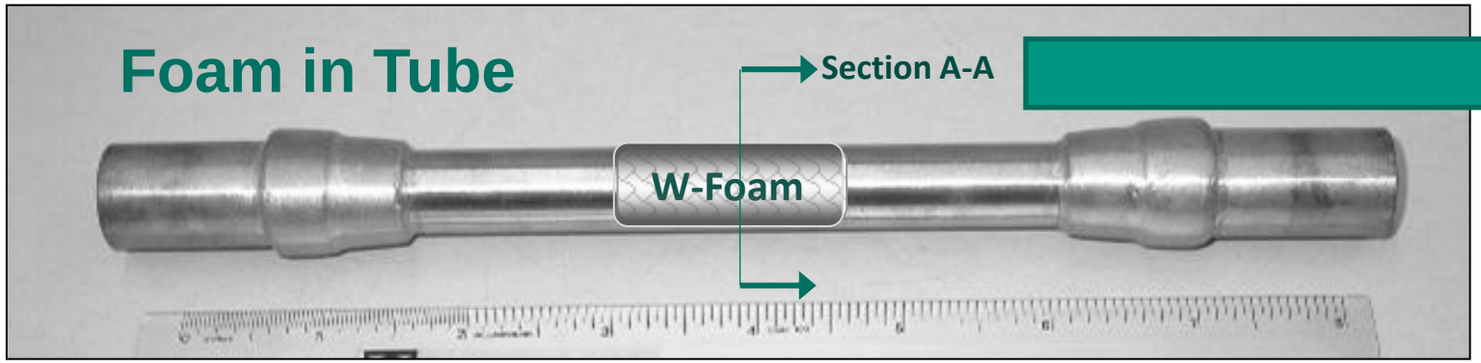


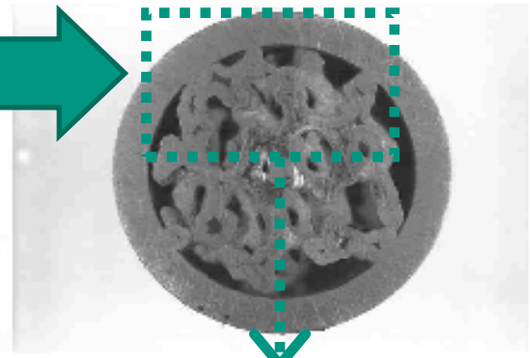
→K. Kleefeld, S. Gordeev, 2000
→S. Hermsmeyer, K. Kleefeld, 2001

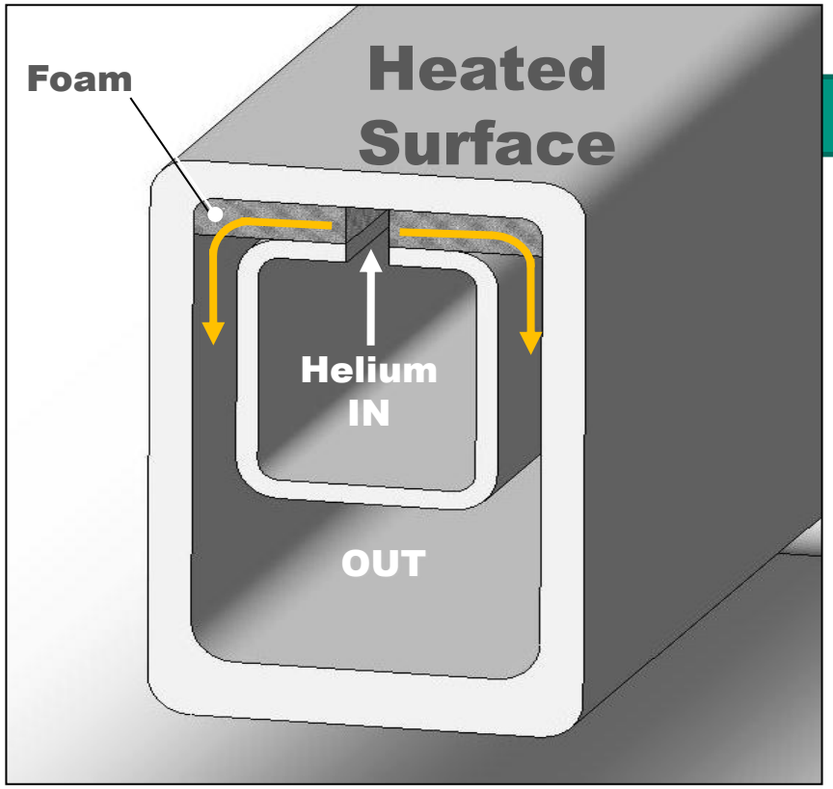


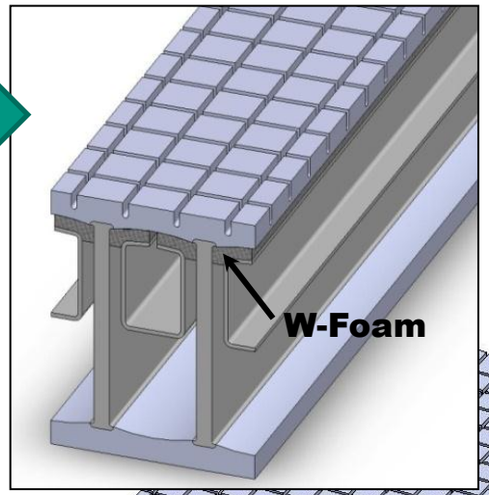


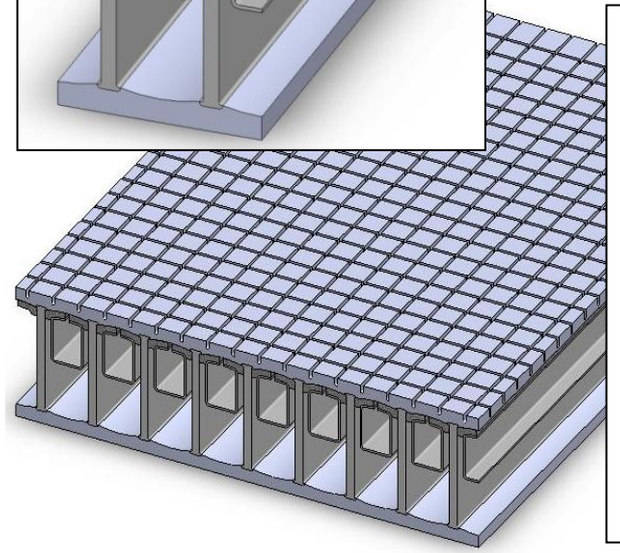
Divertor Concepts, 10 MW/m²

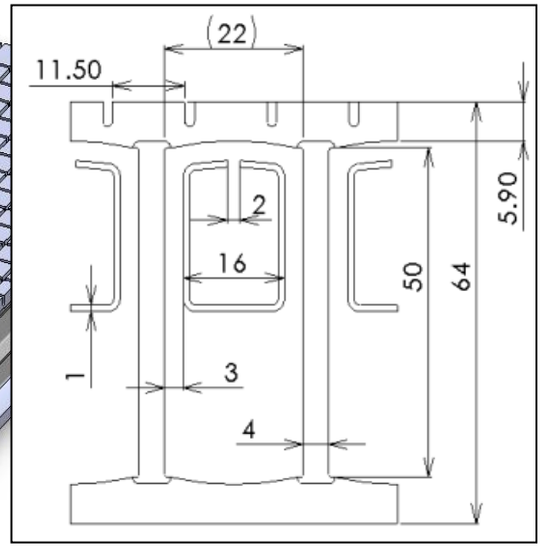












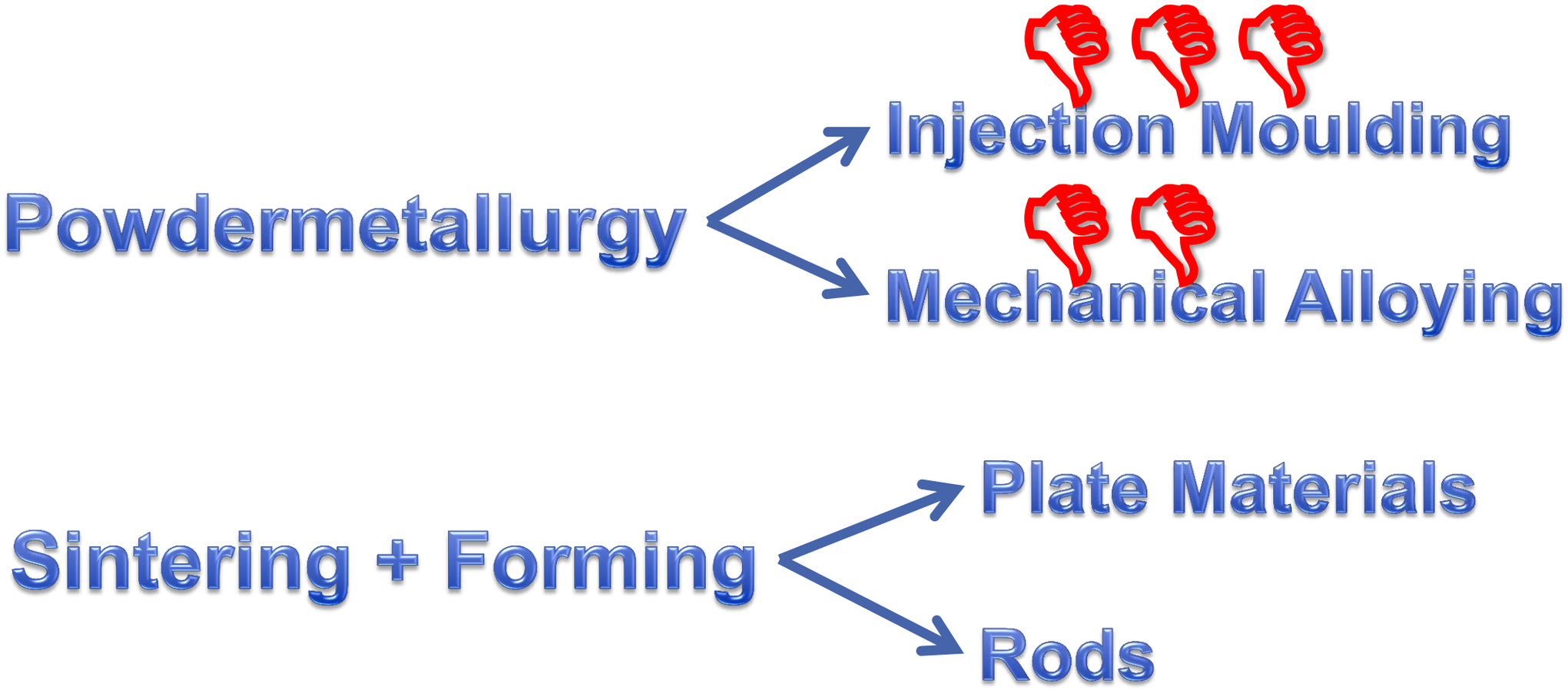
→ S. Sharafat *et al.*, 2005-2009

Conclusion for ALL Helium Cooled Divertor Concepts

The main divertor part is a pipe-like structure (with open or closed ends) with different cross-sections (rectangular or round) on which the armour can be attached.

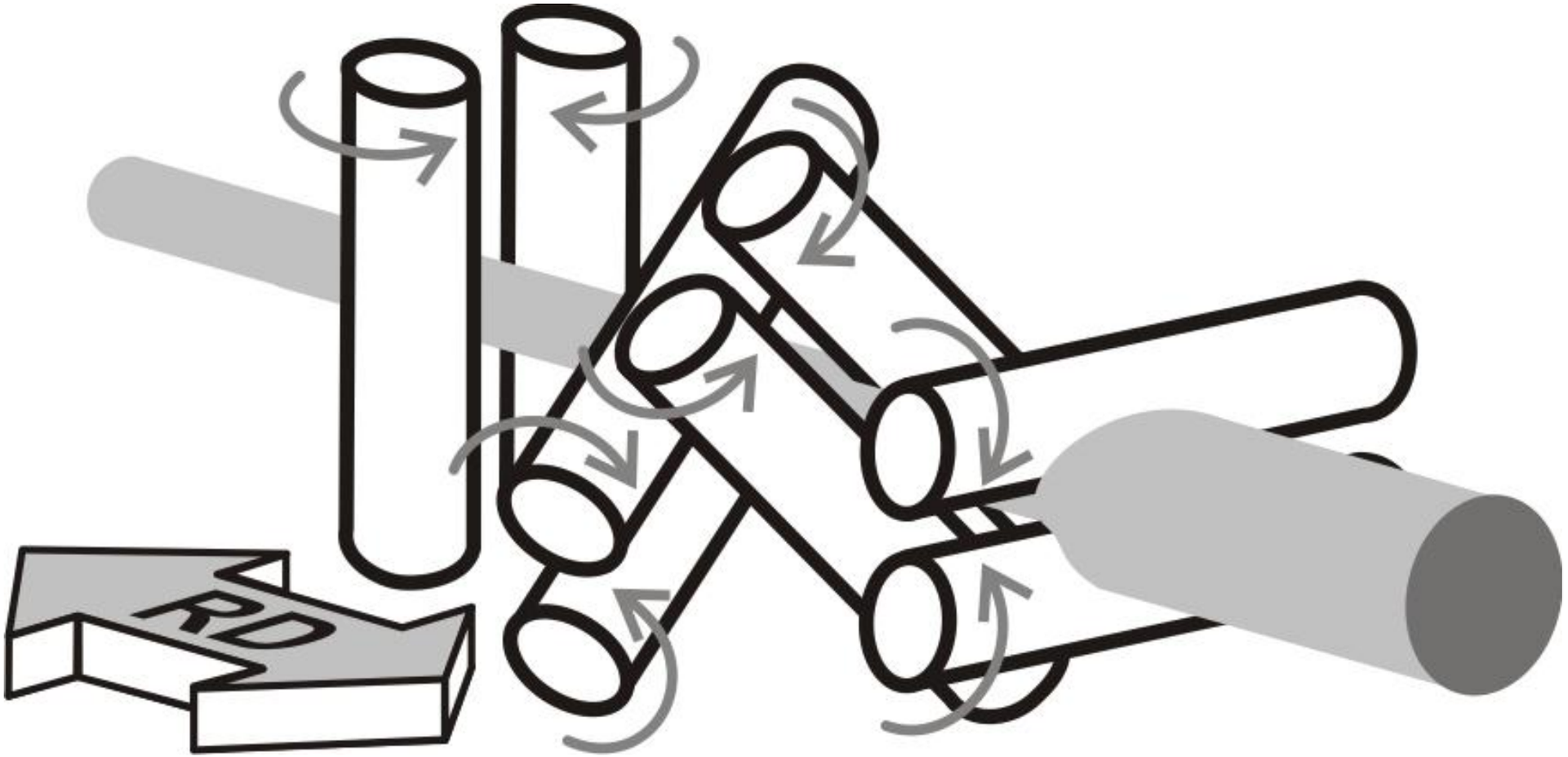
Main Question for Structural Divertor Materials

How to fabricate pipe-like structures?



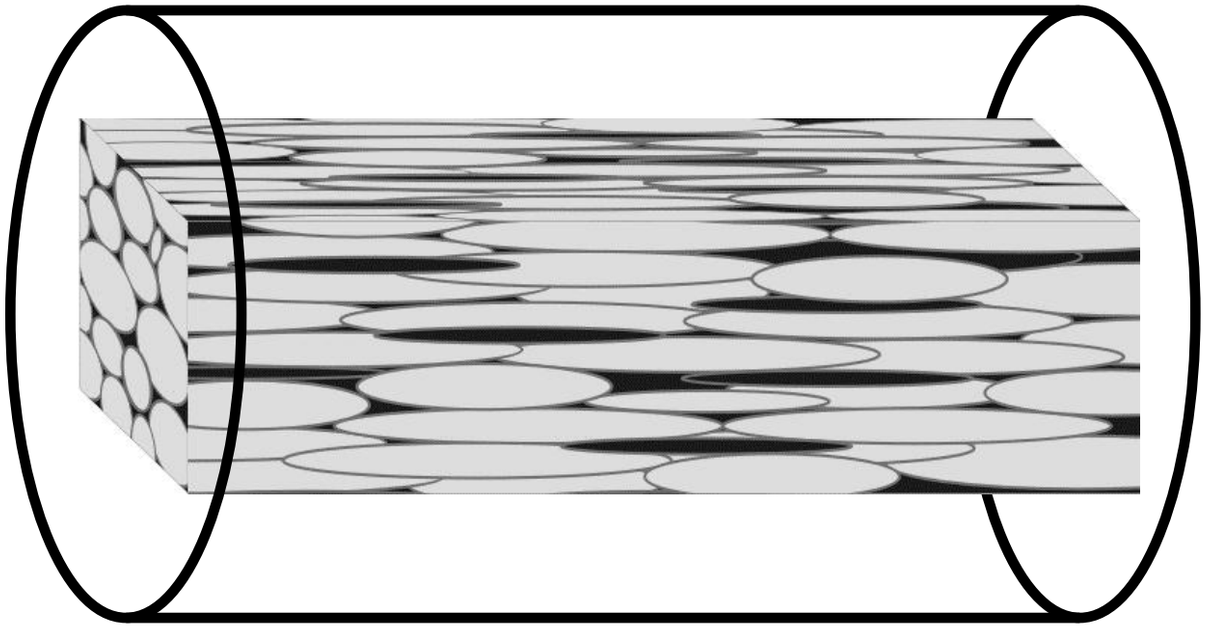
Half-finished Products

Rolling (or Swagging) of Rods

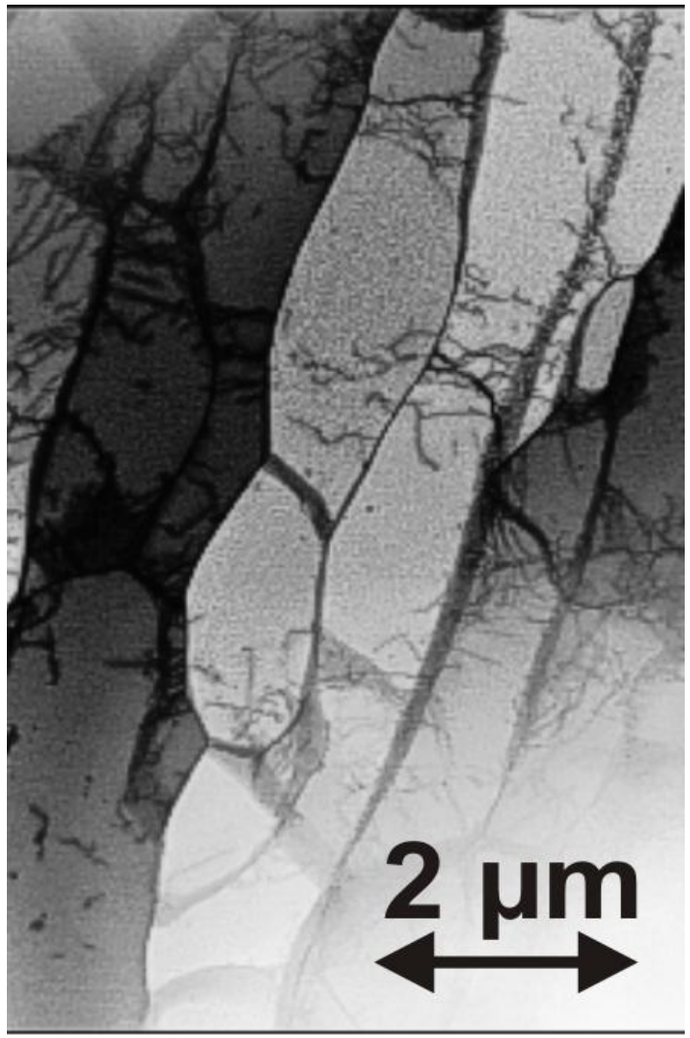


Microstructure Anisotropy

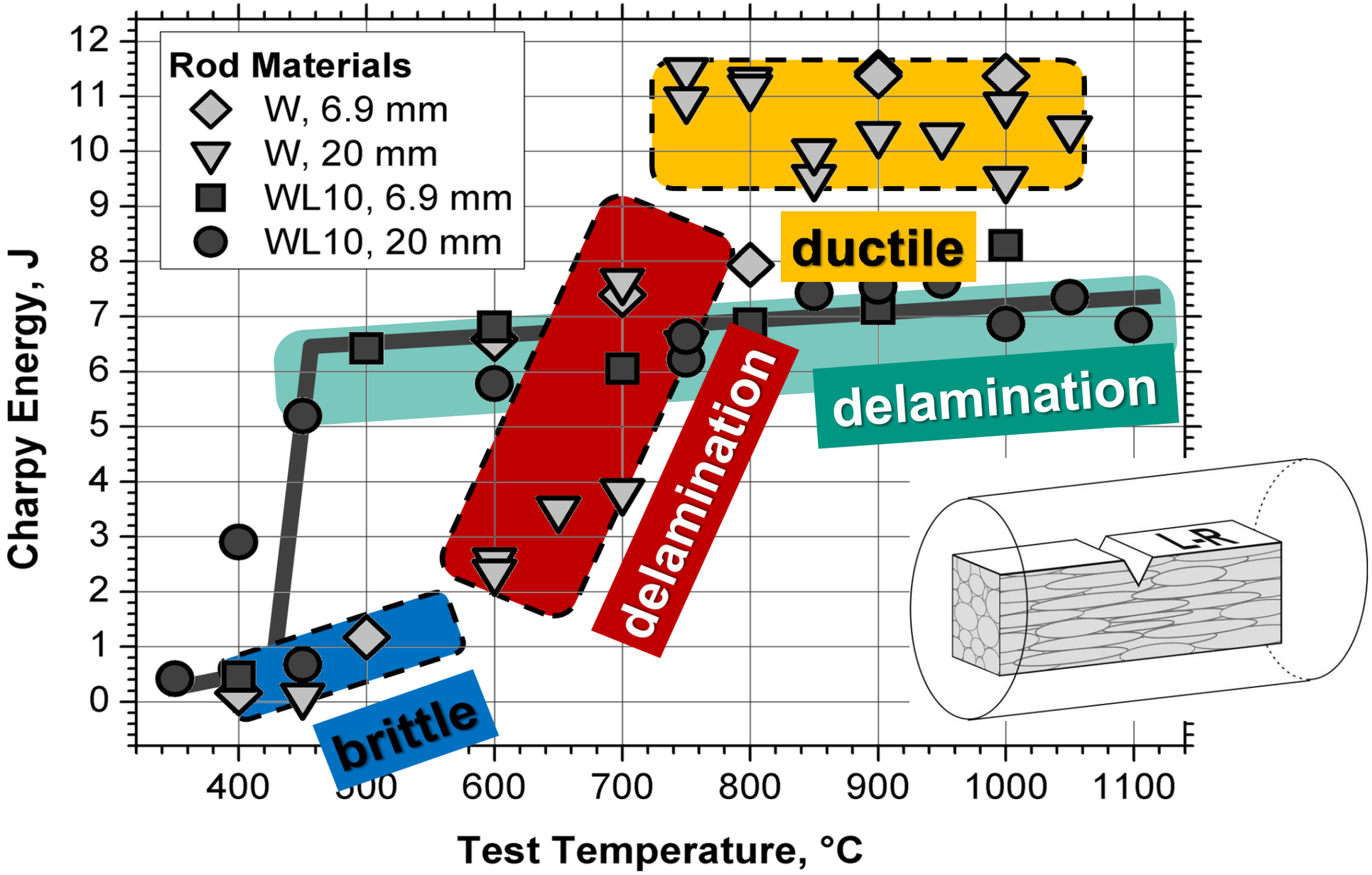
Rods



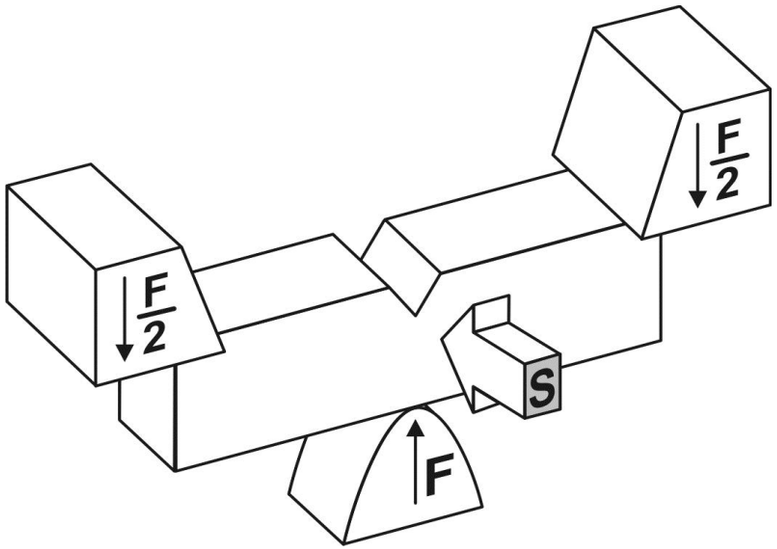
Bundle of „Fibres“

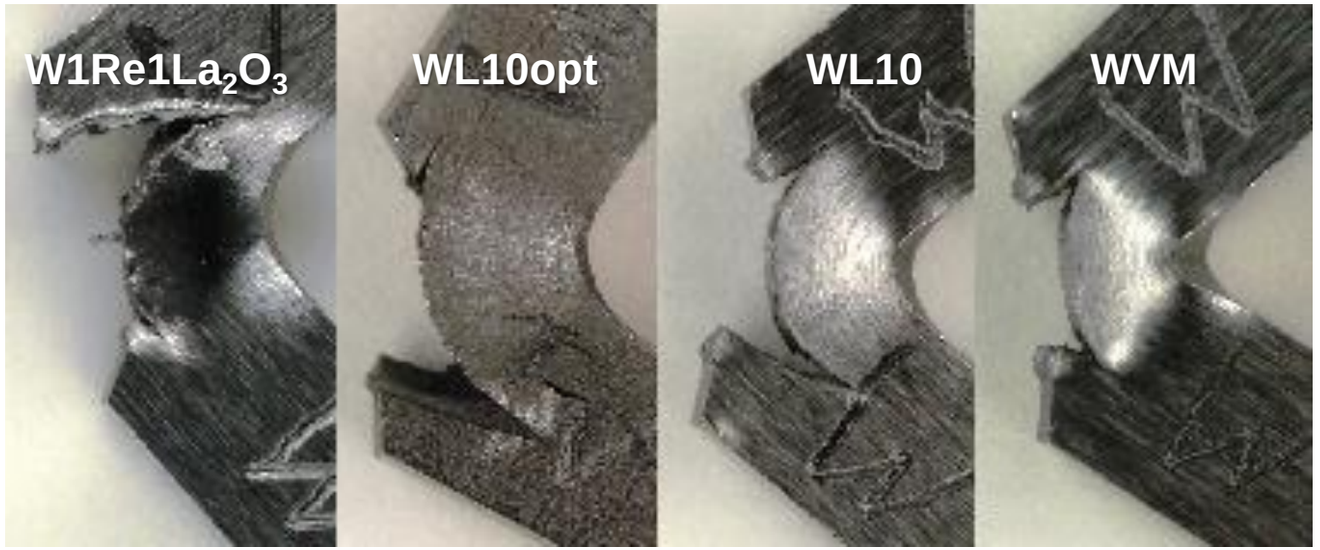


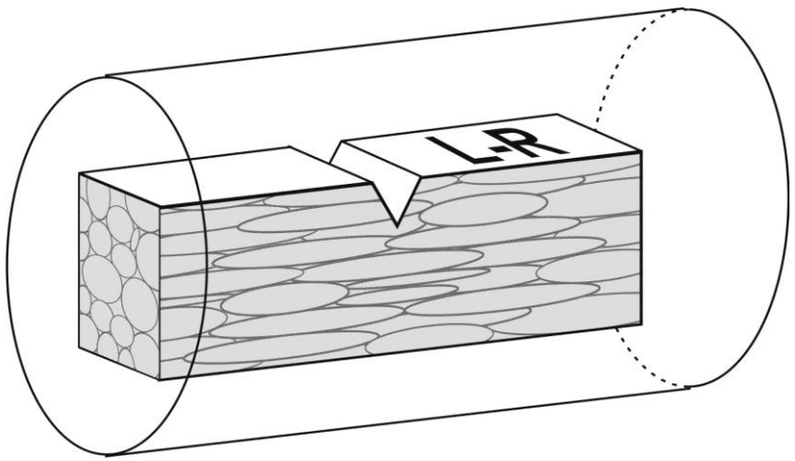
Rods: Fracture Characteristics

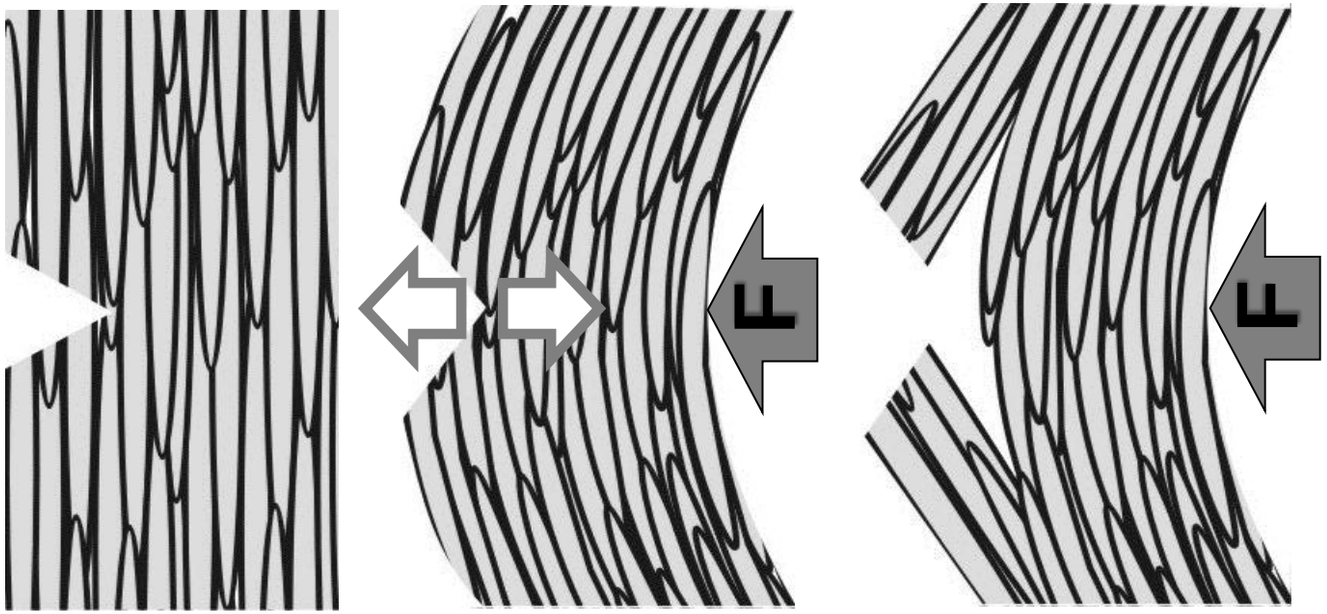


Delamination Fracture in Rods



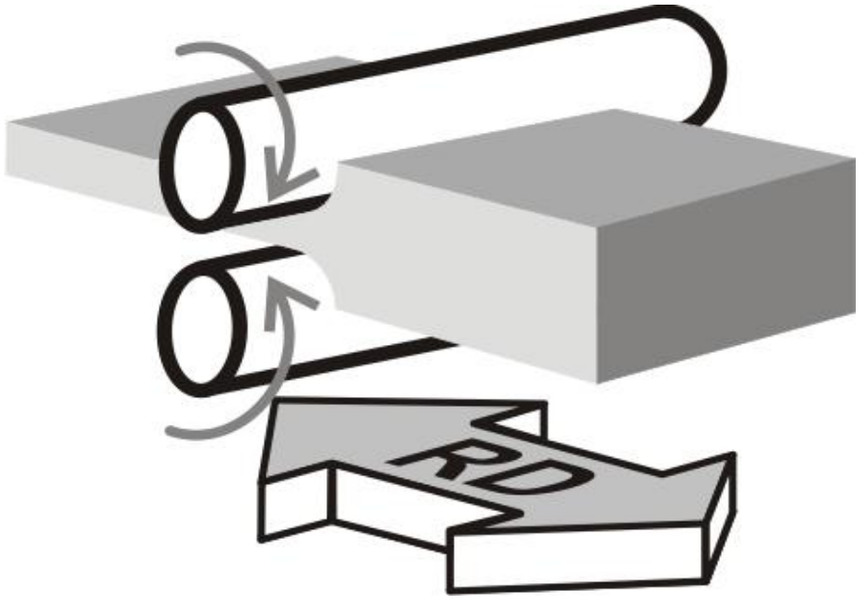




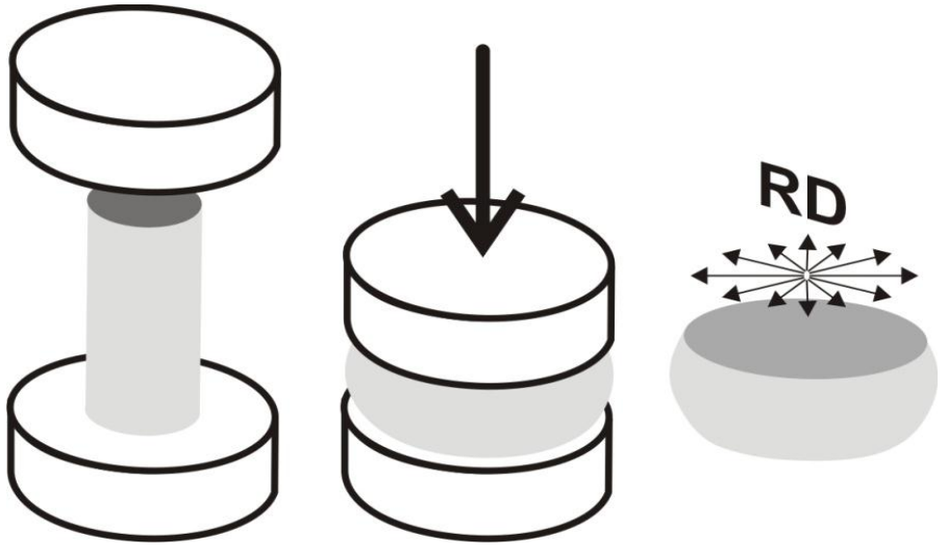


Half-finished Products

Rolling of Plates

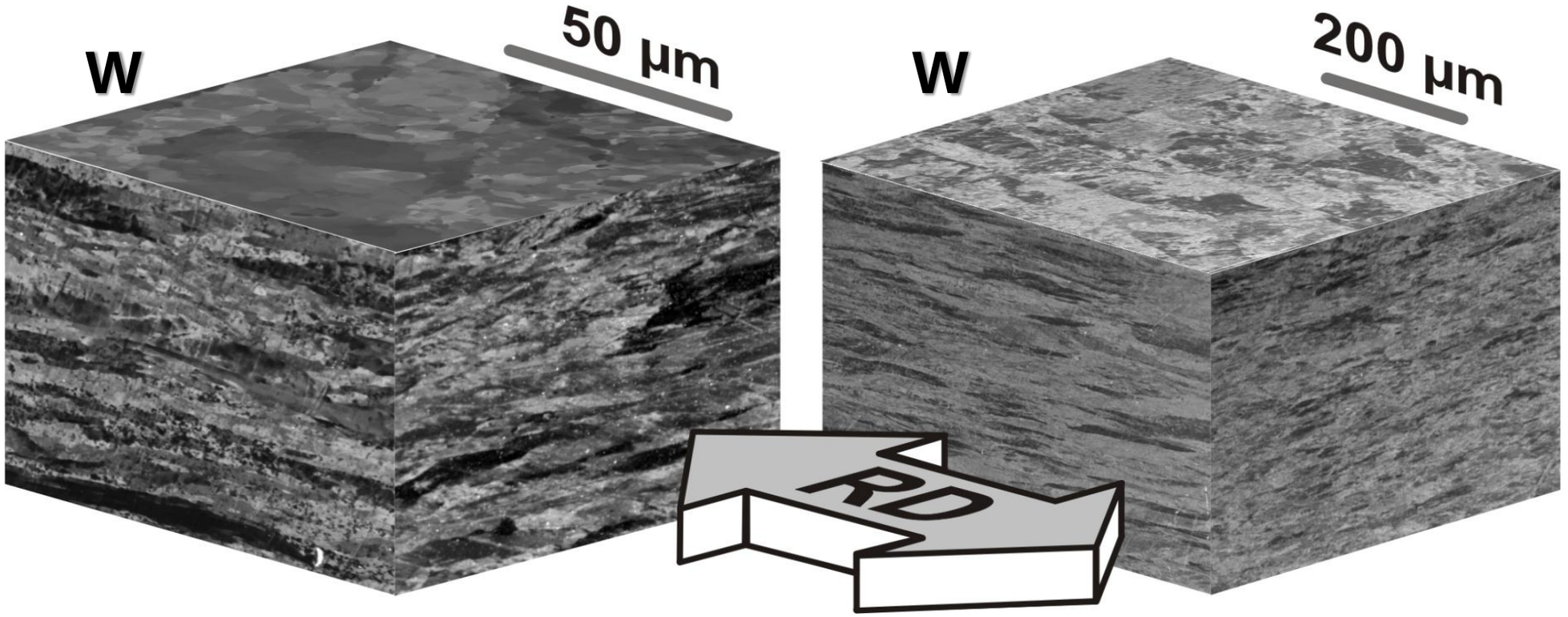


Forging of Round Blanks



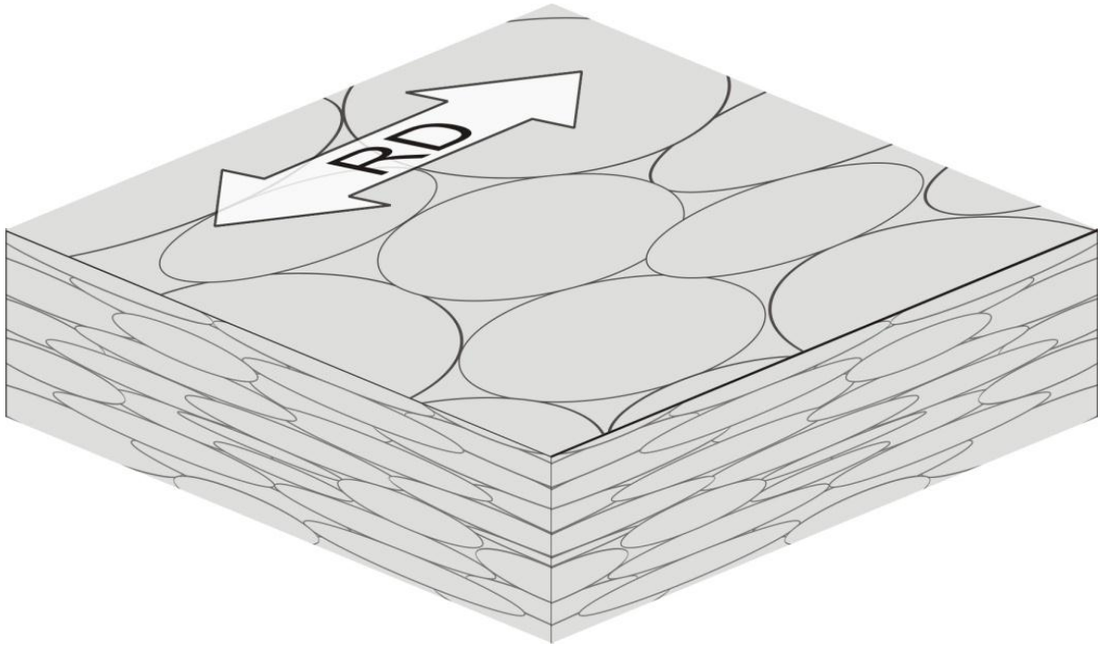
Microstructure Anisotropy

Plates: SEM / FIB channeling effect

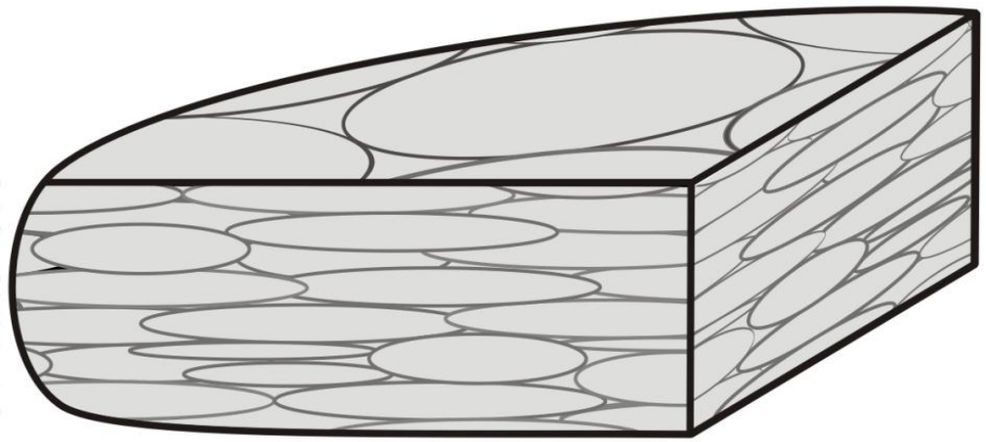


Microstructure Anisotropy

Plates

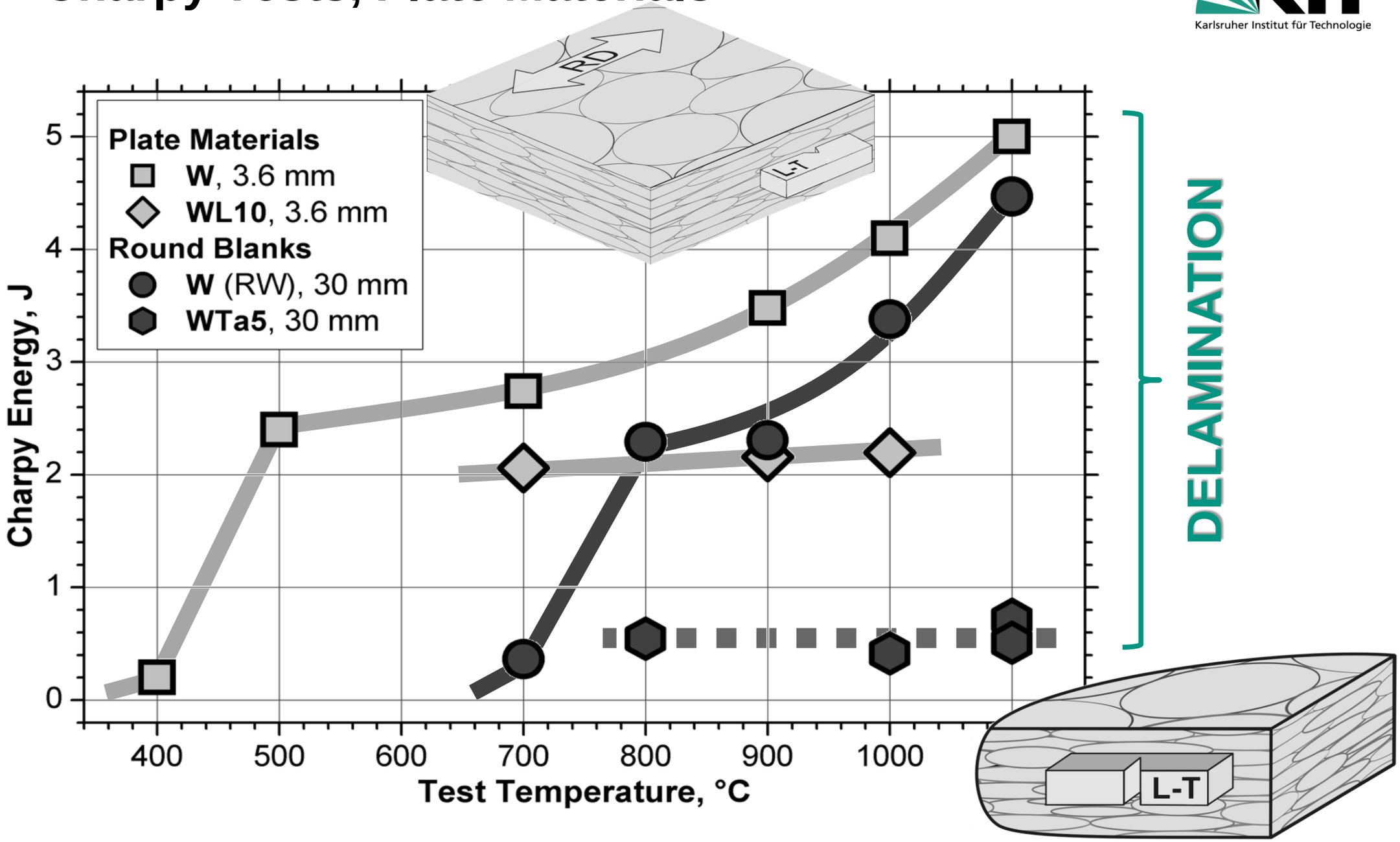


Round Blanks

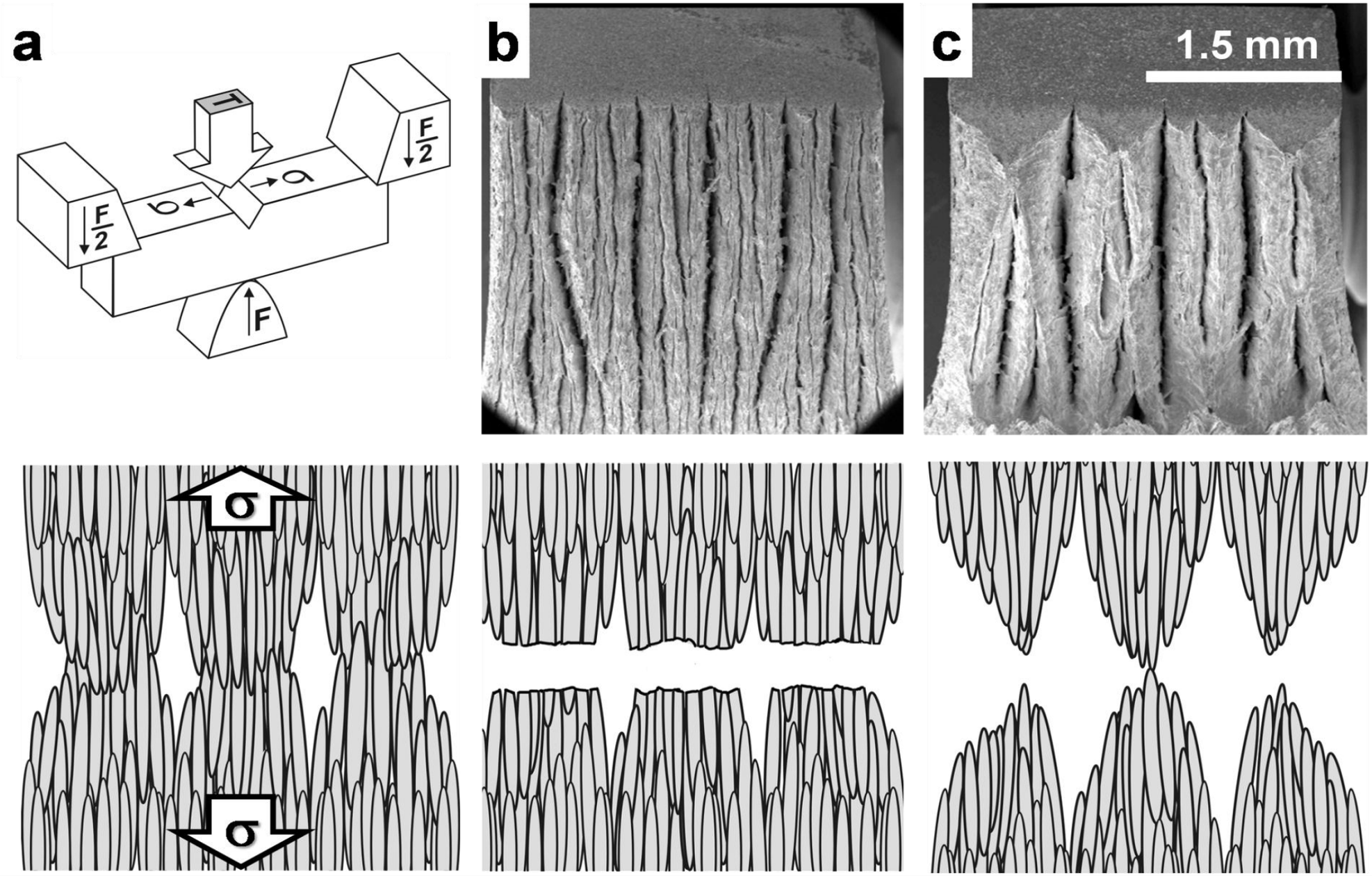


Stack of „Pancakes“

Charpy Tests, Plate Materials

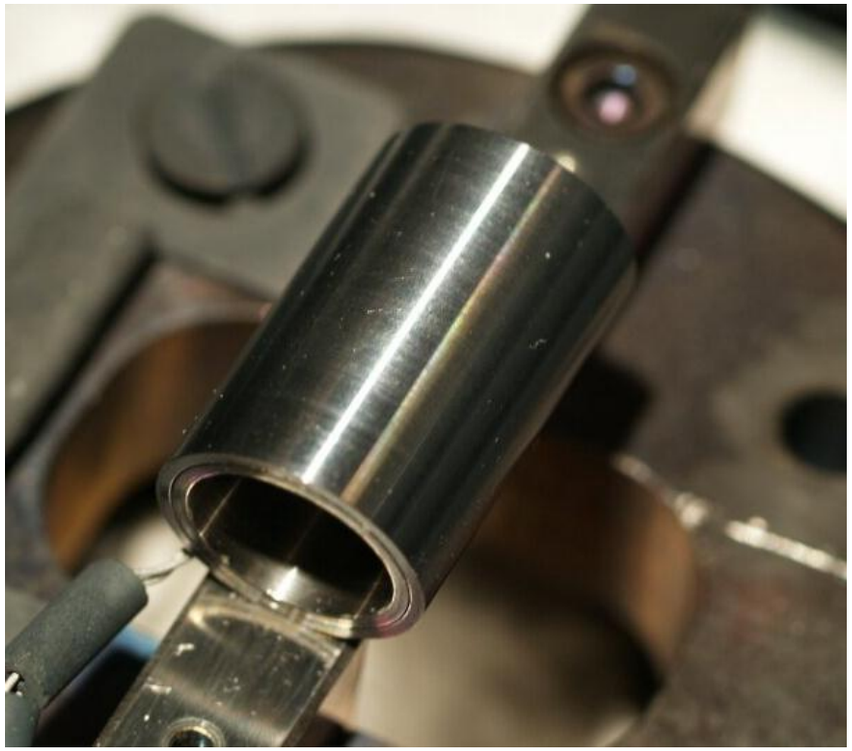


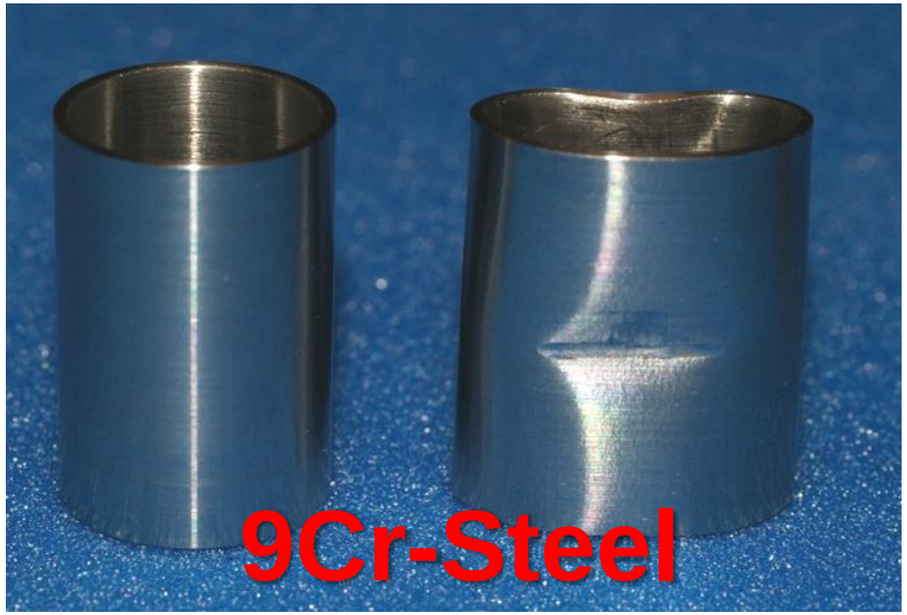
Delamination Fracture in Plates



Pipe Fabrication of Rods

Pipe Impact Test



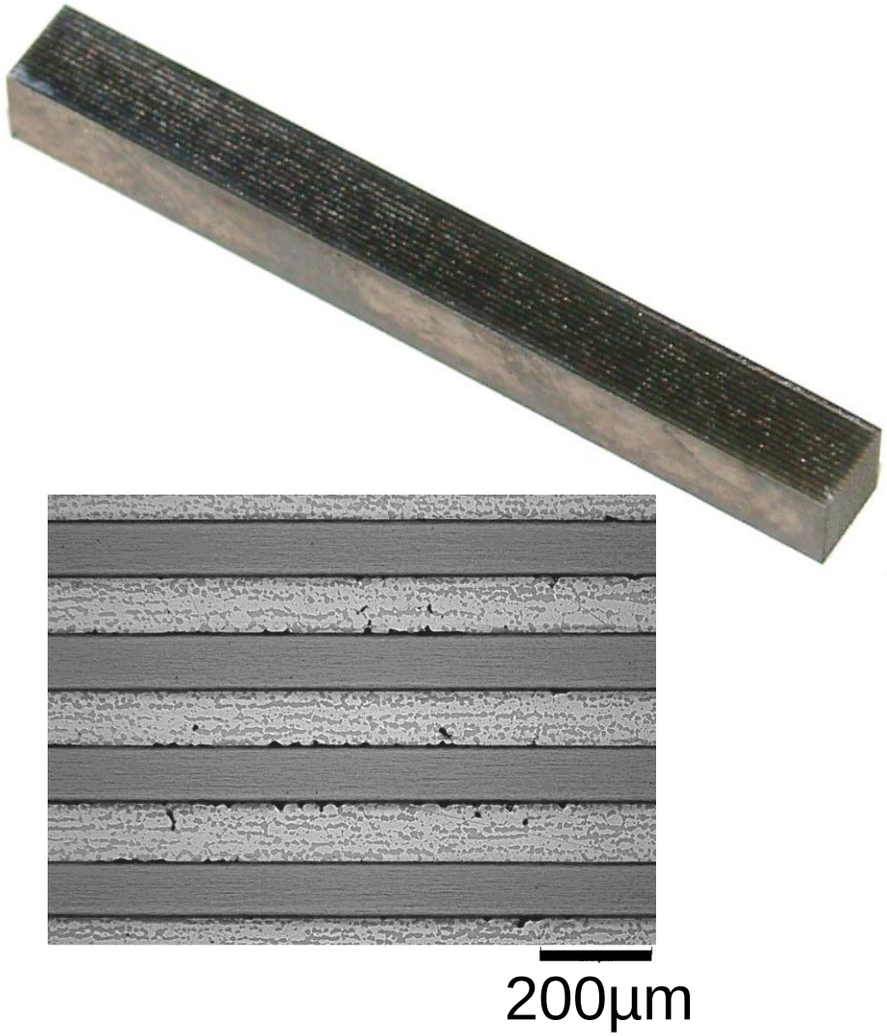


B. Dafferner, P. Norajitra, KIT

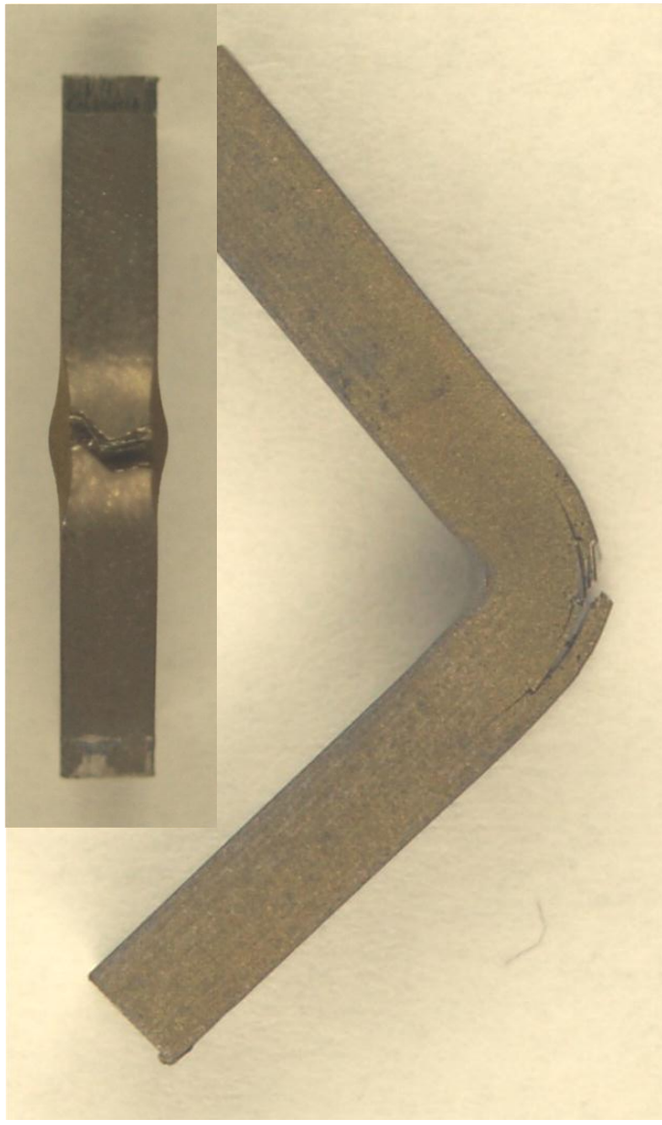
Solution: Composite Materials?

Ductile W-Foil

Sandwich of W-Foils

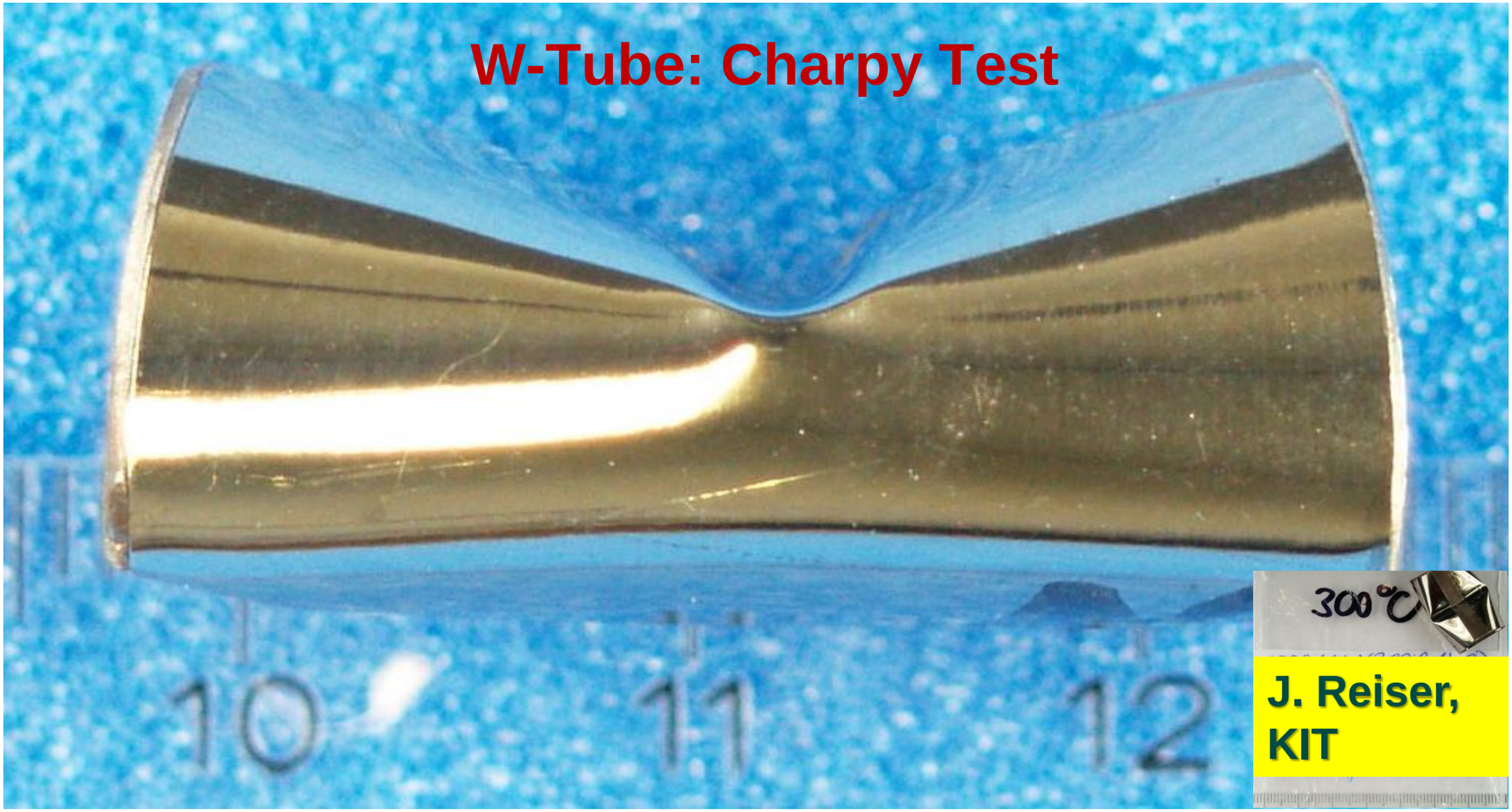


Fracture Behaviour



J. Reiser, KIT

Pipe Fabrication of Sandwich Material



CONCLUSIONS

- **No material available which fulfills all design criteria (strength, heat conductivity, DBTT)**
- **No DEMO divertor concept ready which is feasible with existing materials**
- **Lower operating temperature about 800°C (due to irradiation → has to be confirmed)**
- **Upper operating temperature limit given by loss of strength or recrystallization (depends strongly on material, about 1000-1300°C)**
- **Water cooling as fall-back option not confirmed yet (many doubts!)**

There is still a large discrepancy between the DEMO designs and the available materials !

Thank you very much!

Whenever you see this, please remember that tungsten rods are not a good choice for pipe fabrication !

Thanks to all contributors to the EFDA Topical Group on Fusion Materials