Technical University
of **Leoben**

Science 4 Technology – Poster Exhibition 2026

Department: Materials Science

Chair: Materials Physics

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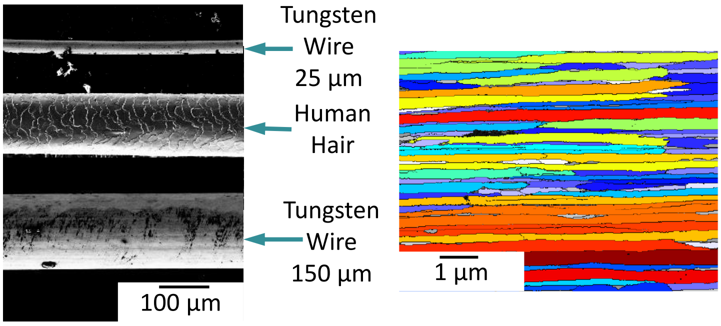
Splitting Hairs:
Testing Mechanical Properties of Tungsten Fine Wires

Tungsten fine wires are used in demanding applications where materials must withstand high stresses and harsh environments. To ensure reliable performance and long service life, it is important to understand how their microstructure influences mechanical properties and failure behavior.

Material and Application



Left: Scanning electron microscope (SEM) micrograph tungsten fine wires compared with a human hair, right: electron backscatter diffraction (EBSD) micrograph of the microstructure.

The wire drawing process creates elongated grains, which lead to direction-dependent mechanical properties.

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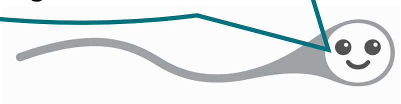
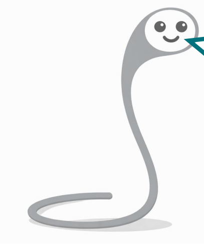
Left: Wire coil, middle: light bulb with a fine wire filament, right: medical robot.

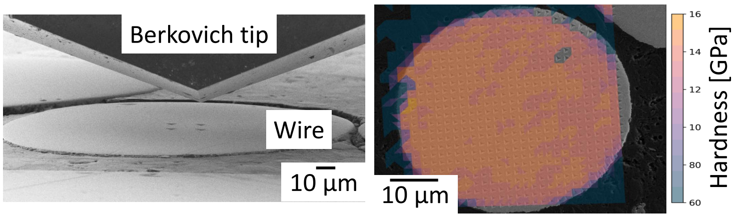
I can be as small as 10 µm in diameter, your hair is approximately 75 µm thick, and can be used in applications such as surgical tools, wafer cutting, lighting, and silicon crystal growth.



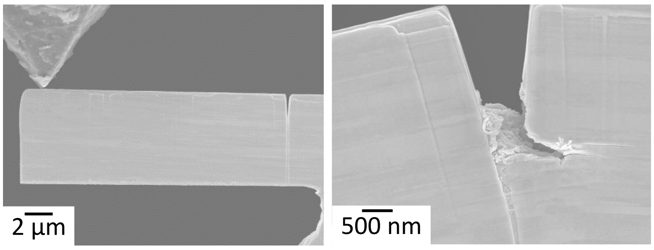
In-situ micromechanical testing



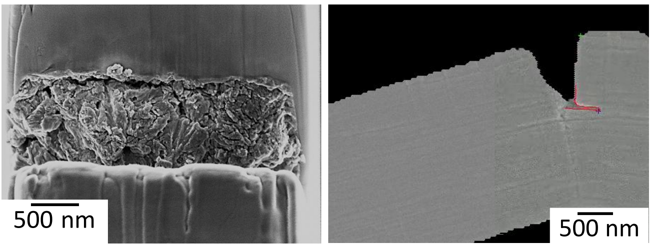
In-situ micromechanical tests allow tiny samples, such as I am, to be deformed while being observed in a microscope. This enables to directly study deformation and crack formation at the microscale.



Left: in situ nanoindentation testing, right: hardness map over a wire cross section.



Left: Microcantilever testing, right: Microantilever after testing.



Left: Fracture surface, right: Semi-automated crack tracking.

These techniques enable the measurement of properties such as hardness and fracture behavior in very small material volumes. Semi-automated crack length analysis is increasingly used to evaluate fracture processes efficiently.

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Micro- and Nanomechanics

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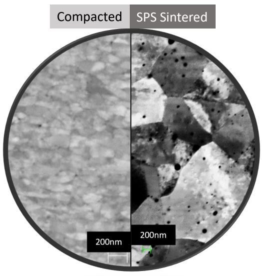
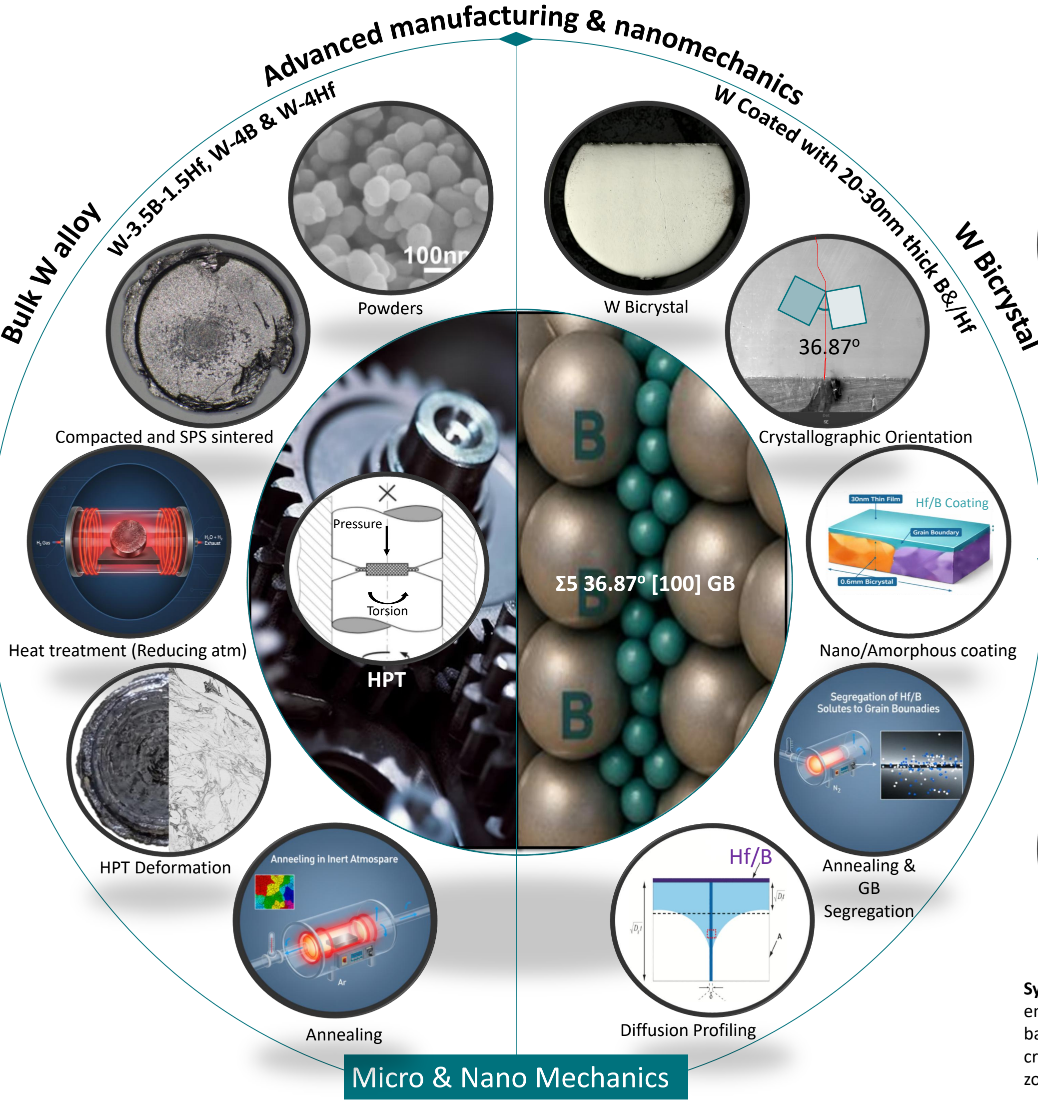
TUNGSTEN INTERFACE ENGINEERING

FOR PLASMA-FACING COMPONENTS IN NUCLEAR FUSION

Motivation: Tungsten has low fracture toughness because of intrinsically weak grain boundaries, limiting its reliability in extreme environments. This work engineers grain boundaries via controlled Boron and Hafniun segregation to tune cohesion and fracture behaviour. Bulk ultrafine-grained HPT-processed W alloys reveal the impact of segregation on the nanoscale, while a crystallographically defined W bicrystal quantifies segregation through diffusion profiles and grain boundary mechanical properties, establishing fundamental structure-chemistry-property relationships.

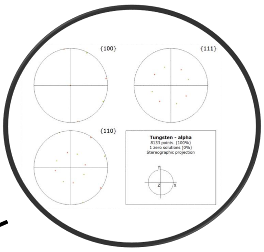
SEM Analysis



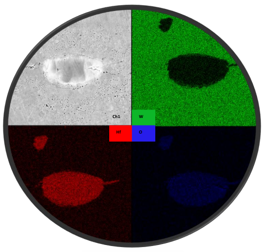


Pole Figure

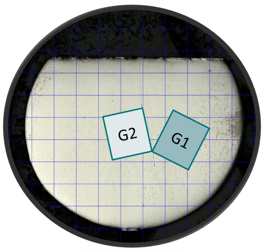
Bicrystal



EDX Analysis



Symmetric GB



Symmetric GB: Uniform binding energy, predictable solute mobility, balanced dislocation emission and crack blunting (symmetric plastic zone) on both crystals.

Hope to Achieve: Future work will utilize in-situ nano-mechanical testing to directly observe real-time fracture mechanisms and quantify toughness in both bulk alloys and bicrystals (at symmetric GB segment) at elevated temperatures. This aims to reveal how Hf and B segregation stabilizes GB's against failure and influences the brittle-to-ductile transition.

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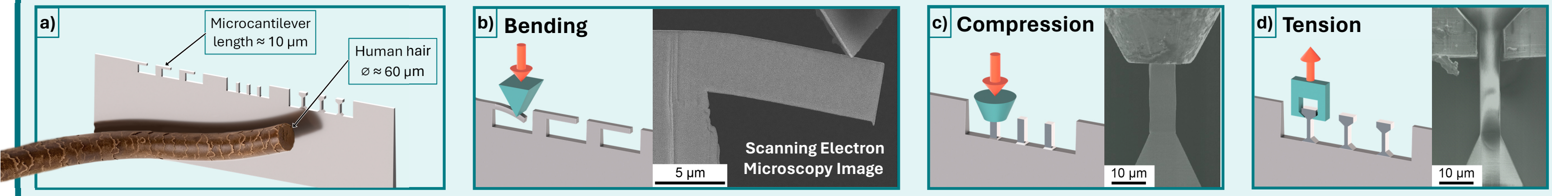
From Pixels to Strain Fields

Computer Vision and FEM Relaxation Reveal Sample Strain in Microscale *In Situ* Mechanical Testing

In situ Micromechanical Testing

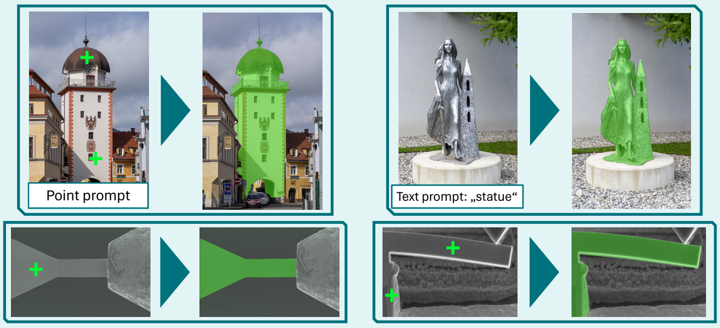
This technique measures **mechanical properties** at the micrometer scale, through **mechanical loading of micro-samples** inside an **electron microscope**. Small regions of material (e.g. thin lamellas, a) can be used to prepare micro-samples, which can be loaded in different geometries (b-d), while recording images continuously during the experiment using the microscope.



With miniaturization of devices (semiconductors, MEMS, thin films, etc.), micromechanical testing has become an integral part of materials research. The quantification of such experiments is mostly limited to load-displacement data, while the recorded *in situ* microscope images are considered qualitative information. This work shows how quantitative information can be extracted from electron microscopy image series.

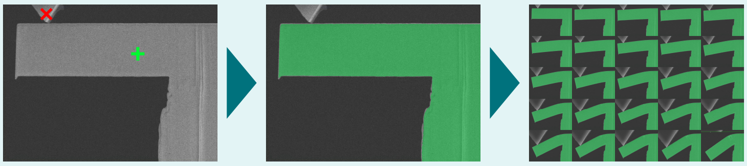
Leveraging Advances in Computer Vision

Foundational image segmentation vision models are able to detect and isolate objects from their surroundings. The Segment Anything Models (SAM 2, SAM 3, released by Meta) can be prompted through points, boxes and text.



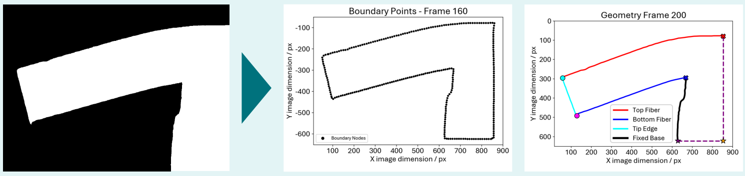
Trained on the large SA-1B dataset (1.1 B masks), the model generalizes well

When applied to a series of electron microscopy images acquired during a loading experiment, deformation of the micro-sample can be tracked throughout the experiment.



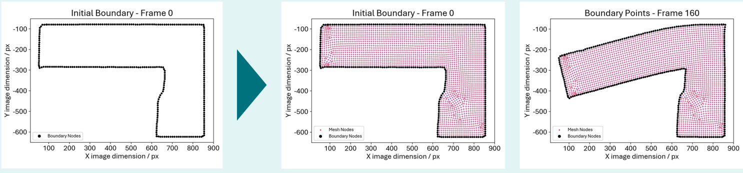
Point prompt on the first frame, mask propagates through the image series

The outlines of the binary masks are converted into a series of contour points and divided into sections at contour edges.



Meshing and Finite Element Relaxation

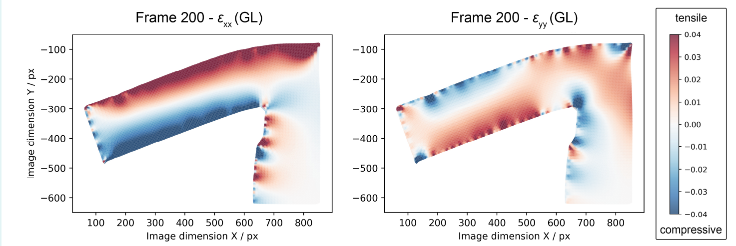
The mask outline is used to build a mesh from the first image of the experiment. Subsequent masks deform the initial mesh through shape change of the outline. This shift is propagated to the interior of the mesh, via finite element relaxation of all quadrilateral nodes.



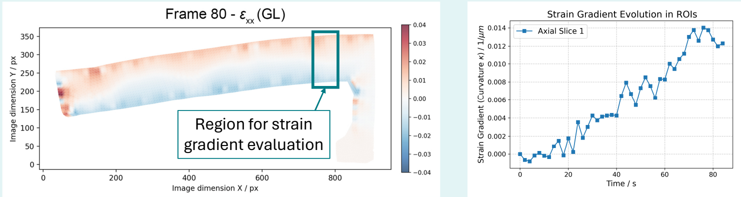
The displacement field $\mathbf{u}(X)$ of all nodes allows calculating evolution of strain fields during loading:

$$\boldsymbol{F} = \boldsymbol{I} + \nabla \boldsymbol{u} \qquad \boldsymbol{E} = \frac{1}{2}(F^T F - I)$$

Deformation gradient *Green-Lagrange strain tensor*



Strain fields in ε_{xx} show tension in the upper cantilever fiber, compression in the lower fiber. Strain gradient evolution and neutral fiber position can be evaluated over time.



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