Deformation Mechanisms in BCC High Entropy Alloys at Cryogenic Temperatures

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A contribution to the **"HEA branch"** of the SPP.

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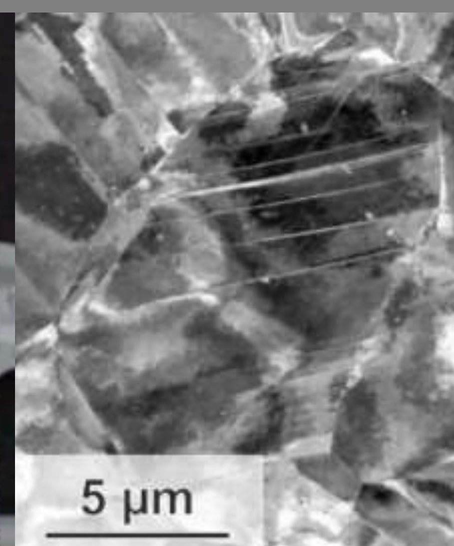
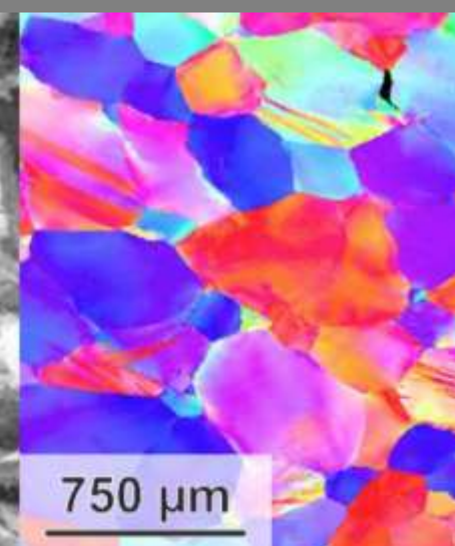
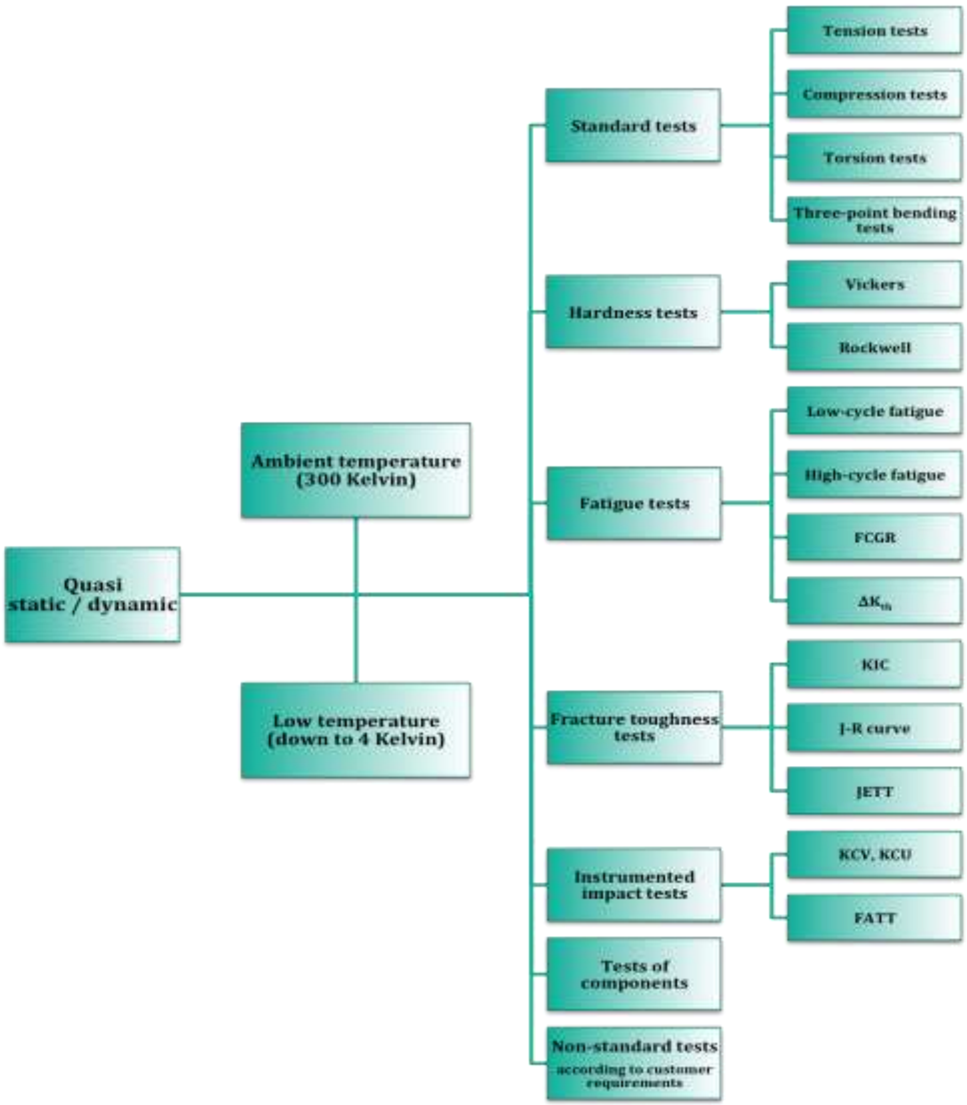




Cryogenic material laboratory within ITEP

- Necessity to characterize materials at operational temperatures
  → RT – 4.2 K
  - Mechanical properties (tensile, fracture, fatigue…)
  - Electro-mechanical investigations
  - Thermal conductivity / expansion
  - In-house development and production of appropriate sensors
  - Optical Emission Spectrometer Analysis
  - Additional investigations like surface roughness, optical, SEM & X-ray diffraction analysis
- Advantage of combination of test methods in one laboratory with expertise of about 30 years

Available mechanical tests at CryoMaK facilities



CryoMaK facilities for testing mechanical properties at low temperatures

Test facility	Maximal force +/- kN	Temperature K	Test type	Standards *
MTS25	25	RT → 7	Standard tests Fatigue tests Fracture toughness tests Tests of components Non-standard tests	DIN EN ISO 6892-1 ASTM E8 DIN ISO 15579 ASTM E 1450 DIN ISO 19819 JIS Z 2277 ASTM E 466 JIS Z 2283 ASTM E 606 ASTM E 647 JIS Z 2284 ASTM E1820
MTS50	50	RT → 77		
MTS100	100	RT → 4		
ATLAS	650	RT → 4.2		
TORSION	160 – axial 1000 Nm – torsion	RT → 4.2		
PHOENIX	+/- 100	RT → 4.2	Standard tests Non-standard tests	
GALDABINY **INSTRON CEAST 9350**	450J 757J	RT → 77 RT	Instrumented Impact Tests	ISO 148 ASTM E23 JIS Z 2202
INNOVATEST NEXUS 4302	30 Kgf	RT		ISO 6507-2 ASTM E92

* These are only examples of standards. We perform tests according to a variety of other standards as well.

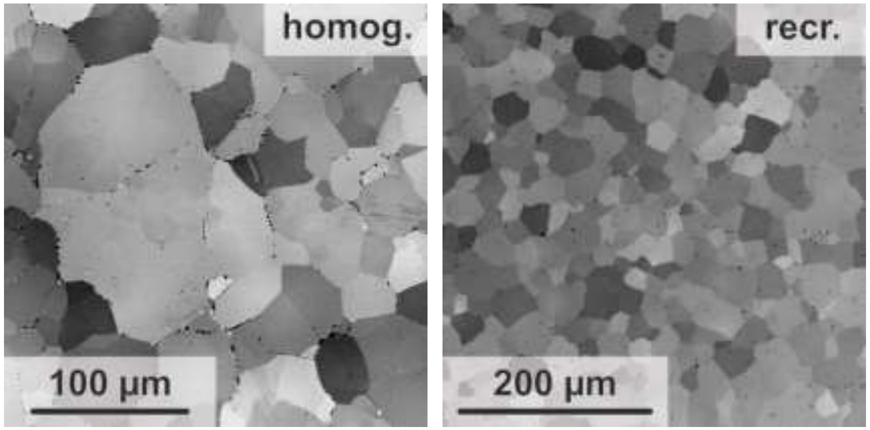
Testfacility CryoMaK

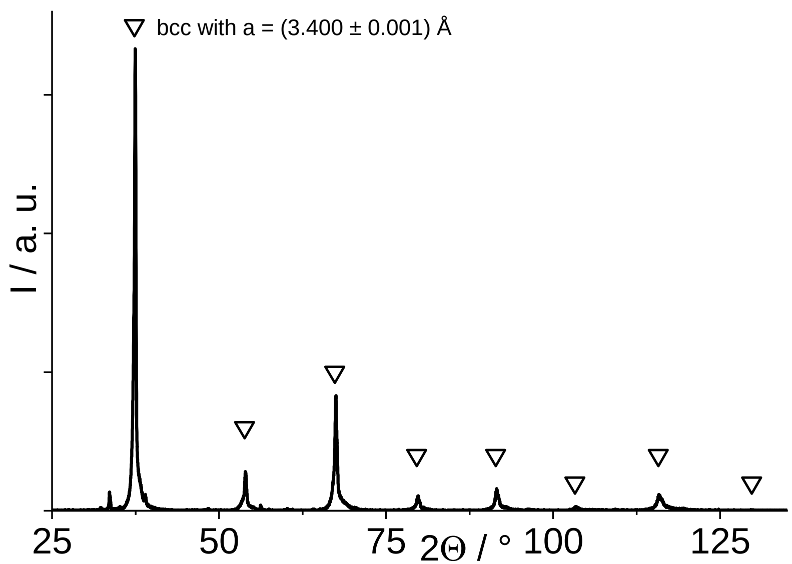
MTS25 & 50
axial ± 25 kN und ± 50 kN

MTS 100kN
axial ± 100 kN

Production of HfNbTaTiZr

for reproducible materials testing and characterization



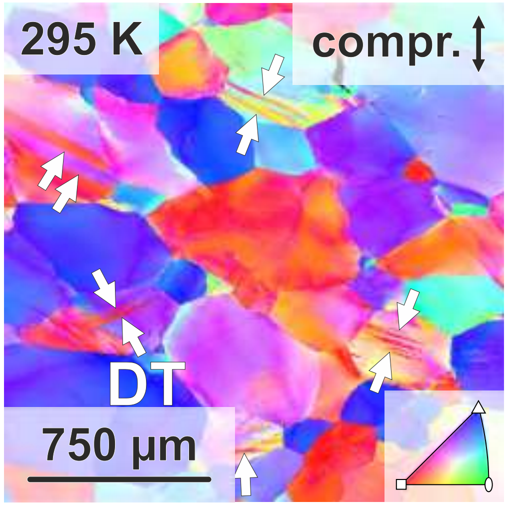


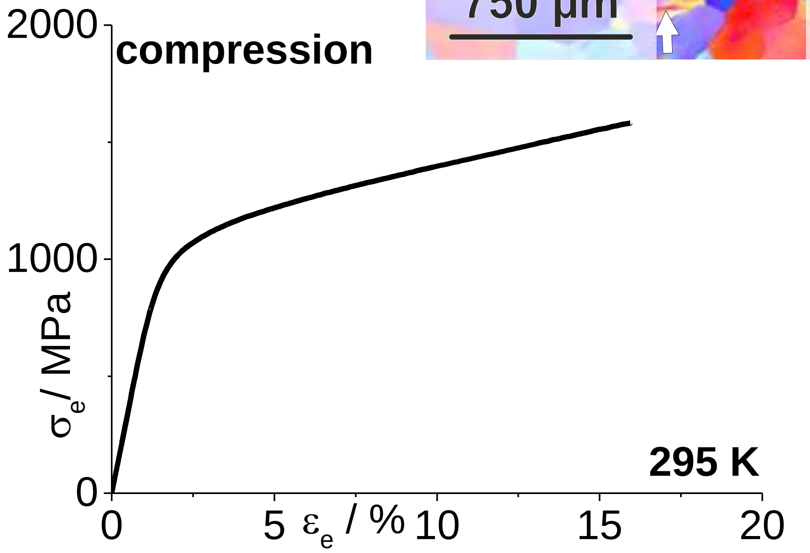
- **HfNbTaTiZr**
- **Manufacturing**
- **Arc-melting**
- **Homogenization: 1100°C/72h**
- **Rotary swaging: φ = 1.39**
- **Production of samples**
- **Static recrystallization: 1100°C/1h**

Preliminary work

Peculiarities of deformation in HfNbTaTiZr

- **initial work on homogenized material** only
- **localized deformation** for large strains at room temperature
- **localization partially due to deformation twinning** is active at **room temperature**
- twinning modes can only **partially be attributed** to the most **common BCC twin system**
  (but only when orientation relation is applied twice)

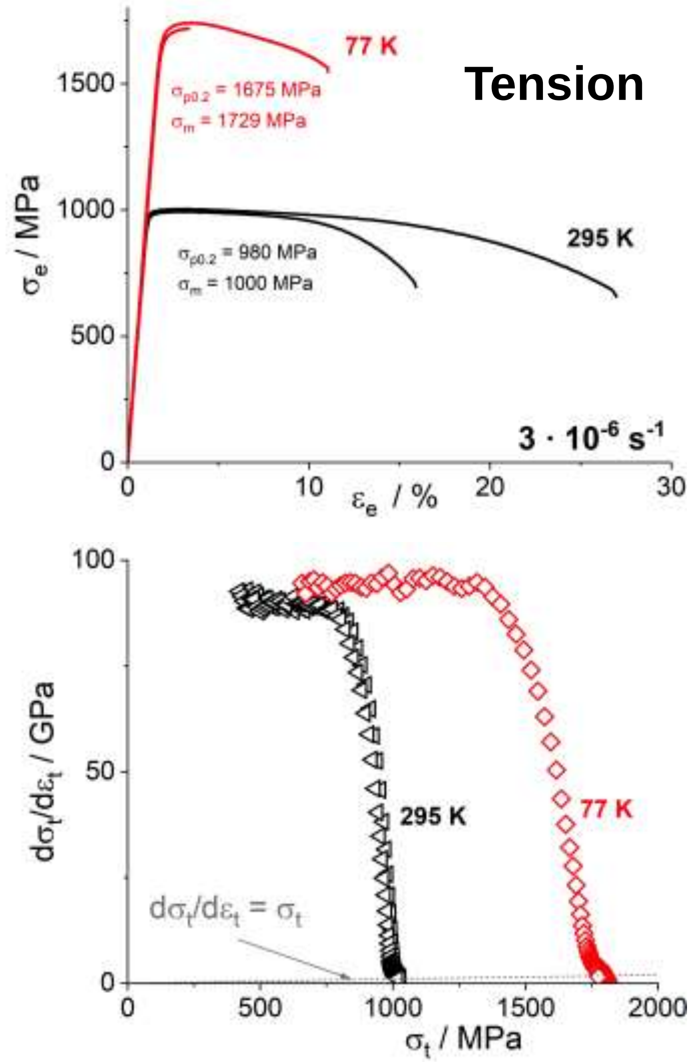




Current work

Peculiarities of deformation HfNbTaTiZr

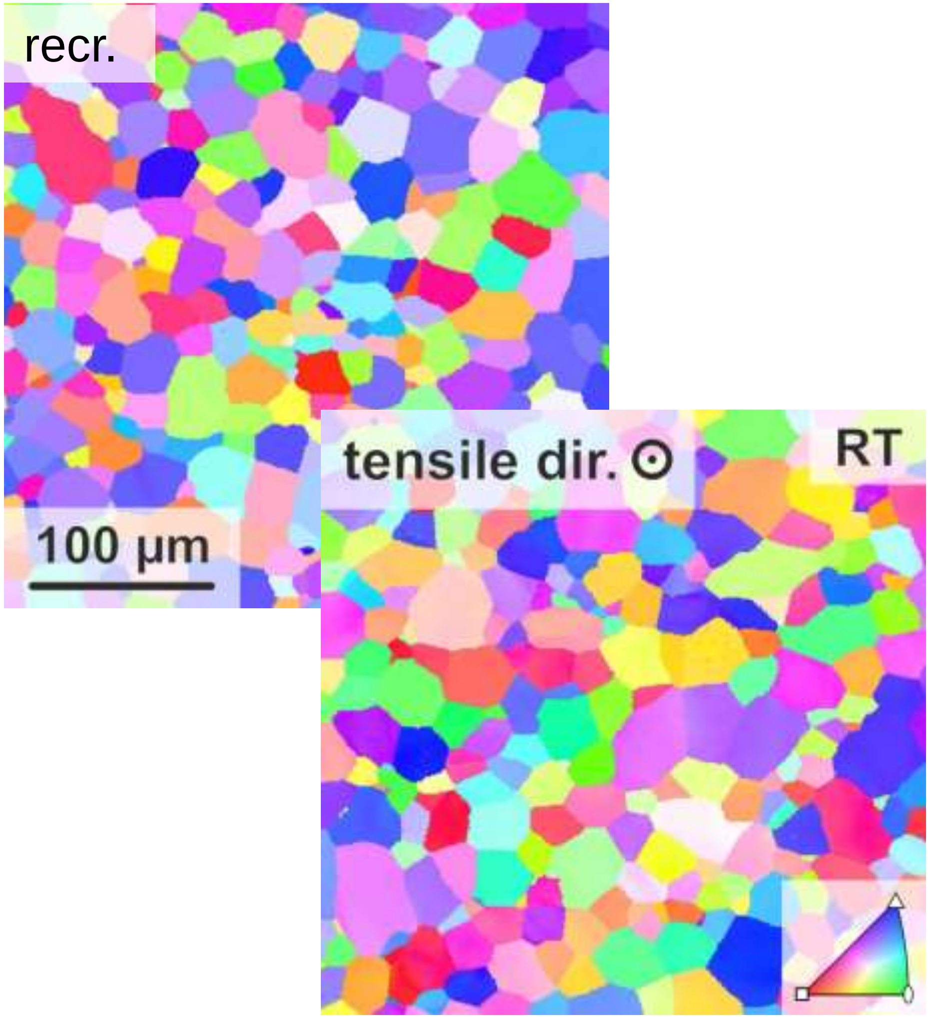
- successful manufacturing of **tensile and compression test samples from single, recrystallized batch**
- **high strength but low work-hardening** during tensile loading



Current work

Peculiarities of deformation HfNbTaTiZr

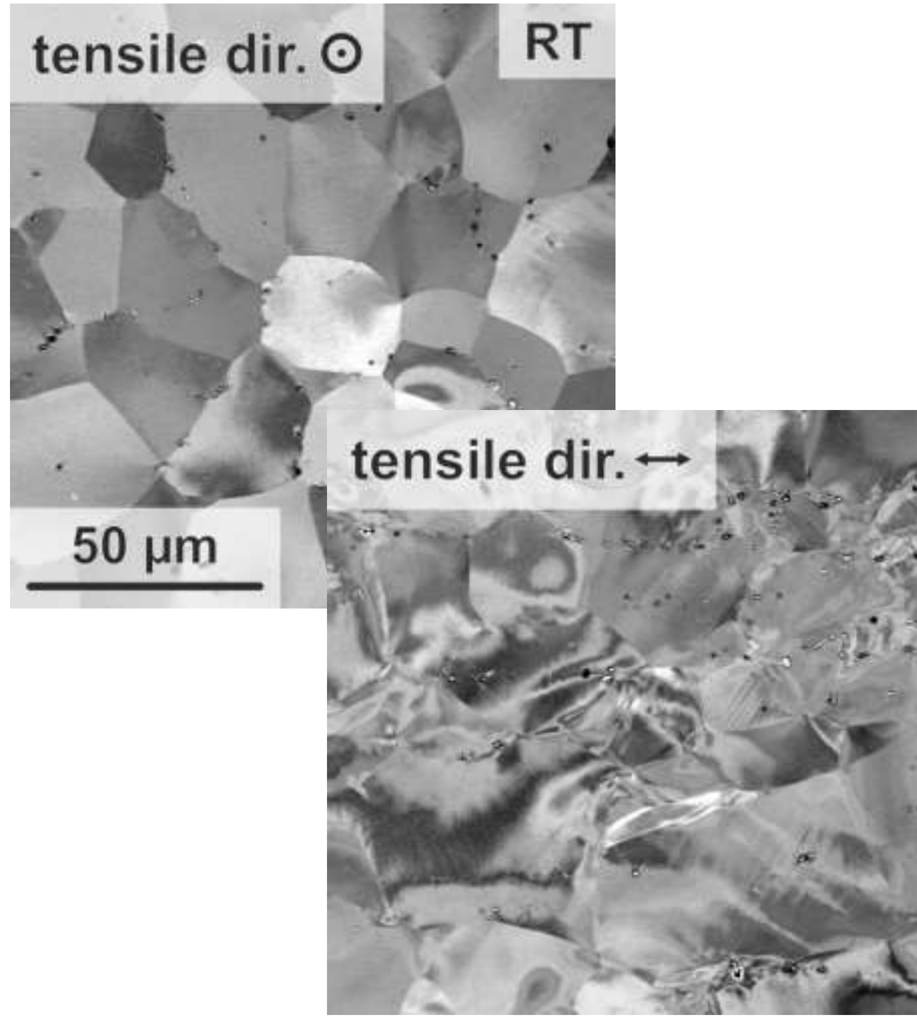
- no obvious **indications for twins**
- texture evolution according to the **expected slip systems** (slip direction)



Current work

Peculiarities of deformation HfNbTaTiZr

- **limited localized deformation** within uniform part of the samples at room temperature
- **more pronounced in the necking region** due to higher strain
- planned experiments:
  - increasing applied strain by compression testing
  - lowering temperature to facilitate deformation twinning



Summary

- production for reproducible materials
- initial work on homogenized material
- successful manufacturing of tensile and compression test
- planned experiments:
  - increasing applied strain by compression testing
  - lowering temperature to facilitate deformation twinning
- influence of microstructure parameters (grain size, twins …)