Microstructure Optimization of Ti-36Nb-2Ta-3Zr-0.3O for Implant Applications

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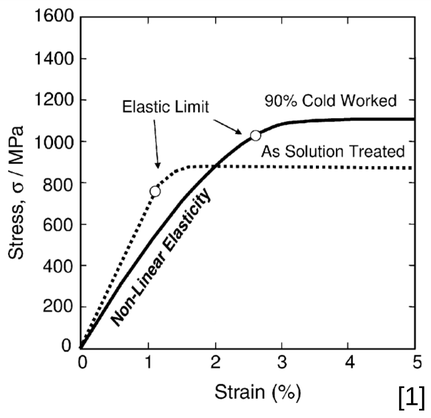
State of the Art

- Third generation medical alloy
- Young's modulus: approx. 50 GPa
- Maximum strength: close to 1100 MPa
- Avoidance of potentially critical elements



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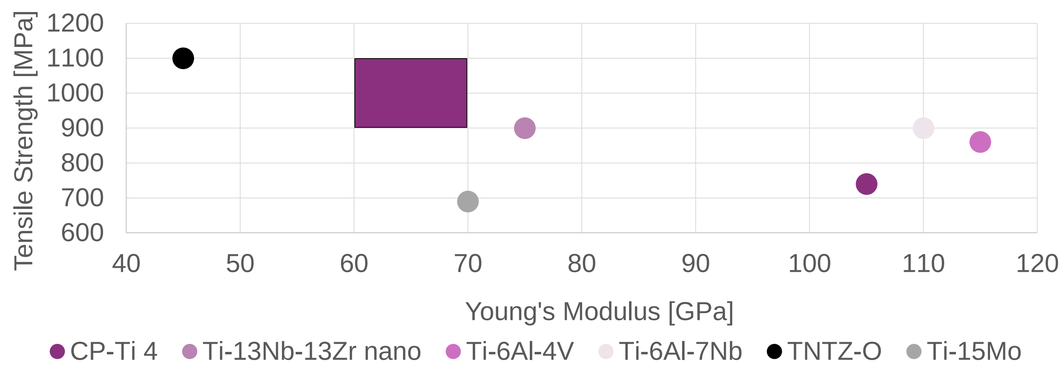
- Compositions of TNTZ-O:
  - Nominal: Ti-36Nb-2Ta-3Zr-0.3O
  - Actual: Ti-36.6Nb-1.78Ta-2.94Zr-0.31O

- Physical and mechanical properties (cold worked state):
  - Lower Young's modulus, elastic strains of > 2% possible
  - Non-linear elastic behaviour
  - Work hardening comparably low; possible explanation: dislocation-free mechanisms, stress-induced reversible martensitic transformation, giant faults

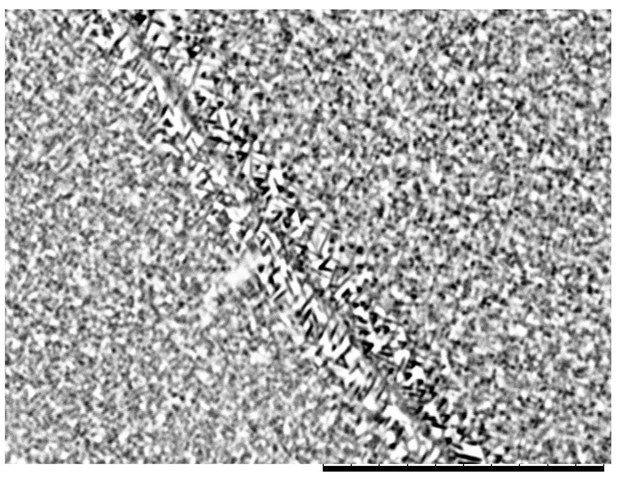
TNTZ-O as implant material



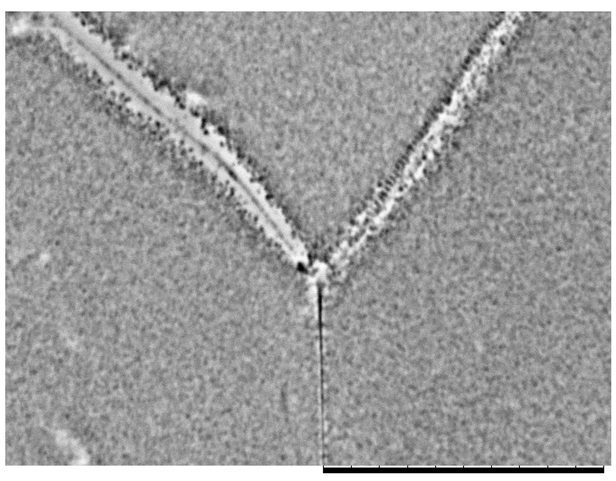
- Actual use: orthodontic wire in cold-worked state only
- Optimal properties: purple rectangle
- Goal: enable use as implant material in non-cold-worked state
- Research project: new implant design, conventional material production route, microstructure optimization

Microstructural Investigations

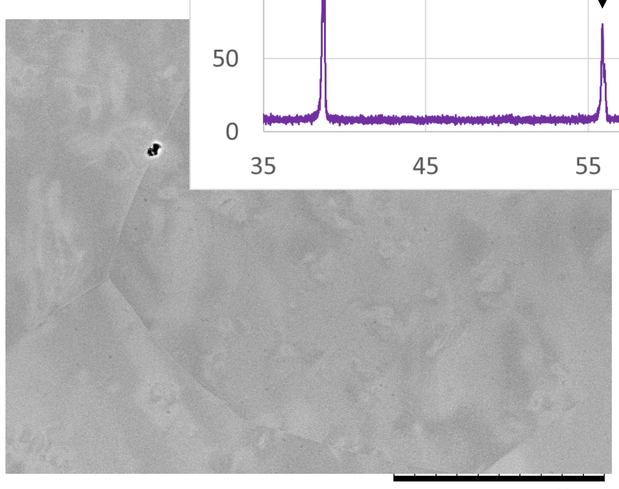
- Three possible phases: α, β and ω, no α''-martensite detected after β-anneal + water quenching
- Implant-adapted mechanical properties by microstructure optimization
- Next step: equiaxed primary α + nano-sized α_s-precipitates in β-matrix

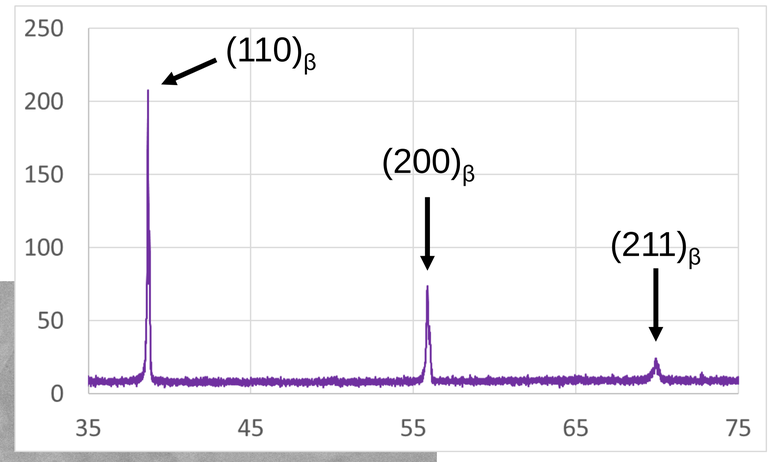


α-precipitates in β-matrix



ω-precipitates in β-matrix

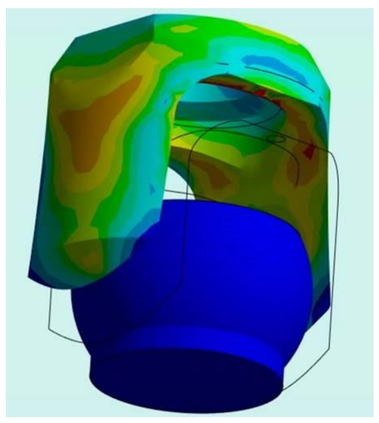


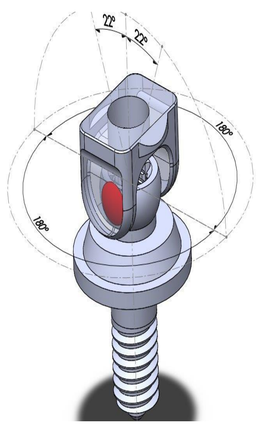


Single-phase β microstructure and XRD analysis

Implant Design

- Common design problems: jamming, erosion, increased force on incorrect removal
- Successful manufacturing of implants with 3 mm diameter





Ingot Production

- Combination of PAM and CC-VIM of compacts (Ti-, Zr-sponge, Ta, Nb, TiO_2)
- First molten ingots of TNTZ-O do not contain high density inclusions

PAM / CC-VIM facility

Further Research

- First attempts very promising: scale-up to ingots of 140 kg followed by thermo-mechanical treatments
- Two-step heat treatments to precipitate fine dispersed α-phase
- Investigation of mechanical (tensile and fatigue) and biological properties (bone adhesion, bacterial colonization)
- Implant production and testing

[1] Kuramoto, Shigeru; Furuta, Tadahiko; Hwang, Junghwan; Nishino, Kazuaki; Saito, Takashi (2006): Elastic properties of Gum Metal. In: Materials Science and Engineering: A 442 (1-2), S. 454–457. DOI: 10.1016/j.msea.2005.12.089.