STRUCTURE AND MECHANICAL PROPERTIES OF ULTRA-FINE GRAIN TITANIUM

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Introduction

It is required that material for dental implants is bio-compatible, it must not be toxic and it may not cause allergic reactions. It must have high ultimate strength Rm and yield value Re at low density ρ and low modulus of elasticity E. Metallic materials used for dental implants comprise alloys of stainless steels, cobalt alloys, titanium (coarse-grained) and titanium alloys. Semi-products in the form of coarse-grained Ti or Ti alloys are used as bio-material for medical and dental implants since the second half of the sixties of the last century. Titanium is at present preferred to stainless steels and cobalt alloys namely thanks to its excellent bio-compatibility. Together with high bio-compatibility of Ti its resistance to corrosion evaluated by polarisation resistance varies around the value of 10^3 R/Ωm. It therefore holds a dominant position from this viewpoint among materials used fort dental implants.

For these reasons pure titanium still remains to be a preferred material for dental applications. Development trend in the case of this material is oriented on preservation of low value of the modulus of elasticity and on increase of its mechanical properties, especially strength. According to the Hall-Petch relation it is possible to increase considerably the strength properties of metals by grain refinement. That's why it is appropriate to use for dental implants rather fine-grained Ti instead of coarse-grained Ti. Nano-titanium is characterised by exceptional mechanical properties, among which high strength and high yield value are of utmost importance. Strength properties of (n) Ti must have the following values: UTS > 1000 MPa, YS > 850 MPa.

Experimental

Materials

Commercially pure (CP) titanium bars and sheets were used in this study. The average grain size of the as-received CP titanium is ASTM No. 4. Tensile specimens with a gauge of 50 mm length, 10 mm width and 3.5 mm thickness were machined with the tensile axis 3 oriented parallel to the final rolling direction. The specimens were deformed at room temperature with different initial strain rates. Figure 1 presents the initial microstructure and Figure 2 microstructure of Ti after cold forming.

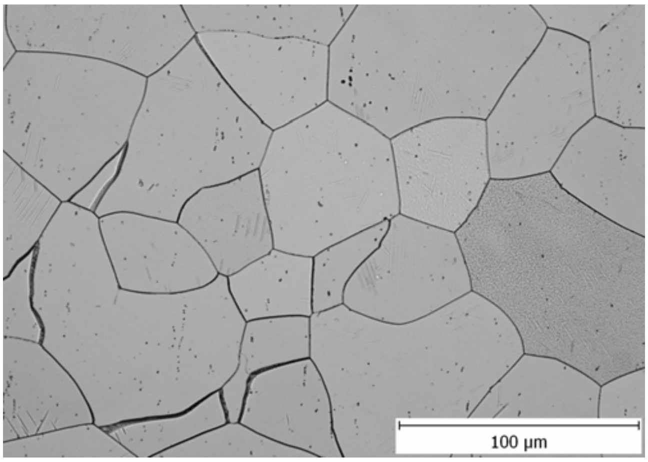

Fig. 1 Initial microstructure of commercially pure titanium Grade 2

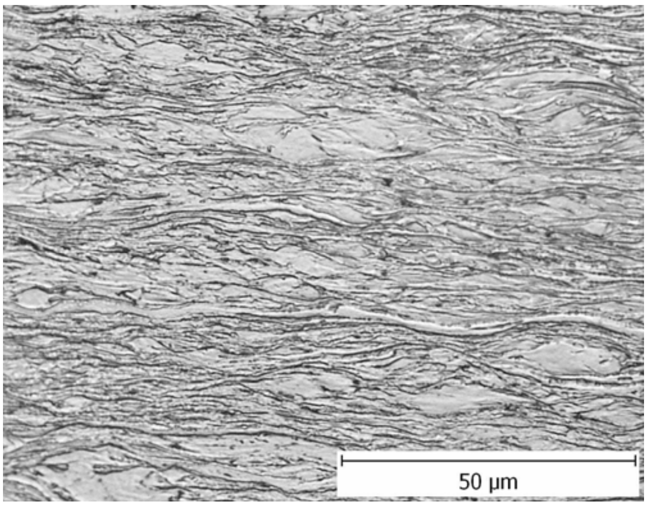

Fig. 2 Microstructure of commercially pure titanium Grade 2 after cold forming (deformation e = 90 %)

Specimens were sectioned along the gauge and grip parts of the deformed sample. The samples were then polished by application of 10% HF, 10% HNO_3 and 80% H_2O for 20 seconds. Chemical analysis and mechanical properties of CP titanium are given in Table 1 and Table 2.

Table 1 Chemical analysis CP Titanium, (weight %)

N	O	C	Fe	Al	Cr	Ti
0.03	0.10	0.04	0.03	0.01	0.01	Rest.

Table 2 Tensile results CP Titanium after condition annealing at 649°C/1 hour

Tensile strength (MPa)	Yield strength (MPa)	Young´s modulus (GPa)	Elongation (%)
355	278	102	21

Nano-titanium is characterised by exceptional mechanical properties, among which high strength and high yield values are of utmost importance. Strength properties of (n)Ti must have the following values: UTS > 1000 MPa, YS > 850 MPa.

Chemical purity of semi products for (n)Ti was ensured by technology of melting in vacuum and by zonal remelting. The obtained semi-product was under defined parameters of forming processed by the ECAP technology. The output was nano-structural titanium with strength around 1050 MPa [1].

Results and Discussion

Semi products from individual heats were processed with use of the modified programs by the ECAP technology. Structure of nTi after application of the ECAP process is shown in the Figures 3 to 5. The structure was analysed apart from light microscopy also by the X-ray diffraction. Table 3 summarises the obtained basic mechanical properties (n)Ti.

Table 3 Mechanical properties (n)Ti after ECAP

Forming process	Tensile strength (MPa)	Elongation at break (%)	Young´s modulus (GPa)	d_z (nm)
ECAP (10 pass.)	1050	10	97,5	150

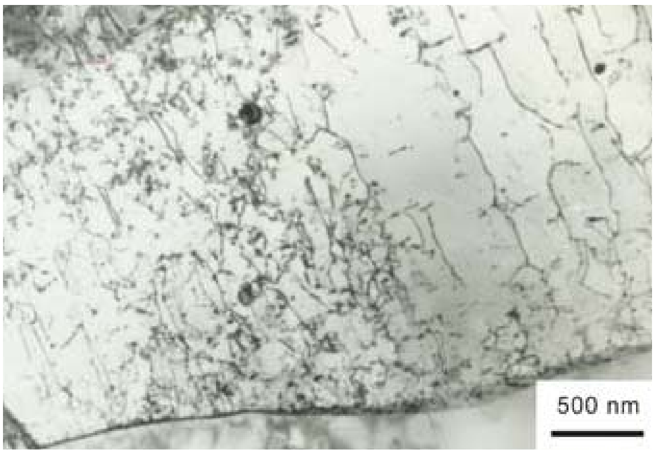

Fig. 3 Substructure of CP titanium Grade 2 in the initial state

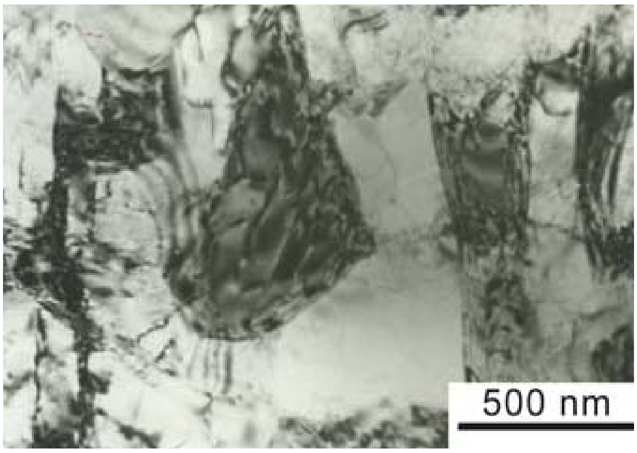

Fig. 4 Substructure CP titanium of the sample after 4 ECAP passes

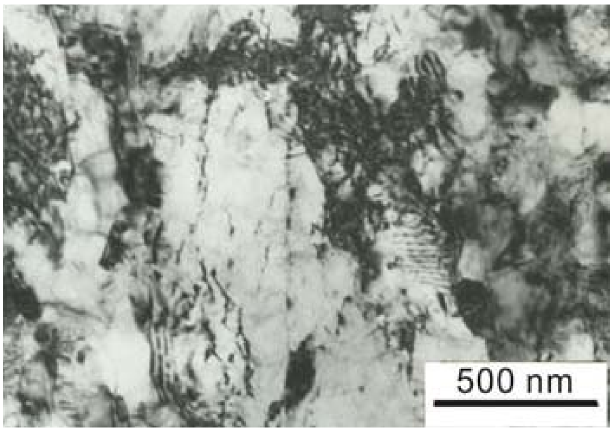

Fig. 5 Substructure CP titanium of the sample after 10 ECAP passes

Conclusion

Technology of manufacture of nano-titanium was proposed and experimentally verified. Grain refinement in input materials was obtained by the ECAP process. In conformity with the Hall-Petch relation the strength properties of Ti increased significantly as a result of grain refinement. The obtained mechanical properties correspond with the declared requirements. Nano-titanium has higher specific strength properties than ordinary titanium. Strength of nano-titanium varies around 1050 MPa, grain size around 150 nm.

Acknowledgement

Authors of the paper would like to express their gratitude for financial support of the GAČR 106/091598

References

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