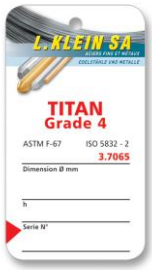

TITAN Grade 4

3.7065 - EN Ti 4 / ASTM B348 and F 67 - CP Titan Grade 4
For the medicine, micro-engineering, watch making etc.

Features and Peculiarities

Titan Grade 4 is a high quality and strength CP titanium VAR (Vacuum Arc Melted and remelted CP titanium. Its contents in C, O, N and H are closely controlled. The Fe content is limited in harmony with the O content to permit a satisfactory cold forming and deformation to high strength levels without impairing the final ductility. Its corrosion resistance in chloride containing mediums is excellent. Titan Grade 4 is totally biocompatible and non-allergenic. It exhibits a good oxidation resistance. Anodic oxidation permits to achieve a large spectrum of interference color of the surface. That also improves the fretting wear resistance.

Uses

Titan Grade 4 is well indicated as implant material and as material for applications in the medical, surgical and dental fields as well as in micromechanical engineering and in the watch making industry for components for movements and the watch exterior. It has an excellent corrosion resistance in seawater and marine environments. Its high corrosion resistance in chlorine containing mediums indicates it for applications in the chemical industry. This titanium grade can easily be oxidized anodically offering a broad spectrum of interference colors that reduce the fretting wear resistance.

Standards

Material number	3.7065
EN & DIN	Ti 4
ISO	5832-2
AFNOR	T 60
ASTM	B 348, F 67
UNS	R 50700

Chemical composition (%wt.)

C	Fe	O	N	H	Ti
max.	max.	max.	max.	max.	balance
0.08	0.50	0.40	0.05	0.0125	

Dimensions and Executions

- Bars: 3m (2m), cold drawn, ground polished, rugosity: Ra ≤ 0.5 µm
  Tolerance: ISO h6 (h7), Other tolerances on request
  ø > 1.0 mm: pointed and chamfered
  Straightness: max. 0.4 mm/m; Rm > 800 MPa: max 0.5 m/m
  SWISSLINE: ø > 6.0 mm
  Cracking proof test DIN/EN 10277-1, Tab. 1
  ø < 2.00 mm: class 1
  ø ≥ 2.00 mm: class 3

Other executions on request

Availability

Dimensions courantes en stock, see: Delivery program

Mechanical Properties

According to ISO and/or ASTM:

UTS/Rm	680 – 800 MPa	ø 5 – 12 mm:	800 – 900 MPa
YS0.2/$Rp_{0.2}$:	620 MPa		620 MPa
Elongation A:	ø < 9.0 mm: ≥ 12%		≥ 10%
	ø ≥ 10.0 mm: ≥ 10%		

Machining

Cutting speed:	Vc ≈ 20-40 m/min
Feed:	0.10-0.20 mm/R
Lubricant-coolant:	individual choice

- The optimal cutting conditions depend on the machine tool, the cutting tools, the chip dimensions, the lubricant-cooling fluid, as well as the tolerances and surface the roughness to be achieved.

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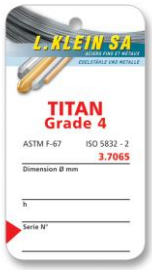

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Grain size

ASTM E112 Number: ≥5

Cold working capability

- Cold: Rm ≤ 930 - 1135* MPa
  $Rp_{0.2}$: ≤ 655 - 825* MPa
  *Indicative values only
- UTS/Rm and $YS_{0.2}/Rp_{0.2}$ are function of the amount and type of cold working.
- High strengths are achievable by cold working up to 95% total reduction. It can be achieved by repeated cold deformations up to approximately 35-40% followed by 500-540°C/1h stress relieving anneals.

Anneal temperature

- 600°C/0.5-1h

Stress relieving

- ≤ 500°C/1h on finished or intermediate products
- Stress relieving treatment can also be applied between the rough and fine or finishing machining operations. This to reduce or eliminate the possible internal stresses build in during heavy or rough machining that may lead to distortions.

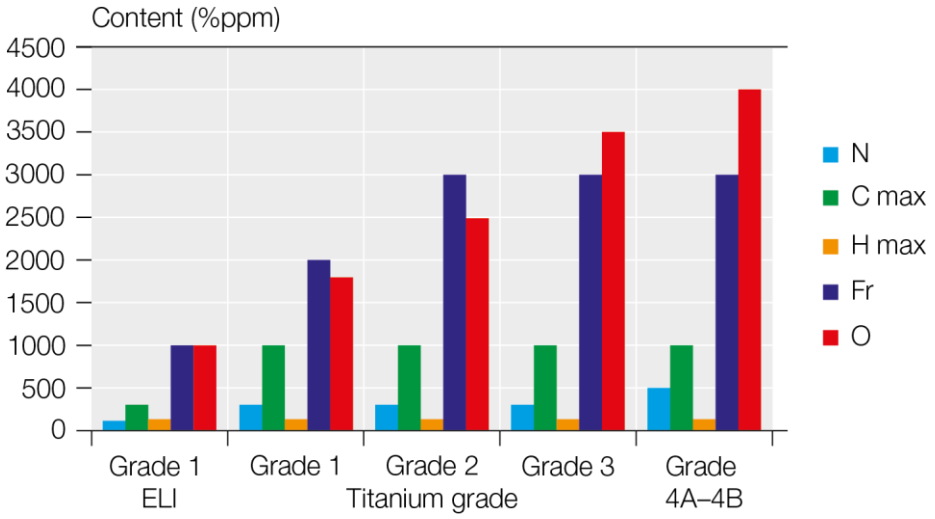
Final stabilization anneal

- 420-440°C/1h

Comparison of the composition of the CP titanium grades

The choice of the adequate Grade of CP titanium is essentially a decision based on the composition and the mechanical properties.
The Figures 1 and 2 show this aspect of the best choice of CP titanium Grade for the aimed use.

Figure 1
Composition of the titanium CP Grades



O, Fe et C are the three elements which could be regarded as alloying element per se and the elements allowing the control of the achievable mechanical properties. The others chemical element of the composition are controlled impurities.

Negative role of hydrogen

Hydrogen diffuses easily and readily in titanium and titanium alloys. It renders them brittle. The pick up and presence of hydrogen must be avoided by any means. The sources of the H contamination are the protective atmospheres, and the chemical and electrochemical reactions producing hydrogen.

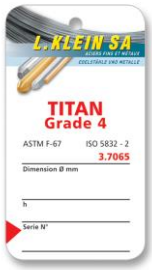


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Figure 2
Achievable mechanical properties of the Titanium 1-4 grades

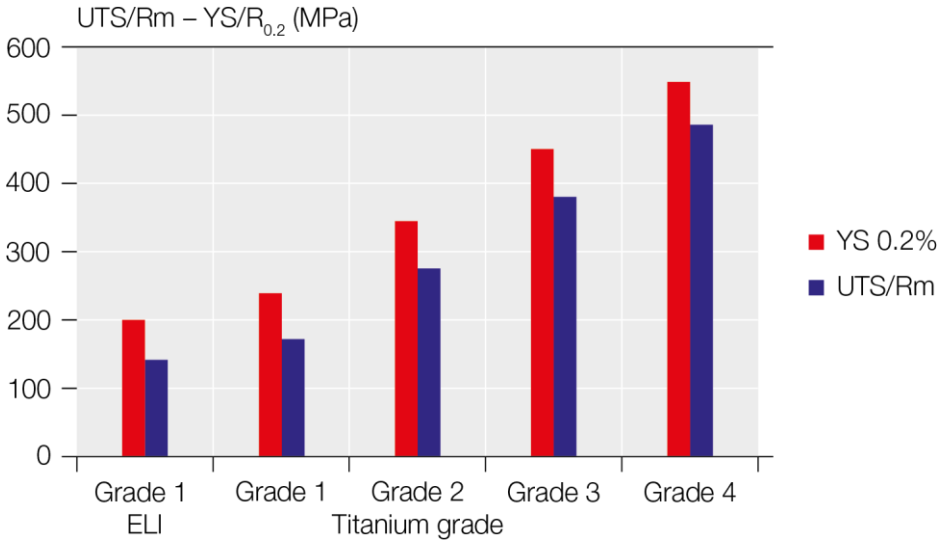

Figure 2 shows the indicative mechanical properties in the annealed condition that can be obtained with the Titanium CP Grade.

Pickling

Titan Grade 4 can be pickled with a solution of:
– 10 parts of HCl Hydrochloric acid and
– 1 part of HF Fluor hydric acid.
The proper setting of the dissolution allows controlling the intensity of the pickling with the surface condition to obtain or satisfy.
- Pickling permits to obtain chemically clean surfaces not retaining residual contaminations due to the processing.

Passivation

Titanium reacts spontaneously in the presence of oxygen to form a protective passive oxide layer. The thickness of this layer is in the low nanometer range. It provides and warrants the excellent corrosion resistance and biocompatibility of Titan Grade 4.
- Electro polishing of Titan Grade 4 permits to reinforce the passive oxide layer. But its main role is to clean the surface of any residual contaminations that cannot be as efficiently removed by pickling only.

Corrosion resistance

Titan Grade 4 as an excellent corrosion resistance, the second best of all titanium and titanium alloys after Titan Grade 2, the best benchmark reference to be matched or to be compared to by all materials for medical applications.

Biocompatibility

The biocompatibility of Titan Grade 4 in the human body is excellent, but the second best after Titan Grade 2. It is not allergenic and is the second benchmark, or reference to match, or to be compared to by all materials for medical applications, notably implants.

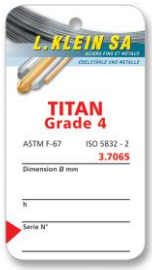

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Figure 3
Anodic oxidation

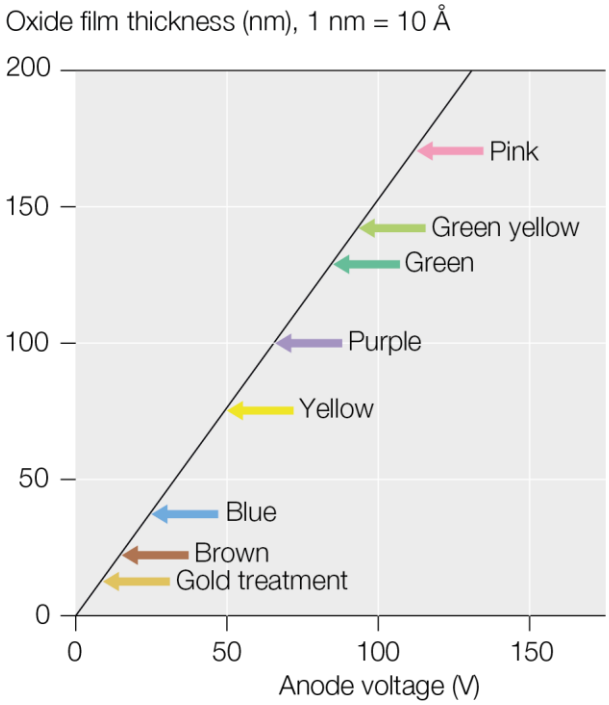


Table 1
Relation between the observed color and the thickness of the oxide layer

0	46.0	92.0	137.9
3.1	49.0	95.0	141.0
6.1	52.1	98.1	144.1
9.2	55.2	101.1	147.1
12.3	58.2	104.2	150.2
15.3	61.3	107.3	153.3
18.4	64.4	110.3	156.3
21.5	67.4	113.4	159.4
24.5	70.5	116.5	162.5
27.6	73.6	119.5	165.5
30.7	76.6	122.6	168.6
33.7	79.7	125.7	171.6
36.8	82.8	128.7	174.7
39.8	85.8	131.8	
42.9	88.9	134.9	

Titan grade 4 can easily be anodic oxidized in oxidant acid baths, such the phosphoric acid (H_3PO_4) or sulfuric acid (H_2SO_4). As shown by Figure 3, a large spectrum of interference colors can be produced in function of the concentration of the selected oxidant acid, i.e. 4M H3PO4, the temperature and the applied voltage. No additive or coloration pigment is necessary. The colors observed are pure interference colors.

Color spectrum

The interference colors arise by the reflexion and refraction oft he incident visible light on the surface of the metal. As shown in Table 1, anodic oxidation can produce a large spectrum of colors.

Reinforced Biocompatibility

The excellent biocompatibility of titanium Grade 4 is due to its capacity and capability to spontaneously passivize in the presence of oxygen to form a TiO_2 oxide layer. This layer as shown in Table 1 is very thin < 2-3 nm. Thicker layers as produced by anodic oxidation, reinforce the biocompatibility and corrosion resistance.

Corrosion resistance

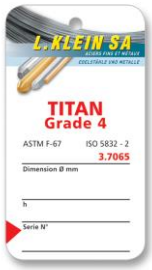
The corrosion resistance of titanium Grade 4 is excellent. It can still be reinforced by the formation of a thicker TiO_2 oxide layer produced by an anodic oxidation.

Resistance to fretting

The thicker TiO_2 oxide layers produced by anodic oxidation improve the gliding properties. These oxide layers can be exploited to improve the gliding properties, the wear and fretting resistances. These improvements can be exploited to enhance the gliding properties during cold forming and working of titanium Grade 4.

Exploitation of the color spectrum

The large color spectrum produced by the anodic oxidation can be used for the benefit of the jewelry industry (Table shows 58 various distinct colors), and for fast recognition or identification, as for example in the medical field.



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Physical properties

Properties	Unit	Temperature (°C)				
		20	200	300	400	500
Density	g cm^{-3}	4.51				
Young modulus E	GPa	105-110	92	85	78	72
Modulus of compression	GPa	110				
Shear modulus	GPa	45				
Poisson coefficient	-	0.31-0.37				
Thermal Conductivity	$W.m^{-1}.K^{-1}$	17	15	15	15	15
Electrical resistance	$\Omega.mm^2.m^{-1}$	0.55	0.58	0.595	0.605	0.615
Thermal expansion	$W.m^{-1}.K^{-1}$	20–100°C	20–200°C	20–300°C	20–400°C	20–500°C
	10^{-6}	8.6	8.9	9.5	9.6	9.7
Magnetic susceptibility	10^{-6}	3.4	3.5	3.6	3.9	4.0
Specific heat	$J.g^{-1}.K^{-1}$	0.523				
Emissivity (1-10) visible ligth	-	0.3				
Reflexion coefficient	-	0.56				
Melting range	°C	1665-1677				
Allotropic α/ß transus	°C	913				
α structure cubiqc centered	°C	≥913				
ß structure hexagonal	°C	≤913				
Magnetic relative permeability µr at	955 $H.m^{-1}$	1.00005-1.0001				

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