Titanium and Titanium Alloy Grade Density Guide

— Technical Department Purpose: Foreign trade quotation weight calculation, customer technical communication, process calculation reference Note: Densities below are industry-standard values (commonly used in ASTM/GB systems).

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1. Why Do Different Grades Have Different Densities?

Pure titanium has a density of approximately **4.51 g/cm³**. Differences in density between titanium alloy grades are **fundamentally determined by the type and content of alloying elements**:

Alloying Element	Density (g/cm³)	Relative to Ti	Effect on Alloy Density
Al (Aluminum)	2.70	Lighter	**Decreases** density
V (Vanadium)	6.11	Heavier	Slightly increases
Mo (Molybdenum)	10.22	Heavier	**Significantly increases**
Sn (Tin)	7.31	Heavier	Increases
Zr (Zirconium)	6.51	Heavier	Increases
Pd (Palladium)	12.02	Heavier	Minor effect (trace addition)
Ni (Nickel)	8.90	Heavier	Increases
Si (Silicon)	2.33	Lighter	Minor effect (trace)

Summary of the pattern:

Commercially pure titanium

- (Gr1–4): 4.51 g/cm³, no alloying elements

α+β alloys

- (TC4, etc.): higher Al content → density drops to 4.43–4.48

β alloys / β-rich alloys

- (TB8, TC19, etc.): high content of high-density elements such as Mo and V → density rises to 4.65–4.90

Nickel-titanium alloy

- (NiTi): Ni content ~55% → density rises substantially to ~6.45

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2. Density Reference Table by Grade

2.1 Commercially Pure Titanium

GB	ASTM	ISO	Nominal Composition	Density (g/cm³)	Remarks
TA1	Gr1	ISO 5832-2	CP Ti (ultra-low O)	**4.51**	All CP Ti calculated uniformly at 4.51
TA2	Gr2	ISO 5832-2	CP Ti (standard)	**4.51**	Most widely used grade
TA3	Gr3	—	CP Ti (high O)	**4.51**	
TA4	Gr4	—	CP Ti (highest O)	**4.51**	

CP Ti grades Gr1–4 contain essentially no alloying elements; density is identical at 4.51 g/cm³.

2.2 Common α / α+β Alloys

GB	ASTM	ISO	Nominal Composition	Density (g/cm³)	Remarks
TC4	Gr5	ISO 5832-3	Ti-6Al-4V	**4.43**	Workhorse grade; Al

					lowers density
TC4ELI	Gr23	ISO 5832-3	Ti-6Al-4V ELI	**4.43**	Same density as TC4
TA7	Gr6	—	Ti-5Al-2.5Sn	**4.48**	
TA18	Gr9	—	Ti-3Al-2.5V	**4.48**	
TA15	—	—	Ti-6Al-2Zr-1Mo-1V	**~4.50***	*Estimated; verify against standard

2.3 Corrosion-Resistant Titanium Alloys

GB	ASTM	Nominal Composition	Density (g/cm³)	Remarks
TA9	Gr7	Ti-0.2Pd	**4.51**	Pd is trace; close to CP Ti
TA9-1	Gr11	Ti-0.2Pd (low O)	**4.51**	
TA10	Gr12	Ti-0.3Mo-0.8Ni	**4.51**	Close to CP Ti

2.4 High-Temperature Titanium Alloys / β Alloys (β-rich)

GB	ASTM	Nominal Composition	Density (g/cm³)	Remarks
TA19	Ti6242S	Ti-6Al-2Sn-4Zr-2Mo-0.1Si	**4.54**	Aero-engine high-temp parts
TC19	Ti6246	Ti-6Al-2Sn-4Zr-6Mo	**4.65**	High Mo content; density notably higher
TB8	Ti-15-3-3-3	Ti-15Mo-3Al-3Nb-0.2Si	**~4.82***	*Estimated; Mo as high as 15%, verify

TB6	Ti-10V-2Fe-3Al	—	**~4.65***	*Estimated; verify

2.5 Nickel-Titanium Alloys (Shape Memory / Superelastic)

Grade	Nominal Composition	Density (g/cm³)	Remarks
TiNi-SS / TN3 / TNC	Ni ≈ 54.5–57%	**~6.45**	High Ni content; far denser than CP Ti
TiNi-01 / TiNi-02	Ni ≈ 54.8–55.8%	**~6.45**	

*NiTi density is approximately **1.43× that of pure titanium**. Never calculate NiTi weight using titanium density in quotations.*

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3. Five Practical Applications of Density in Business

3.1 Weight Calculation (Most Common)

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Weight (kg) = Volume (m³) × Density (kg/m³)
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Unit conversion: 1 g/cm³ = 1000 kg/m³

Material	Density (g/cm³)	Converted (kg/m³)
CP Ti Gr1–4	4.51	4510
TC4 / Gr5	4.43	4430
TC19 / Ti6246	4.65	4650
NiTi	6.45	6450

Bar (cylinder): Weight = π/4 × D²(mm²) × L(mm) × Density / 1,000,000

Sheet/Plate: Weight = Length(m) × Width(m) × Thickness(mm) × Density

3.2 Grade-Specific Quotation (Prevent Losses)

For the same volume, weight differences between grades can exceed **10%**:

Comparison	Density Difference	Weight Difference for 100

		pcs Φ50×1000mm Bars
TC4 (4.43) vs CP Ti (4.51)	1.8%	≈ 35 kg
TC19 (4.65) vs TC4 (4.43)	4.9%	≈ 95 kg
NiTi (6.45) vs CP Ti (4.51)	43%	≈ 850 kg

Conclusion: For large-tonnage orders, using the wrong density can cause losses of thousands to tens of thousands of RMB. Always calculate by grade.

3.3 Freight and Packaging Cost

Sea and air freight is charged by weight. Density differences directly amplify shipping cost differences (especially for NiTi and TC19-class materials).

3.4 Customer Technical Communication

- "Why is TC4 lighter than CP titanium?" → Because 6% Al content lowers the overall density
- "Why is titanium half the weight of steel but stronger?" → Ti density 4.51 vs steel 7.85; TC4 strength ≥ 895 MPa
- Specific strength (strength/density) concept: TC4 specific strength ≈ 895/4.43 ≈ 202 MPa·cm³/g, superior to most steels

3.5 Process Calculations

- Forging/rolling billet weight: compression ratio calculated from ingot density and volume
- Heat treatment loading: weight converted by density to control furnace load volume
- UT reference-block counterweighting: prepared per actual grade density

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4. Common Misconceptions (Frequent in Foreign Trade)

Misconception	Correct Practice
All titanium calculated at 4.51	Alloy densities differ: TC4 = 4.43, TC19 = 4.65, NiTi = 6.45

Density ≈ grade strength	Density is unrelated to grade strength; it depends only on alloying element type and content
ELI has lower density	TC4ELI has the same density as TC4 (4.43). ELI only reduces interstitial elements O/C/N, not the primary element ratios
Theoretical density gives exact results	Actual ingots/sheets vary ±0.5% due to composition micro-differences; for batch orders, re-verify against actual measured density per heat

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5. Quick-Reference Card

Category	Grades	Density g/cm³
CP Titanium	TA1–TA4 / Gr1–4	4.51
α+β Workhorse	TC4 / Gr5 / TC4ELI	4.43
α Alloys	TA7 / TA18	4.48
Corrosion-Resistant	TA9 / TA10	4.51
High-Temperature	TA19	4.54
High-Temperature	TC19 / Ti6246	4.65
β Alloys	TB8 / Ti-15-3-3-3	~4.82*
NiTi	TiNi series	~6.45

* Grades marked "Estimated" (TB8/TB6/TA15): for formal quotations, request the measured density from the raw material supplier's material test certificate or calculate from heat data.

This document was prepared by the Technical Department for internal quotation, process, and customer communication use.