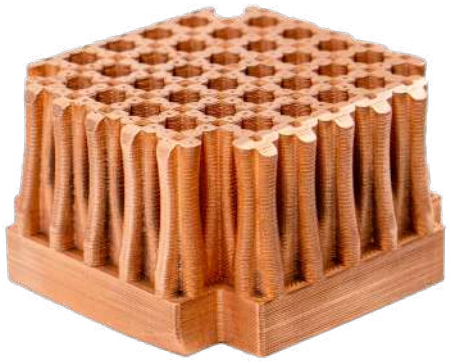
MATERIAL DATASHEET

Copper

Copper is a soft, ductile metal used primarily for its electrical and thermal conductivity. Copper's high conductivity makes it an ideal material for many heat sinks and heat exchangers, power distribution components such as bus bars, manufacturing equipment including spot welding shanks, antennae for RF communications, and more. The ability to print pure copper using Metal X enables geometrically optimized parts that were previously expensive, time consuming, or impossible to make.

Composition	Amount
Copper	99.8% min
Oxygen	0.05% max
Iron	0.05% max
Other	bal



Typical Mechanical Properties	Standard	Temp	Print Setting/ Orientation	Markforged As-Sintered	MIM Standard
Ultimate Tensile Strength	ASTM E8	Room Temp	Solid XY	193 MPa[1]	207 MPa
0.2% Tensile Yield Strength	ASTM E8	Room Temp	Solid XY	26 MPa[1]	69 MPa
Elongation at Break	ASTM E8	Room Temp	Solid XY	45%[1]	30%
Relative Density	ASTM B923	Room Temp	Solid	98%[2]	98%
Electrical Conductivity	ASTM E1004	Room Temp	Solid XY	84% IACS[3]	—
Thermal Conductivity	ASTM E1461	Room Temp	Solid XY & Z	350 W/mK[4]	328 W/mK
Coefficient of Thermal Expansion	ASTM E831-19[5]	68-100°F		9.6 x 10^{-6}/°F	8.7 x 10^{-6}/°F
	ASTM E228	68-150°F		9.7 x 10^{-6}/°F	8.9 x 10^{-6}/°F
		68-200°F		9.8 x 10^{-6}/°F	9.1 x 10^{-6}/°F
		68-250°F	Solid Z	9.9 x 10^{-6}/°F	9.3 x 10^{-6}/°F
		68-300°F		10.0 x 10^{-6}/°F	9.4 x 10^{-6}/°F
		68-500°F		10.1 x 10^{-6}/°F	—
		68-750°F		10.5 x 10^{-6}/°F	—

See following page for full mechanical property data at multiple orientations and print settings.

1. Tensile bars are sub-sized and are sliced with default copper settings except raft is turned off. Copper defaults to solid parts. For leak resistant the Leak Resistant (Alpha) setting is used.
2. Density is based on a theoretical value of 8.96g/cc.
3. Electrical conductivity, when evaluated with eddy current instruments, is usually expressed as a percentage of the conductivity of the International Annealed Copper Standard (% IACS). The conductivity of the Annealed Copper Standard is defined to be 0.58 × 108 S/m (100 % IACS) at 20°C.
4. Thermal diffusivity measured per ASTM E1461. Diffusivity was converted to Conductivity using, Thermal Conductivity = Thermal Diffusivity * Density * Specific Heat. Assuming specific heat of Copper = 0.385 J/g-K per "Handbook of Chemistry and Physics 72nd Edition."
5. Markforged as-sintered Coefficient of Thermal Expansion (CTE) was measured by a 3rd party lab using Thermal Mechanical Analysis (ASTM E831). The MIM handbook reference used a Push Rod Dilatometer (ASTM E228)

These data represent typical values for Markforged Copper as-sintered. Markforged samples were printed with Solid Infill setting. All values based on 3rd party testing except for relative density which was tested by Markforged. These representative data were tested, measured, and calculated using standard methods and are subject to change without notice. Markforged makes no warranties of any kind, express or implied.

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Copper

Full Mechanical Properties	Standard	Temp	Print Setting/ Orientation	Markforged As-Sintered	MIM Standard
Ultimate Tensile Strength	ASTM E8	Room Temp	Solid XY	193 MPa[1]	207 MPa
			Solid Z	117 MPa[1]	
			Leak Resistant XY	197 MPa[1]	
			Leak Resistant Z	141 MPa[1]	
0.2% Tensile Yield Strength	ASTM E8	Room Temp	Solid XY	26 MPa[1]	69 MPa
			Solid Z	26 MPa[1]	
			Leak Resistant XY	31 MPa[1]	
			Leak Resistant Z	32 MPa[1]	
Elongation at Break	ASTM E8	Room Temp	Solid XY	45%[1]	30%
			Solid Z	15%[1]	
			Leak Resistant XY	58%[1]	
			Leak Resistant Z	15%[1]	