PROTIQ
A Phoenix Contact Company



MATERIAL EXPERTISE

COPPER 3D PRINTING AT PROTIQ

Inductors, heat exchangers and cooling components made of highly conductive copper

since 2013
Copper 3D printing

58 MS/m
electrical conductivity (pure copper, 100% IACS)

415 W/(m·K)
thermal conductivity (pure copper)

4
copper materials on the PROTIQ Marketplace

COPPER: IDEAL FOR ELECTRICITY AND HEAT, DEMANDING IN 3D PRINTING

Copper conducts electricity and heat better than almost any other technical metal. This makes it the material of choice for parts that carry current or dissipate heat: inductors, heat sinks, heat exchangers and busbars. In 3D printing, they are made directly from CAD data and without tooling – even in geometries that are hardly possible to produce conventionally, such as parts with integrated cooling channels.

At the same time, copper is one of the most demanding materials in 3D printing: it cannot be processed reliably with standard parameters. What it takes is experience in process development and material control – and PROTIQ has it like hardly anyone else: we were the first provider worldwide to process highly conductive copper by laser melting and are today one of the leading specialists in copper 3D printing.

THREE REASONS WHY COPPER IS DIFFICULT

Reflection

Copper reflects a large part of the incident laser energy. Melting the powder is much more difficult than with stainless steel, for example.

Heat conduction

Heat flows away from the melt zone very quickly. Material, laser, process control and geometry must be precisely matched.

Purity

Even small impurities or oxygen reduce conductivity. Powder handling, shielding gas and quality assurance are crucial.

How we manufacture: selective laser melting (SLM)

The system applies copper powder layer by layer onto a build platform. A laser melts it precisely where the part is created – directly from the CAD data and in one piece.



FROM “IMPOSSIBLE” TO SERIES MATERIAL

2011 “Copper in laser melting? Impossible.” – that was the common view.

2012 Our self-developed laser melting system runs for the first time.

2013 Test series with Fraunhofer; breakthrough at the end of 2013: the first provider worldwide to process highly conductive RS copper by laser melting.

2014 Copper inductors in series production, in industrial quality.

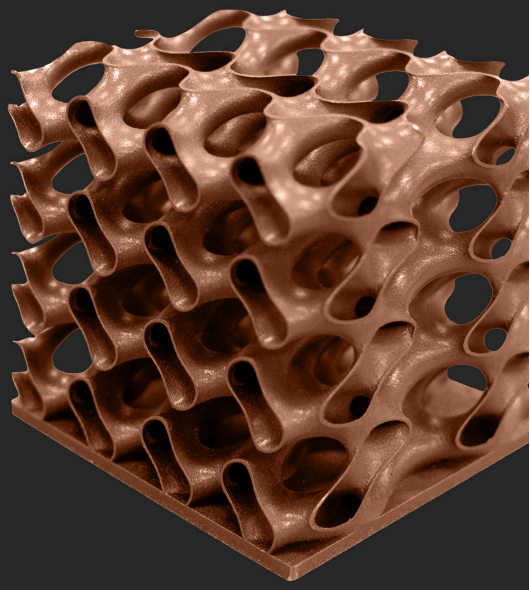
2015 Simulation-based optimization of inductors.

2018 Series process for pure copper – 100% copper.

2019 The first provider worldwide to offer pure copper for online ordering on protiq.com.

2022 Best values for density and conductivity – according to AM Power, “Study on Additive Manufacturing of Copper”.

2025 Pure copper low-O_2 for particularly high purity.



WHAT SETS PROTIQ APART IN COPPER 3D PRINTING

Pioneer in copper 3D printing

Since the world’s first breakthrough in 2013, we have continuously refined powder qualities, scan strategies and process parameters for copper.

Our own materials and processes

We manufacture pure copper, pure copper low-O_2 and RS copper ourselves – tailored to each application.

Engineering for inductors

From the inductor configurator and custom shapes to simulation-based optimization.

Proven in practice

In a customer project, optimized 3D-printed induction coils lasted 4 to 6 times longer.

COPPER MATERIALS AT A GLANCE

Four copper materials are available on the PROTIQ Marketplace. PROTIQ manufactures pure copper, pure copper low-O_2 and RS copper in its own production.

Material	Key features	Electrical conductivity	Thermal conductivity	Typical parts
Pure copper	100% copper, highest electrical and thermal conductivity	58 MS/m	415 ± 10 W/(m·K)	Inductors, heat sinks, heat exchangers, busbars
Pure copper low-O_2	Particularly low in oxygen, for high purity	on request	on request	Electronics cooling, inductors, low temperatures
RS copper	In use since 2013, proven for inductors	51 MS/m (edge), 32 MS/m (core)	265 W/(m·K)	Inductors
CuCr1Zr	Alloy with higher strength and hardness	on request	on request	Contact parts, electrodes

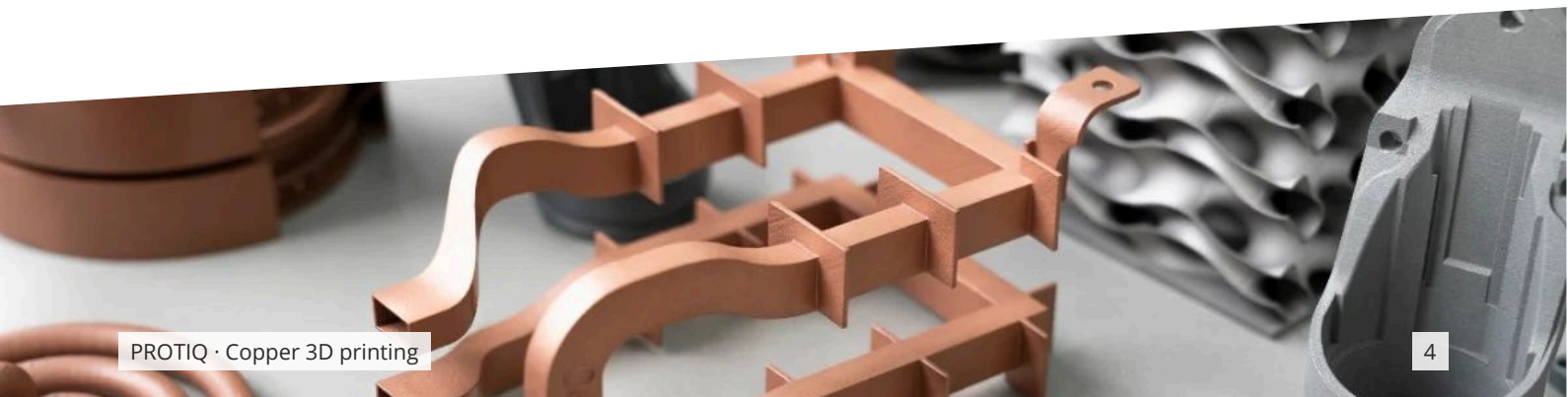
Pure copper

Electrical conductivity	**58 MS/m**
Thermal conductivity	**415 ± 10 W/(m·K)**
Density	**8.9 g/cm³**
Tensile strength (as built)	**220 ± 10 MPa**
Yield strength Rp0.2 (as built)	**140 ± 20 MPa**
Elongation at break (as built)	**50 ± 10 %**

RS copper

Electr. conductivity (edge / core)	**51 / 32 MS/m**
Thermal conductivity	**265 W/(m·K)**
Density	**8.7–8.9 g/cm³**
Minimum wall thickness	**0.6 mm**
Media-tight from wall thickness	**1 mm**
Leak test	**6 bar compressed air**

Values according to the PROTIQ material data sheet; values for pure copper low-O_2 and CuCr1Zr are available on request. Choose the right material for your part in the configurator – or ask us directly. We are happy to advise you.



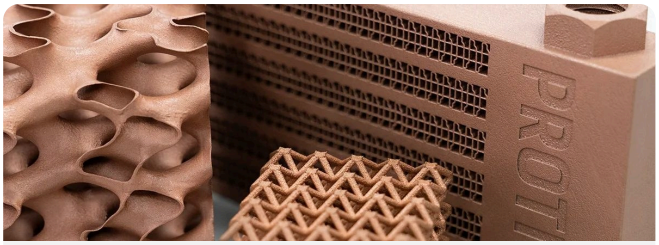
WHAT 3D-PRINTED COPPER IS USED FOR

Wherever current has to be conducted or heat dissipated – and geometry makes the difference.



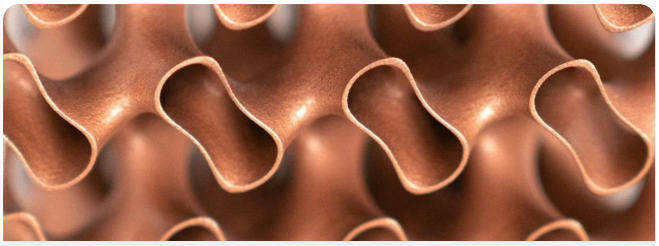
Inductors

Hollow copper coils with integrated cooling channels for induction heating – precisely matched to the workpiece, also configurable online.



Heat exchangers and heat sinks

Curved cooling fins, lattice and gyroid structures and integrated channels increase the surface area and improve heat transfer.



Data centers and electronics cooling

Cold plates and cooling components with freeform cooling channels – from chip cooling to liquid cooling in data centers.



Busbars and conductor structures

Current-carrying parts precisely adapted to the available space – in geometries that are only possible to a limited extent conventionally.



Functional prototypes

Contact parts, connectors and conductor structures such as hairpin windings for electronics and electric motors – fast and without tooling.



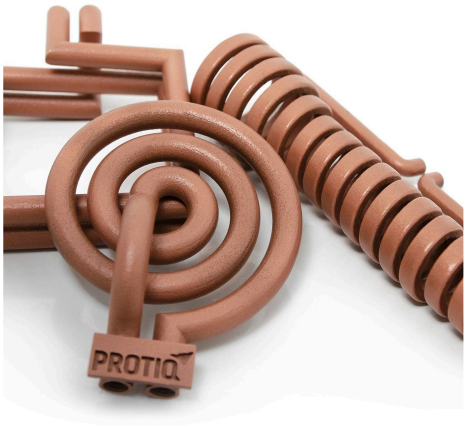
Low temperatures

In cryogenic applications, even small impurities reduce conductivity. This is where the high purity of pure copper low-O_2 comes in.

COPPER INDUCTORS

PROTIQ manufactures inductors for induction heating from 100% copper by selective laser melting – in one piece, without brazed or welded joints and directly from CAD data.

In induction heating, the heat is generated directly in the workpiece – where the coil induces eddy currents. The more precisely the inductor is matched to the workpiece, the more accurately the heat can be controlled. That is why every part geometry needs its own inductor.



Surface hardening

Highly stressed parts such as gear components are heated locally and quenched – for greater surface hardness.

Induction brazing

Two parts are heated precisely and evenly and joined with a filler metal.

Hot forging

Parts are heated before forming – with a precise inductor only where needed.

MANUFACTURING COMPARED

	Bending and brazing	CNC milling and joining	3D printing (SLM)
Production	Manual bending and brazing	Milling from solid, then welding or brazing	Directly from CAD data, in one piece
Geometry	Only relatively simple shapes	More complex shapes	Adapted to the workpiece, including rectangular or flattened profiles
Cooling channels	–	Only by joining individual parts	Directly integrated
Joints	Brazed joints	Welded or brazed seams as potential weak points	None
Effort	Very laborious, low repeatability	Time-consuming and costly	No tooling, high repeatability, delivery in a few days

BENEFITS AND DESIGN

- Custom inductor geometries without tooling costs
- Integrated cooling channels and very compact designs
- Longer service life thanks to the seamless design
- Free cross-sections and coil shapes, minimal bending radii
- Exact implementation of CAD data, high repeatability
- More precise heating and shorter cycle times

DESIGNING INDUCTORS CORRECTLY

250 × 250 × 280 mm
Part size in one piece; larger inductors in segments

from 1.0 mm
Wall thickness with guaranteed tightness up to 6 bar air pressure

approx. 3 mm
Minimum inner diameter, so that the build powder can be completely removed

approx. 1–2 mm
Spacing between turns, so that support structures can be removed

Any cross-section
Round, rectangular, flattened or freeform

No joints
No welded or brazed seams, even with complex shapes

Combine
Inductor head printed, connection jaws conventional – often the most economical option

Coordinate early
For delicate shapes, we are happy to check your design in advance

Guide values for the phase in which your CAD data is created; the values actually possible depend on the geometry. Thinner walls from approx. 0.5 mm are possible by arrangement, but without a tightness guarantee.



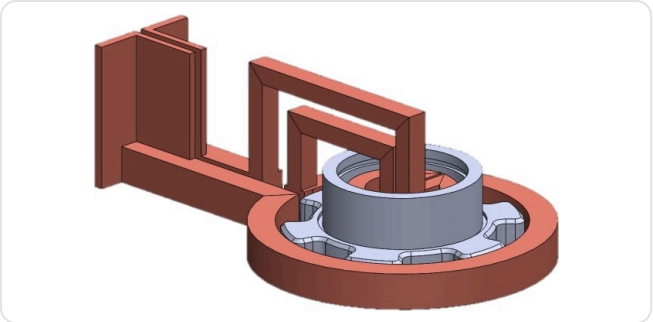
"Companies benefit significantly from additive manufacturing in the design and use of copper inductors. Short delivery times, greater design freedom and high repeatability create measurable advantages: optimized coil shapes increase the efficiency of the heating process and reduce cycle times."

Max Wissing, Technical Sales, PROTIQ GmbH



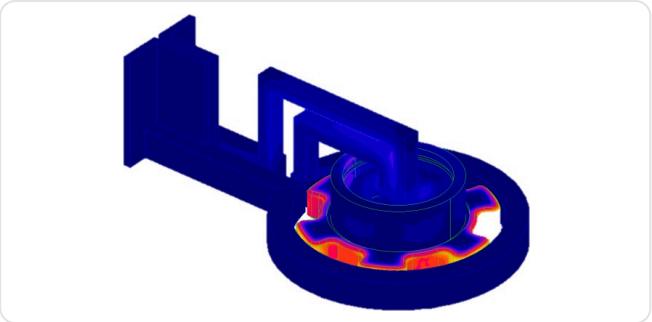
SIMULATION AND OPTIMIZATION

Conventionally, many trial geometries are produced and tested in real heating trials before the optimal coil is found. With numerical simulation, we make the coil's behavior visible, determine an optimized geometry – and then manufacture it from highly conductive copper.



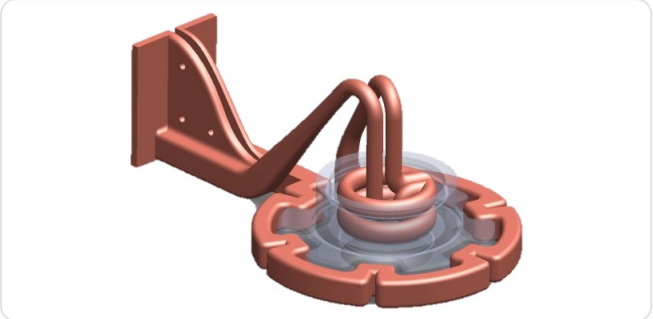
1 Starting point

Bent and brazed inductor: the coil shape follows the largest diameter, so the workpiece is heated unevenly.



2 Simulation

The simulation shows temperature distribution, current density and magnetic field – and where the part gets too hot or too cold.



3 Optimized geometry

The coil hugs the part evenly – for uniform temperatures. Hardly possible to produce conventionally.



4 Printed inductor

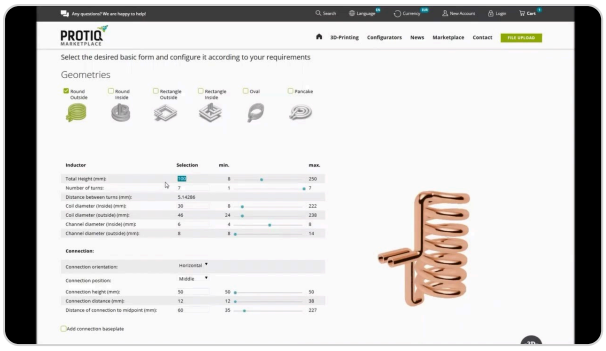
Laser-melted from copper: more consistent part quality, less scrap and shorter cycle times.

YOUR BENEFITS

- Insight into otherwise invisible process influences
- Coils with ideal properties for your process
- Fewer real trials – saving time and costs
- Optimized pure copper coils in just a few days

THE INDUCTOR CONFIGURATOR

For simple coil shapes, you do not need a CAD program: in the free configurator, you adapt one of six basic shapes using a modular principle. The price is calculated automatically, and production can start right after you order.



1 **Choose a basic shape**
Six standard shapes for internal and external field inductors.

2 **Configure inductor**
Height, cross-section, diameter, turns, coil and channel dimensions.

3 **Define connection**
Optionally with holder and custom base plate.

4 **Order**
Automatic online price, can be ordered directly in pure copper or RS copper.

- No CAD skills needed, intuitive operation
- More than 20 parameters, real-time price
- Guaranteed printability of every configuration
- Delivery a few days after ordering

HOW TO GET YOUR INDUCTOR

SIMPLE COIL SHAPE

Configure inductor online

Choose a basic shape, adapt it and order directly.

EXISTING DESIGN

Upload CAD data

Choose a copper material, receive a quote automatically, order online.

CUSTOM SHAPE AND OPTIMIZATION

Discuss your project

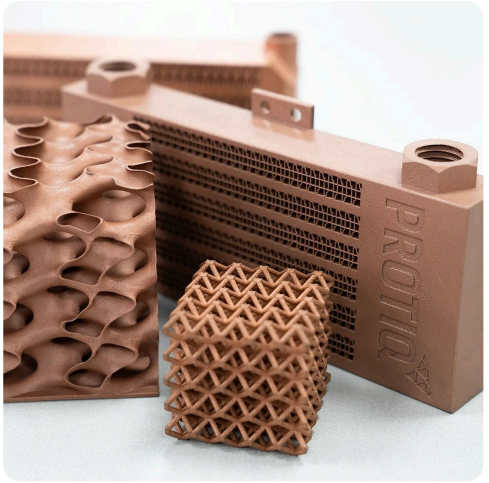
For complex geometries or simulation, we advise you personally.

Configure your inductor online now protiq.com/induktor-konfigurator ▶

HEAT EXCHANGERS AND HEAT SINKS

3D printing produces heat exchangers and heat sinks with internal channels, gyroid and lattice structures – more surface area for heat transfer in less space.

Channels, surfaces and wall thicknesses are designed for function rather than the limits of the tool. Since no tooling is needed, this pays off even for prototypes, functional samples, one-offs and small series.



STRUCTURES THAT MAKE THE DIFFERENCE

Gyroid structures

Divide the space into two separate, intertwined channel systems – ideal for guiding two media past each other.

Lattice structures

Fine, open lattices increase the surface area with little material and weight.

Freeform channels

Follow the contour of the heat source – for uniform heat transfer and low pressure loss.

Fins and cooling pins

Three-dimensionally curved or densely arranged – for better heat transfer to air or liquid.

Copper or aluminum?

Material	Thermal conductivity	Density	Suitable for
Pure copper	415 ± 10 W/(m·K)	8.9 g/cm³	Maximum heat transfer in a small space, e.g. cold plates
Aluminum (AlSi10Mg)	103 ± 5 W/(m·K)	2.67 g/cm³	Lightweight heat exchangers when weight matters

Copper conducts heat about four times as well as AlSi10Mg; aluminum weighs only about a third. The medium, corrosion and mechanical load also play a role. Values according to the PROTIQ material data sheet, laser-melted.

Power electronics | Data centers | Industry and mechanical engineering | Electric drives and battery systems | Medical technology

DATA CENTERS AND BUSBARS

AI and high-performance computing are driving up power densities – cooling is becoming the central task. Conventional air cooling is reaching its limits, and liquid cooling is gaining importance. 3D-printed copper enables cooling components that can hardly be produced conventionally.



Cold Plates

Cooling channels are integrated directly into the plate and guide the coolant precisely to the hotspots – with low pressure loss and therefore less pumping energy.

Heat sinks

Lattice structures, complex fins and organically optimized cooling surfaces increase the surface area – particularly effective with copper.

Heat exchangers

Flow channels for uniform heat transfer and low pressure loss in less space.

- Freeform cooling channels instead of straight bores
- Designed for low pressure loss
- More cooling surface in the same space
- Several functions in one part

Busbars and power distributors

GPU clusters and AI applications need reliable power distribution with rising power densities and little space. 3D printing produces pure copper busbars, power distributors and connectors that are precisely adapted to the available space – ideal for complex geometries, prototypes and small series.



YOUR COPPER PROJECT WITH PROTIQ

Manufactured in Blomberg, ISO 9001 certified – and with individual quality assurance on request.

Testing methods we offer

- **Conductivity** by eddy current testing
- **Dimensional accuracy** by computed tomography and fringe projection
- **Hardness** according to Vickers (DIN EN ISO 6507)
- **Surface roughness** by stylus profilometry
- **Tightness** by pressure test with compressed air up to 6 bar
- **Part density** using the Archimedes method
- **Strength** by tensile test (DIN EN ISO 6892)
- **Microstructure** by metallographic examination

Upload file

Upload 3D data to protiq.com, choose a copper material, see the price instantly.

Configure inductor

Simple coil shapes in the free inductor configurator.

Discuss your project

Custom shapes, simulation or low-O_2: **+49 5235 34 38 00**

This brochure and more to download

Information material in the **download area**, technical articles on copper and inductors at **protiq.com/downloads**.

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