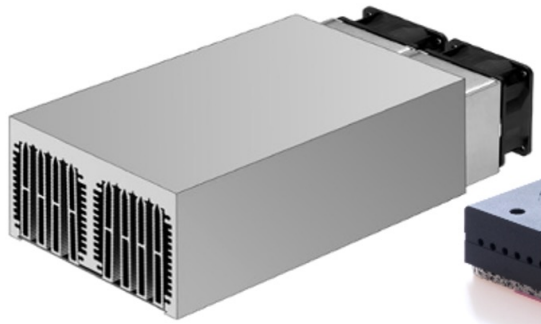
porecool
porous cooling systems

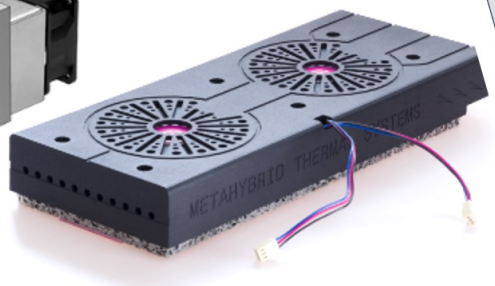
UNIQUE WORLDWIDE

BEFORE | **AFTER** | **NEW WORLD OF COOLING SYSTEMS AND HEAT STORAGES**

with many new features

64% smaller
69% lighter
high added value





FOR ELECTRONICS, MACHINES, DATA CENTRES, PLASTIC PARTS AND MORE

Think differently. Cool better.

INDUSTRIE PREIS 2018 BEST OF — METAHYBRID Components BEST OF Solution in R&D Industry Award, Germany

THIN KING — OPENPORE Aluminum Lightweight Technology Award Baden-Württemberg, Germany

THIN KING — METAKER® Surface Lightweight Technology Award, Baden-Württemberg, Germany

NEW, INDIVIDUAL, HIGH-PERFORMANCE, COMPACT, LIGHTWEIGHT, MULTIFUNCTIONAL COOLING SYSTEMS

Efficiency of cooling systems depends directly on material properties, size of heat transfer surface, shape and surface properties of the solid, fluid properties, flow form, flow velocity, viscosity and thermal conductivity.

POREC OOL cooling systems are made from open-pore chill cast aluminum. This new class of materials differs substantially from foamed, sintered or 3D-printed materials and has many new features and heat transfer phenomena that are attractive for high-performance thermal management.

The technological novelty of PORECOOL cooling systems generates the new engineering knowledge and new potentials that cannot be realized with other technologies.

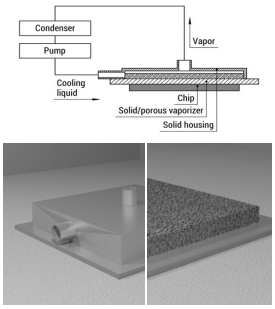
NEW CAPABILITIES INCLUDE

- direct transfer of heat from hot spots to carrier media by a conduction-convection mechanism,
- better efficiency with smaller dimensions and weight,
- better flow acoustics and directional independence of the cooling circuit,
- enormous design freedom for heat sinks, flow circuits, board layouts, device designs and component packages,
- enormous integration capability in installation spaces, hybrid systems and function bundles and much more.

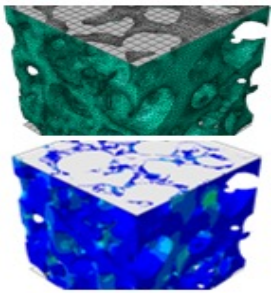
OUR OFFER

Consulting | Product development | Prototyping | Production

Development



Simulation



Manufacturing

Functional surfaces

Multifunctionality

CASE STUDY

MANAGEMENT SUMMARY.

Novel PORECOOL cooling systems are made from open-pore chill cast aluminum – an established series technology. This new class of materials defines the next step in the evolution of thermal components and systems with new thermal management potentials, that cannot be realised with other technologies.

Hundreds of possible material variants, novel multi-material systems, new heat transfer phenomena and optionally modified material properties form a completely new world for strategic product development. That requires new special knowledge, new way of thinking and application-specific hypothesis-driven approach.

This document shows a partial result of a agile design sprint in the preliminary investigation phase of the PORECOOL innovation process.

New improvement opportunities for thermal components and systems include

Efficiency, weight, dimensions, resilience, multifunctionality, integrations, lifetime, acoustics, air/water flow, filtration and dust protection, new boards layouts and devices designs, sustainability, strategis customer value.

Possible applications for thermal redesign

Heat sinks, heat exchangers, evaporators, condensers, mechanical and electrical machines, enclosures, heat accumulators, energy storages, solar thermal collectors, exhaust systems, catalysts, plastic parts, aluminum parts and much more.

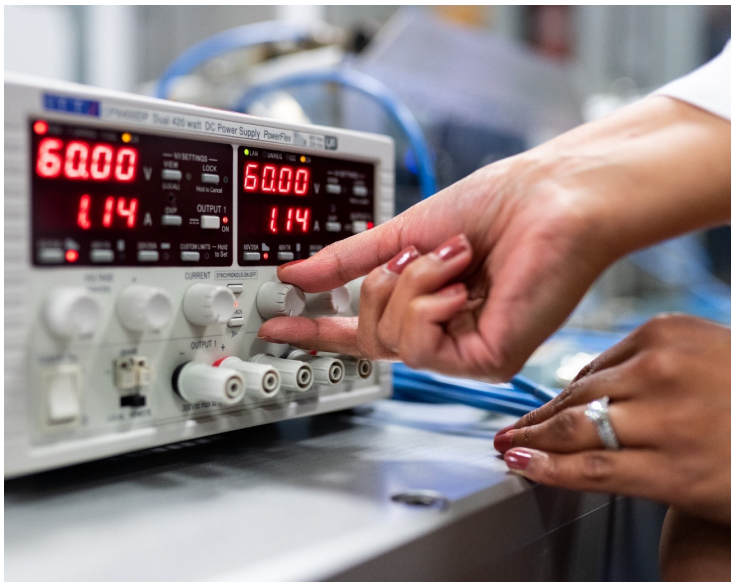
CHALLENGE.

A manufacturer of electronic power amplifiers uses conventional aluminium profile heat sinks for electronics cooling, which account for about 30% of the total weight of the device.

Due to increasing power dissipation in new generations of equipment, even larger heat sinks are needed. This complicates system design and integration, increases the weight of the systems and leads to higher storage, shipping and assembly costs.

Strategic innovation development is aimed at developing lighter and more compact cooling systems that can still ensure efficient heat dissipation from electronic components.

In the search for new technologies, the customer became aware of PORECOOL cooling systems.



SOLUTION APPROACH.

Kick-off.

In a technology workshop, the problem and solution spaces were discussed, hypotheses developed and the objective for the first feasibility study defined.

The objectives.

Focus on design-to-cost for prototypes and series production.

Waiver of many possible optimisation potentials.

At least similar performance like conventional finned heat sink with less dimensions or weight.

The solution approach.

Concept design with price indication for series production.

DoE samples and tests concept, so that maximum information is obtained with minimum test effort.

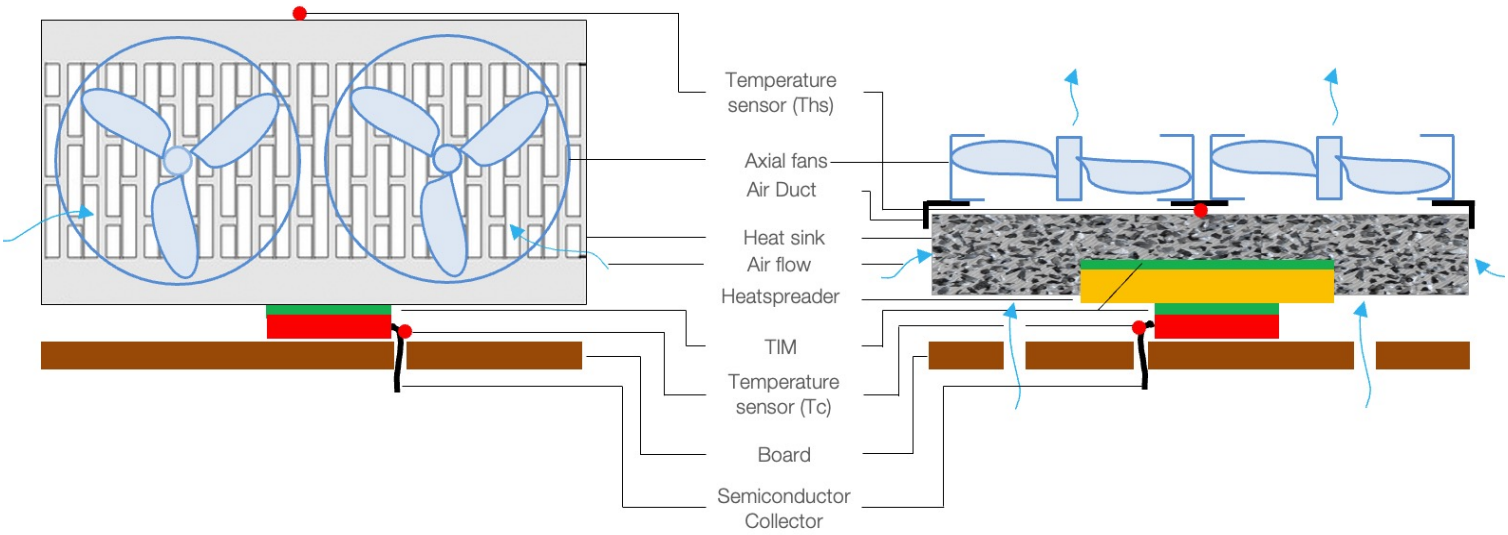
Physical tests on the product, without laboratory measurements or digital simulations.

Direct comparison of performance and price with conventional finned heat sink.

CASE STUDY

EXPERIMENTAL SETUP AND TEST RESULTS.

Conventional finned heat sink | **PORECOOL heat sink (pore size 3-5 mm)**



Parameter	Finned heat sink	PORECOOL heat sink	Advantages of PORECOOL
Installation space without fans, (cm^3)	2.303	819	-64%
Weight, (kg)	3,56	1,1	-69%
Specific surface, (m^2/m^3)	391	760 test sample pore size 3-5 mm	+94%
		1.400 possible alternative pore size 1,6-3 mm	+258%
Material / thermal conductivity, (W/mK)	AlMgSi0,5 / 200	AlSi7 / 160 test sample	-20%
		Al99,5% / 236 possible alternative	+18%
Price for 1.000 pcs., without fans	100%	<100%	system-specific

CASE STUDY

TEST PARAMETERS

Vmain: 220V, Rload: 1 ohm

Output power loss: 300W

Thermal conductivity

Finned heat sink: H65mm, AlMgSi0,5, 200 W/mK

Porecool heat sink: H24mm, AlSi7, 160 W/mK

Heatspreader 1: H4mm, Copper, 400 W/mK

Heatspreader 2: H4mm, AlMg3, 135 W/mK

TIM: H0.175 mm, Graphit sheet, 7,5 W/mK

Fans

Axial: 12V, 70 m³/h

POSSIBLE OPTIMISATIONS.

In the next agile design sprints, the following can be optimized:

- Substitution of AlSi7 with Al99.5% to improve thermal conductivity,
- Modification of the pore morphology to improve the heat transfer coefficient,
- Optimisation of heat sink geometry, air flow and air ducts,
- Production of the porous heat sink and solid heatspreader as a mono-material hybrid to improve thermal conductivity and eliminate the TIM interface,
- Sound-absorbing and dust-protective integration of fans in the porous heat sink to reduce the installation space and improve the acoustics and lifetime.
- New concepts for board layout and device design, without restrictions imposed by conventional heat sinks.

DO YOU WANT TO IMPROVE YOUR PRODUCTS?

ALL FROM A SINGLE SOURCE SOLUTIONS.

Product development for strategis customer value.

We optimise existing or develop new thermal management systems for varios applications with better properties in terms of efficiency, weight, dimensions, resilience, multifunctionality, integrations, lifetime, acoustics, air/water flow, filtration and dust protection, new boards layouts , devices designs and sustainability.

Their properties cannot be realised using either conventional technologies or 3D printing.

Digital ptototyping.

We build and test digital prototypes from hundreds of PORECOOL material models with different pore sizes for various applications - from microelectronics to power plant heat storage.

Physical ptototyping.

Alternatively or in addition to digiatel prototypes, we build physical prototypes or minimum viable products (MVP) for a fast market launch.

Manufacturing.

The PORECOOL systems can be produced in small and very large quantities.

We develop the optimum system, procure the optimum components and organise the optimum series production for your project.

CUSTOMER FEEDBACKS

“It was very interesting. We definitely need to try out your ideas on test samples“.

M. M. / R&D Hardware, Automotive Tier-1

"The idea of having a heat sink the size of a bar of chocolate is really very tempting. We want to order the test samples“.

Dr. M. H. / CEO, Manufacturer power electronics

"We see an opportunity to strategically open up new markets with our products. Let us produce the test samples“.

A. H. / CTO, Heat exchanger manufacturer

"The METAHYBRID technology portfolio offers very many new approaches for our products. We would like to explore the first of these as soon as possible“.

M.W., Head of Adv. Eng., Automotive Tier-1.

„We have completed the tests. The results are promising“.

M. E. / Senior R&D Engineer, Manufacturer power electronics

BETTER THERMAL MANAGEMENT WITH PORECOOL COOLING SYSTEMS

PORECOOL cooling systems enable new, unconventional thinking and design of thermal applications with new technical, economic and ecological potentials.

They are based on functional and structural material innovations in the nano, micro and macro range of light metals, primarily aluminum and its alloys. They can be produced as completely or selectively open-pore monomaterials, monomaterial hybrids, multimaterial hybrids, and those with optionally modified pore surfaces or foreign materials integrated (e.g. thermally conductive) into the pore spaces or metal lattices.

The new properties include:

- direct transfer of heat from hot spots to support media through a conduction-convection mechanism,
- better efficiency with smaller dimensions and weight,
- better flow acoustics and directional independence of the cooling circuit,
- enormous design freedom for heat sinks, flow circuits, board layouts, device designs and component packages,
- enormous integration capability in installation spaces, hybrid systems and function bundles,
- novel modification of mechanical, thermal, electrical, optical and other surface properties,
- easier digitization (temperature and pressure sensors, antennas, signal lights, etc.),
- more sustainable series production in small, medium and large quantities.

New features and heat transfer phenomena

The efficiency of cooling depends directly on the material properties, the size of the heat transfer surface, the shape and surface properties of the solid, the fluid properties, the flow shape, the flow velocity, the viscosity and the thermal conductivity.

Conventional open-cell aluminum foams have been considered attractive candidates for convective heat transfer due to their properties such as low density, high specific surface area, and high permeability. As a better alternative, novel PORECOOL cooling systems offer many new possibilities in the design and performance optimization of thermal applications, unthinkable for conventional aluminum foams.

PORECOOL cooling systems are manufactured from open-pore chill cast aluminum as well as other metals and/or polymers. The porous cast aluminum is substantially different from foamed, sintered or 3D-printed materials and has many new properties attractive for product development and high-performance thermal management, as well as new heat transfer phenomena:

- sustainable gravity die casting process without the use of pollutants and chemicals,
- fine-grained and dense cast structure with very high strength values and approvals for waterproof applications,
- novel multimodal pore morphology and new heat transfer phenomena,
- flexibly adjustable pore sizes in the micro, meso and macro range,
- low density (0.8 -1.3 g/cm^3) and up to 20 times higher compressive strength than conventional aluminum foams,
- up to 8 times higher material volume and up to 10 times higher thermal conductivity than conventional aluminum foams,
- enormous variety of possible material settings, architectures and designs for a wide range of applications,
- any constructions and fastening systems (screwing, pressing, welding, soldering, gluing),
- manufacture as mono- and multi-material hybrids of metals and/or polymers,
- optional novel surface modification and combination with printed electronics (TIM, LED, RFID..),
- and much more.

NEW CLASS OF MATERIALS FOR CONVECTIVE HEAT TRANSFER

Convective heat transfer

Convective heat transfer in porous metals is difficult or impossible to describe analytically. In general, it depends directly on the size of the heat transfer surface and the heat transfer coefficient.

Size of the heat transfer surface

Porous aluminum components can be manufactured in any geometries and dimensions up to 800 mm from Al99,5% or Al alloys. Compared to standard heat sinks made of extrusion profiles, with the same design and comparable settings for fins / pores, they offer:

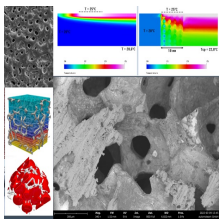
- 3x larger heat transfer surface area,
- 50% less weight,
- higher thermal conductivity of pure aluminum Al99.5%.

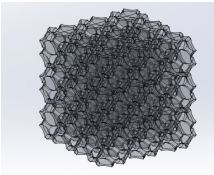
Compared to standard pin heat sinks, for the same design and comparable pin / pore settings, they offer:

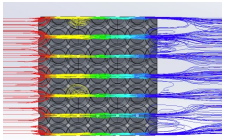
- 1.7x larger heat transfer surface area,
- 50% less weight,
- higher thermal conductivity of pure aluminum Al99.5%.

With complete use of the installation space provided for the conventional heat sink:

- 4.5x larger heat transfer surface area,
- 25% less weight than extrusion heat sinks and 70% more weight than pin heat sinks,
- higher thermal conductivity of pure aluminum Al99.5%.







Heat transfer coefficient

The heat transfer coefficient describes the ability of a gas or liquid to dissipate energy from the surface of a substance. It depends, among other things, on the material properties, flow characteristics, geometric conditions and surface properties.

Porous aluminum structures are open-cell, multimodal metal foams with peculiar pore morphology and enormous variety of architectures that determine their thermal and fluid dynamic behavior:

- hourglass-shaped pores with different sizes in micro, meso and macro scale,
- complex winding of passages with multiple 1-n, n-1 and n-n connections in one flow direction,
- multiple, spatially distributed micro and macro flows with laminar, turbulent and mixed regions,
- multiple, spatially distributed velocity ranges of micro and macro flows,
- solid aluminum matrix (30% - 60% material content) with very good thermal conductivity,
- adjustable properties for better heat transfer with different gases / fluids.

Current research results

The novel multimodal aluminum foams are still little researched. The first evidence from research projects confirms the following hypotheses:

- the pore morphology is the most important parameter for heat transfer,
- larger surface areas in porous metals do not automatically mean better heat transfer coefficient,
- depending on the pore morphology, the heat transfer coefficient can be significantly improved compared to heat sinks with fins, pins, fins, conventional aluminum foams or TPMS structures,
- for extremely large surface areas, as is the case with porous metals, the thermal conductivity of the material is secondary,
- depending on the pore morphology, 50% less material thermal conductivity can transfer 50% more heat,
- depending on the pore morphology, you can transfer 50% more heat with 20% less surface area.

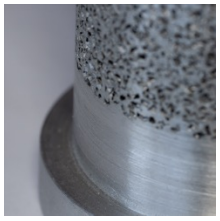
NEW LAYOUTS, DESIGNS AND OPTIMIZED INSTALLATION SPACES

New heat sink and device layouts

The components made of porous aluminum are classically machined and can be formed into any CNC-precise shapes. They are completely open-pored, independent of the flow direction of the cooling medium, and can therefore be integrated into any free installation space.

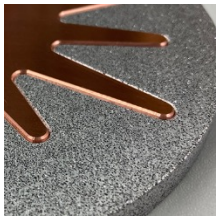
New heat-transferring structures and designs

Components made of porous aluminum are very resilient. They can take on load-bearing functions, offer further functional integration such as attachment points, form load-bearing or decorative housing structures, or completely enclose circuit boards with semiconductors as a kind of sound-absorbing cool box.



New aluminum monomaterial hybrids

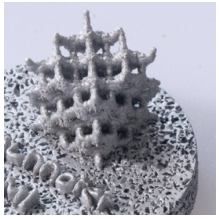
Many different aluminum hybrids can be made uniformly open-pore, graded open-pore, selectively open-pore, selectively solid, and many more. For example, the thermal contact point to the semiconductor can be locally solid aluminum.



New multi-material hybrids and metal matrix composites

Different components made of stainless steel, titanium, copper or aluminum can be integrated into the aluminum monomaterial hybrids. It can be done either directly in the casting process, or subsequently by pressing, welding, soldering, bonding, etc.

Various foreign materials can be added to the aluminum melt or NaCl placeholders as particles or short fibers. This opens up a new material area of open-pore metal matrix composites.

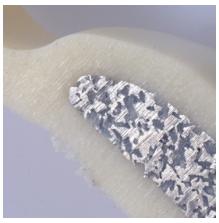


New additive aluminum hybrids

Porous cast aluminum components can be functionalized in additive manufacturing processes. The reverse is also possible - the additively manufactured aluminum parts can be integrated into the components made of porous cast aluminum.

New metal-polymer hybrids

The pores in porous aluminum structures can be infiltrated with polymers. This allows extremely strong, media-dense multi-material systems to be formed for mechanical, fluidic, thermal, chemical, acoustic decorative and other tasks.



New plastic parts with integrated heat sinks

The plastic parts have poor thermal conductivity (PP2 = 0.08 W/mK, PP6 and ABS = 0.17 W/mK, filled potting compounds 6 W/mK). Depending on the material setting, the air-filled open-pore OPENPORE aluminum structures have the thermal conductivity between 30 and 60 W/mK (the thermal conductivity of air = 0.026 W/mK).

They can be helium-tightly integrated into the plastic parts in the area of the hotspots in different ways: fully integrated into the plastic matrix (polymer outside and inside), with metallic contact to the hotspot, with metallic contact to the coolant, with metallic contact to the hotspot and coolant.

NEW MONO- AND MULTIMATERIAL STRUCTURES WITH NEW FEATURES AT THE MICRO AND MACRO LEVEL

Cohesively connected functional areas

One or more massive and open-pored functional areas. Material connection in the casting process. Any pore sizes from 10 µm can be set. Component sizes from 1.5 to 2,000 mm. The material density in the open-pored area is 0.8-1.3 g/cm^3.

Infiltration with materials

Complete or selective infiltration of open-pored functional areas with one or different materials in various primary molding processes (injection molding, thermoforming, resin transfer molding, etc.). Gas-tight, strong composite material without the use of chemicals.

Selective porosity

Separate open-pored functional areas for infiltration with different materials and / or integration of further functions such as heat exchangers, filters, crash elements, energy storage, etc.

Fasteners

Integration of conventional connecting elements in porous and solid functional areas: screwing, riveting, pressing, hooking, ultrasonic welding, soldering, welding, gluing, etc.

Inserts made from other materials

Integration into the open-pored and solid functional areas of inserts made of aluminum, steel, copper, glass etc. Subsequent infiltration of polymers for reinforcement, compression and functional expansion.

MATERIAL PROPERTIES

Standard aluminum casting alloys.

The pore sizes can be freely adjusted using a combination of multimodal NaCl placeholders.

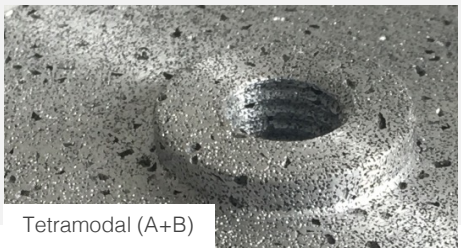
A total of 40 salt fractions with a size between 0.1 mm and 20 mm are available. Larger dimensions are possible on request.

The structure is macroscopically isotropic.

Many other adjustable material properties.

Bimodal A

Bimodal B



Tetramodal (A+B)

New class of materials: open-pore aluminum chill casting

1. Mold filling with salt granulate.

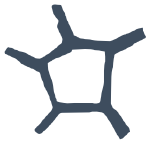
2. Mold filling with Al melt.

3. Conventional processing.

4. Rinse out the salt, done.

COMPARISON OF MICROSTRUCTURES

Open-pored Al cast



Open-pored Al foam

Open-pored sintered material

Series production for over 25 years as filters, silencers, sensor protection, lightweight constructions, decorative parts.

Cast structure with isotropic, adjustable, reproducible properties. Different microstructure than with foamed or sintered materials with better mechanical, fluid mechanical, thermal, acoustic and other properties.

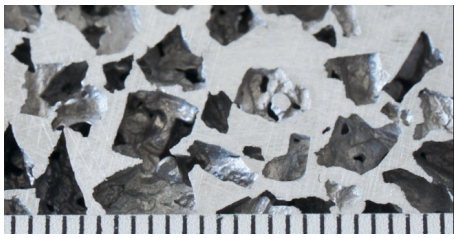
ADJUSTABLE MATERIAL PROPERTIES

Different physical processes such as filtration, sound absorption, shock absorption or heat transfer require specific pore morphology settings.

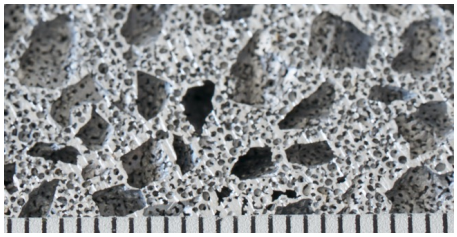
The pore morphology can be set bimodal (2 sizes of NaCl placeholders) or tetramodal (4 sizes of NaCl placeholders).

The sizes of NaCl placeholders can be selected as required between **0,2** mm and **20** mm.

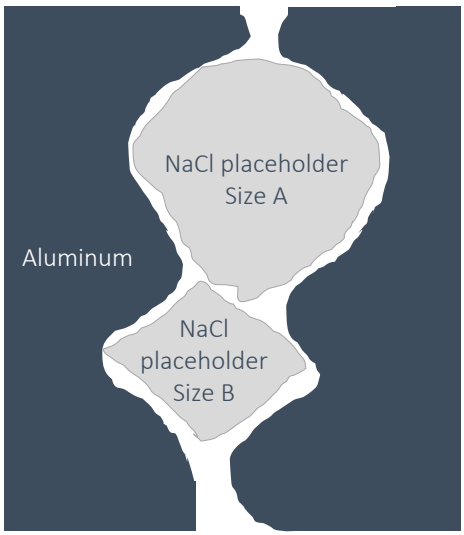
This means that hundreds different materials can be set for all possible applications.



Bimodal 3,0-5,0 mm



Tetramodal 3,0-5,0-0,40-0,63 mm

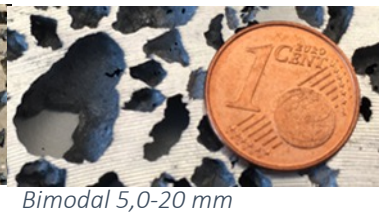


Pore morphology of bimodal material

Bimodal 0,2-0,4 mm

Bimodal 0,35-0,63 mm

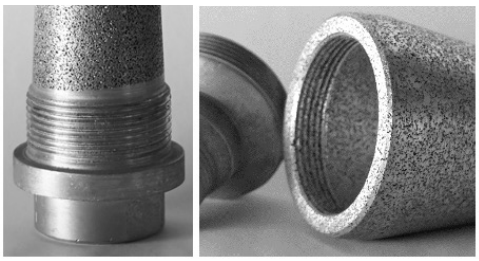
Bimodal 1,6-3,0 mm



Bimodal 5,0-20 mm

PROCESSING AND JOINING TECHNOLOGIES

The material can be processed very well. The machining of open-cell aluminium castings can be carried out with any type of CNC milling or turning machine. For larger constructions, open-pore components can be assembled in the conventional way: press fits, tongue-and-groove joints, screws, rivets, welding, ultrasonic welding, soldering, gluing, etc.



Thread

Riveting and pressing

Glue

Infiltration with polymers

Ultrasonic welding

3D printing

MULTIMATERIAL SYSTEMS AND FUNCTIONAL SURFACES.

INFILTRATION WITH POLYMERS AND MATERIAL BONDING.

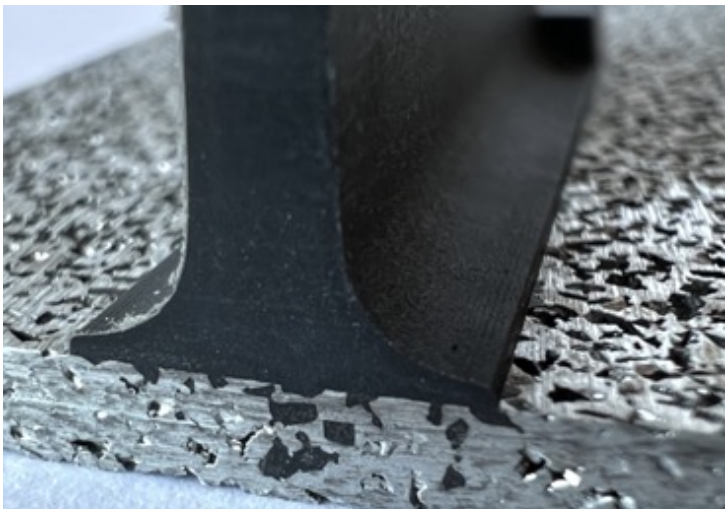
Adjustable and strong.

The PORECOL components can be infiltrated extremely well and media-tight with any polymers in any manufacturing process with a maximum process temperature of 400°C.

Testing the bond strength of the composite with infiltrated PA6GF30 polymer into large and small pores (injection moulding process).

The properties of the bond between aluminium and polymer can be adapted for many functional integrations using different parameters:

- Air and water ducts,
- Seals,
- Vibration dampers,
- Thermal insulation,
- Fastenings.



Local functionalization with PA6GF30 polymer in the injection moulding process.

FUNCTIONAL SURFACES.

Advanced performance and multifunctionality.

The surfaces of open-pored aluminium parts can be functionalised in different processes. Not only the outer but also the inner pores in the entire volume of the component are functionalised. As the open-pored components have an extremely large specific surface area in a small volume, different surface technologies reach their limits under different boundary conditions.

Anodic oxidation (anodising)

This process is suitable for components with larger pores that enable the safe removal of electrolytes. The surface properties correspond to conventional surface properties of anodised aluminium.

METAKER® Surface

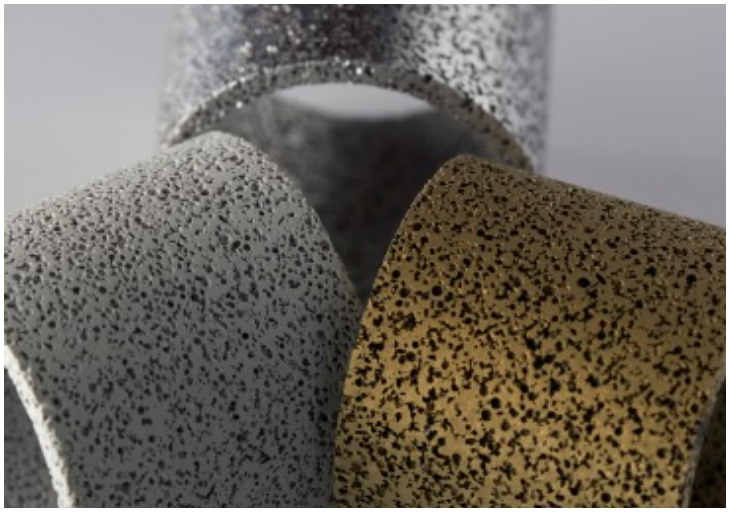
METAKER® Surface is a new technology for powerfull, multifunctional, micro-structured, chemically activated, graded micro-composite surfaces. The process is suitable for smaller components with pores of any size.

PEEK / PEKK coating systems

Coatings with high-performance polymers PEEK or PEKK are particularly suitable for applications where a combination of high corrosion resistance, scratch resistance, temperature resistance and diffusion resistance is required. The process is suitable for small and large components with small and large pores.

Other coating systems

Feasibility studies for other coating systems can be carried out on request.



Bushing made of open-cell AlSi7 cast aluminum (top) with METAKER® Composites surface (left) and PVD coating (right).

porecool
porous cooling systems

PORECOOL SYSTEM SOLUTIONS OF THE HIGHEST COMPETENCE

THE SPECIAL KNOWLEDGE OF HIGHLY SPECIALISED PARTNERS IS THE KEY TO SUCCESS

We have invested 14 years of our decades of experience in product development in international, co-operative research into new materials and the pre-development of numerous applications. Our technology network METAHYBRID combines new technologies with the in-depth expertise and experience of specialised partners from research, product development and production. Our expertise is unique worldwide.

We help you in different project phases to differentiate your products through worldwide unique optimized weight, function, energy, resource and cost efficiency:

- consult, generate ideas, evaluate feasibility, build prototypes,
- solve technical problems and improve existing products,
- develop and industrialize new products,
- identifying and realizing strategic innovation potentials.

OUR EXPERTISE IN PRODUCT DEVELOPMENT

Automotive systems

Roof systems. Doors. Flaps. Seats. Cockpit. Bodywork. Exhaust. Add-on parts. Water management. Sealings. Panelling parts. Trims. Airbags. Cable harnesses. Engine parts.

Thermal systems

Car engine cooling. Heat Exchanger. HVAC. Electronics cooling.

Digital Systems.

Digital complete vehicle product. Digital mock-up. Digital design validation.

Other systems

Different components for gas, compressed air, fluids and vacuum applications.

OUR SERVICES.

- Consulting
- Product development.
- Digital prototyping.
- Physical prototyping and MVP.
- Production at contract partners.

OUR DEVELOPMENT PROCESS.

1. Initial consultation.
2. Definition of goals.
3. Development of concepts.
4. Feasibility study.
5. Industrialisation.

OUR PRODUCTS.

POREC OOL - lightweight cooling systems
COOLSERTS - cooling of plastic parts
FILLSERTS - functions for plastic parts
OPENPORE - parts for diffferent applications

SOME CUSTOMERS OF OUR TECHNOLOGY PORTFOLIO

CONTACT

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