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Electrochemical Additive Manufacturing

ECAM Enabled Thermal Solutions for the AI Data Center

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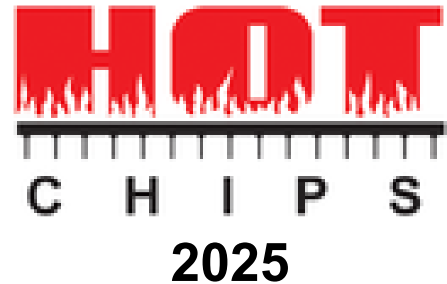

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Overview

AI’s Growing Thermal Challenge:

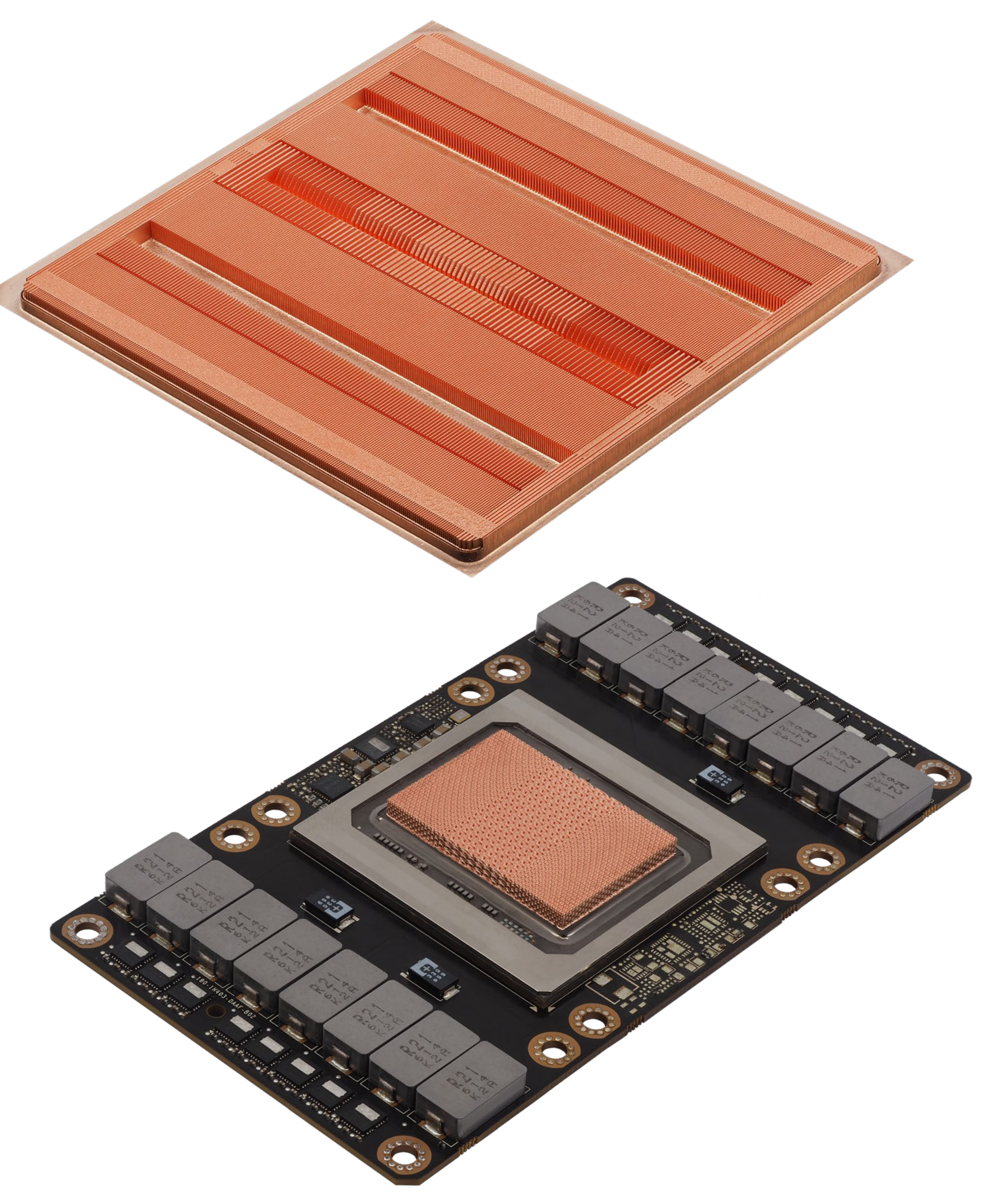
As AI chips become more powerful, they generate unprecedented heat flux, creating challenges for traditional liquid cooling solutions

Next-Generation Design & Cooling Performance

Topological and parametric design techniques, and ECAM manufacturing, can unlock a new level of performance for AI-chip cooling hardware

Future-Proofing AI-Thermal Management Hardware

ECAM is a versatile advanced manufacturing technology that is adaptable to evolving thermal roadmaps in the AI industry



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Demand for Advanced Cooling Solutions

Impact of High Package Power Densities

GPU Architecture	Rubin (2026)	Feynman (2029)	Post Feynman (2032)	Next-Gen Architecture (2035)
GPU Die Size	728 mm^2	750 mm^2	700 mm^2	600 mm^2
GPU Power	800 W	900 W	1,000 W	1,200 W
GPU-HBM Module	R200	F400	Post Feynman GPU-HBM Module	Next-Gen GPU-HBM Module
Interposer Size (GPU, HBM, Interposer)	47.5 mm × 46.2 mm	56.2 mm × 85.2 mm	58.5 mm × 102.8 mm	95.9 mm × 96.4 mm
# of GPU Dies	×2	×4	×4	×8
# of HBM Stack	HBM4×8	HBM5×8	HBM6×16	HBM7×32
Interposer Die Size	2,194 mm^2 (46.2 mm x 48.5 mm)	4,788 mm^2 (85.2 mm x 56.2 mm)	6,014 mm^2 (102.8 mm x 58.5 mm)	9,245 mm^2 (96.4 mm x 95.9 mm)
Total Power	2,200 W	4,400 W	5,920 W	15,360 W

TERA KAIST TeraByte Interconnection and Package Laboratory

Cooling Challenge Driver:

GPU Logic Die Heat Flux is Projected to Grow from 1-2 W/mm^2 to 4+ W/mm^2

Reference: KAIST (Korea Advanced Institute of Science & Technology (KAIST), and Tera (Terabyte Interconnection and Package Laboratory),

Increase in Thermal Design Power and Heat Flux Results in Challenges for Standard Liquid Cooling Hardware

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Limitations of Liquid Cold Plate Performance

Challenges with Straight Channels in Cold Plates

Cold Plate Performance and Optimization

$$Performance \propto \frac{1}{Rth * P_{pump}}$$

- ⬇ Thermal Resistance (R_{th})
- ⬇ Pump Power (P_{pump}) ∝ Pressure Drop (Δp)
- ⬆ Temperature Uniformity, to manage non-uniform heat inputs

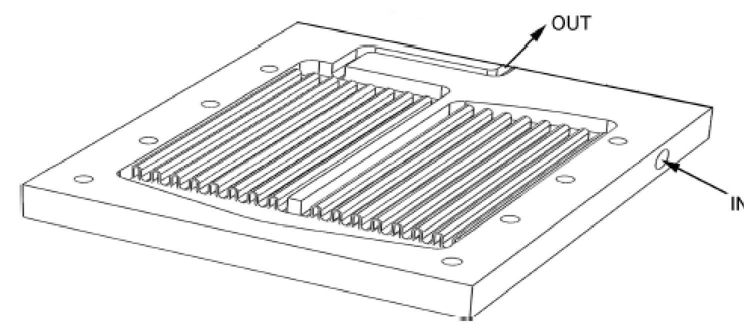
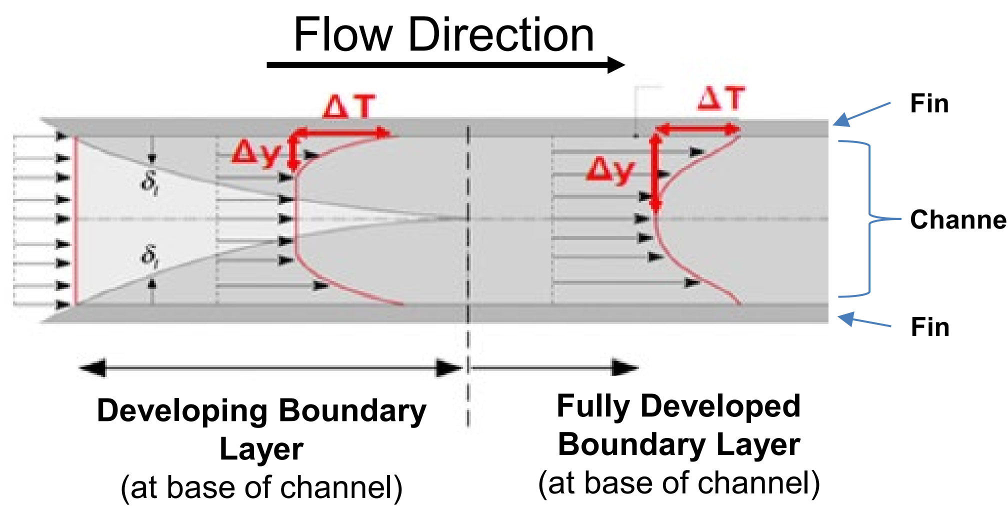


Image Reference:
Kandlikar, S. and Hayner, C., 2011

State of the Art: Microchannel Cold Plate

Image Reference:
Wieland Microcool

Straight Channels Have Limited Performance



***Convective heat transfer deteriorates** along the axial direction with the development of the boundary layer*

Reference:
Jin, L.W., et al, 2014

***Cannot simply increase flowrate** due to erosion limits of copper and tubing (~ 1.5 – 2 m/s)*

Reference:
Ortega, A,, et al., 2022

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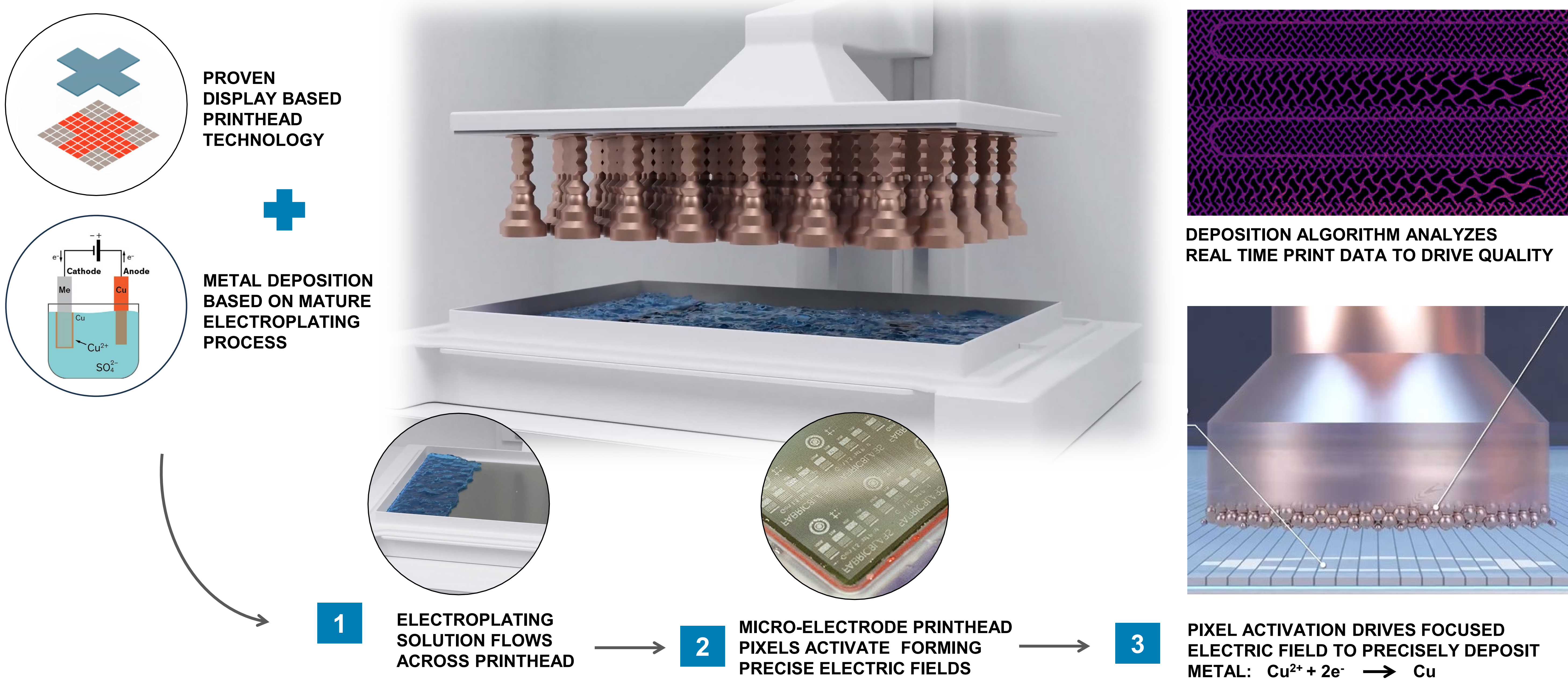
Electrochemical Additive Manufacturing (ECAM)

ECAM Converges High-resolution Display Technology With The Scalability Of Electroplating



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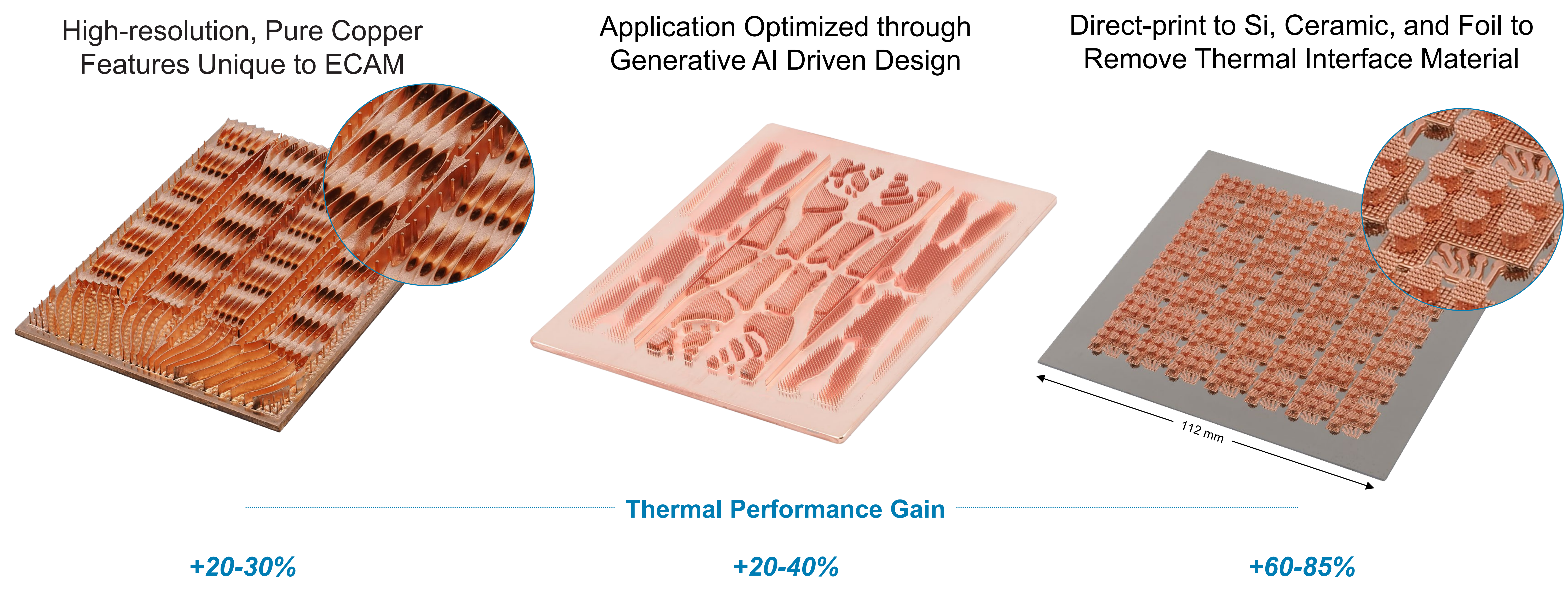
Enhanced Thermal Performance with ECAM

Capabilities of ECAM Technology for Thermal Management Hardware



Enables Thermal Management Hardware Innovation To Meet Industry Roadmap Requirements

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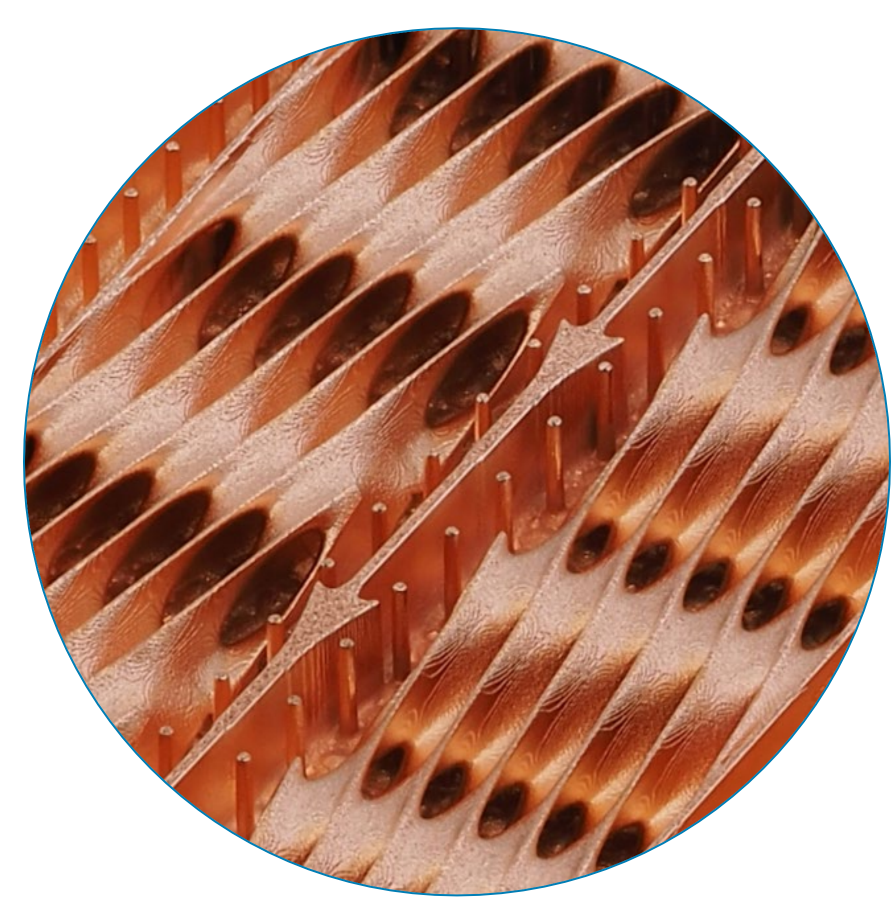
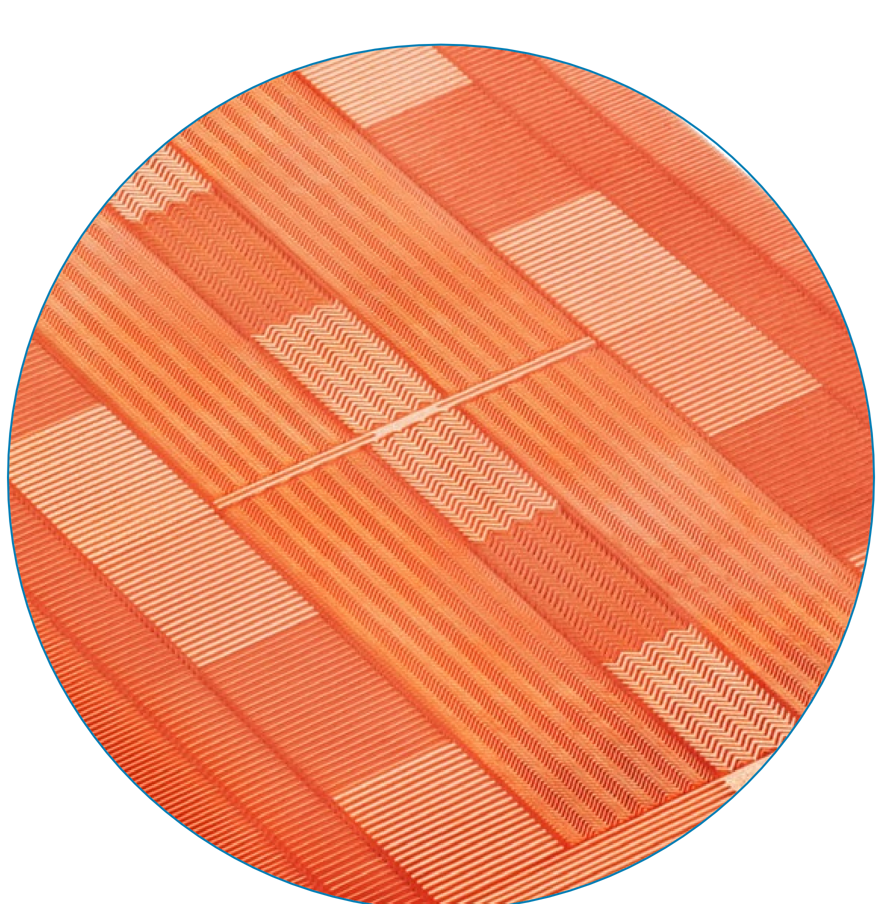
Advanced Cooling Channel Designs

Innovative Solutions for Peak Performance

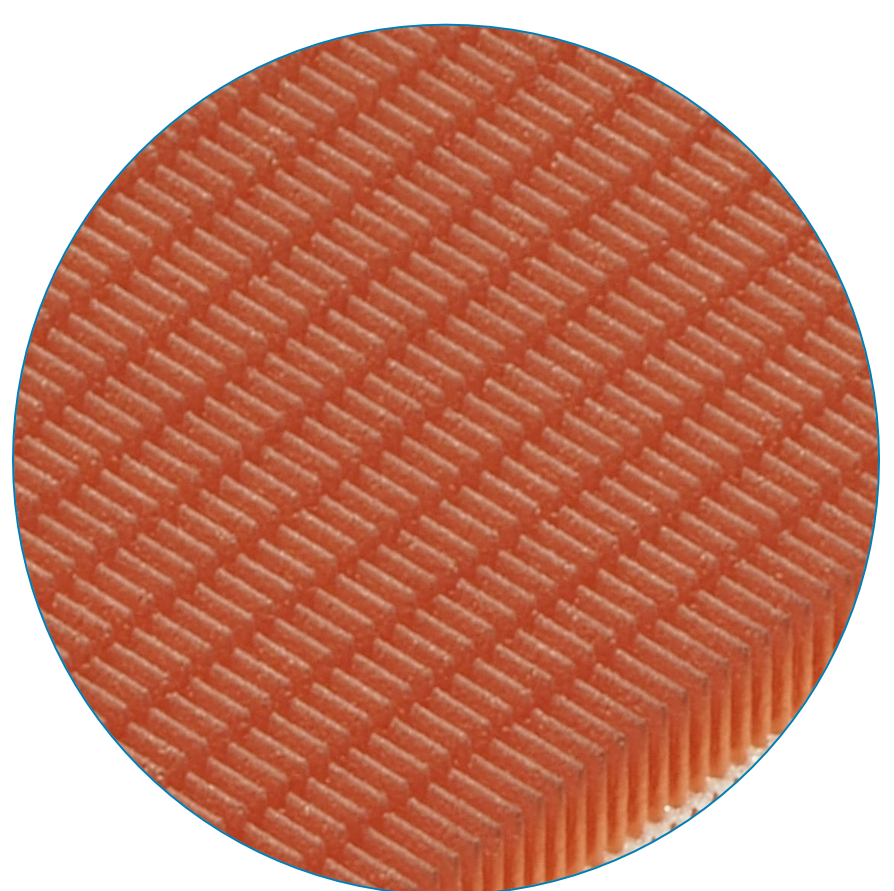
Triply Periodic Minimal Surface Structures, e.g. Gyroids



Parametrically Optimized 3D Cooling Structures



Offset Finlet Structures (Slotted, Offset Microchannel)



Application Specific Cooling Solutions At Comparable Costs To Traditional Manufacturing

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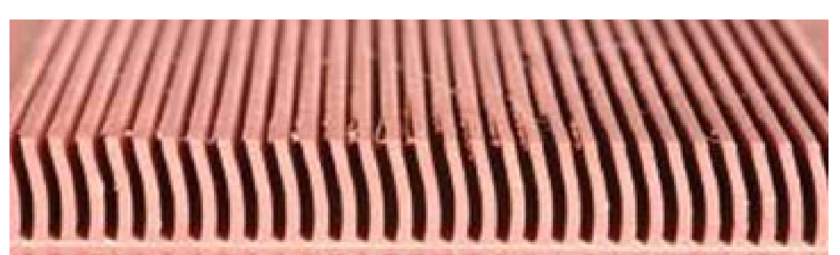
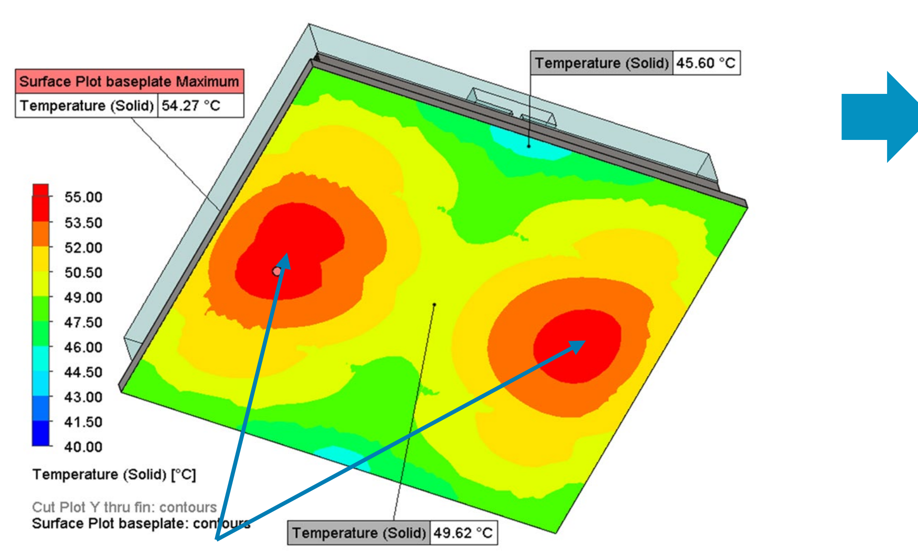
Single Phase Liquid Cooling for AI Chips

Customized Designs for Optimum Performance

Current Products are Limited by Skived Microchannels

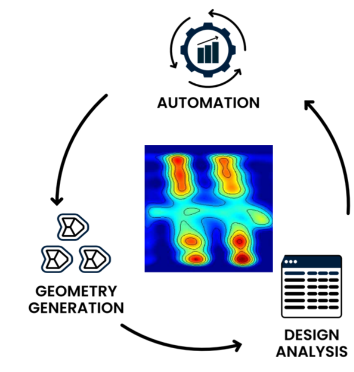


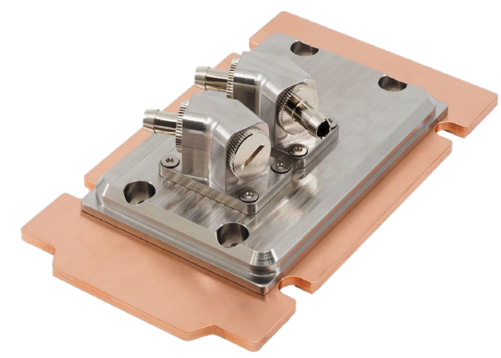


Max Baseplate Temp (°C)	Thermal Resistance, Rth (°C/W)	Temperature Variance, (°C²)	Pressure Drop (psi)
54.3	0.0191	3.99	0.21

Power: 800W
Coolant PG25 , 1.5 L/min, 40°C

Design Optimization for Chipset Power Map

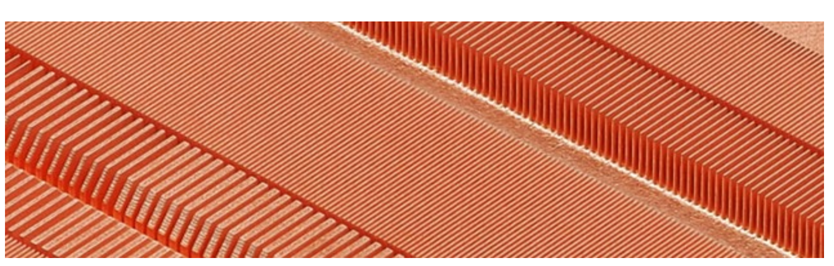


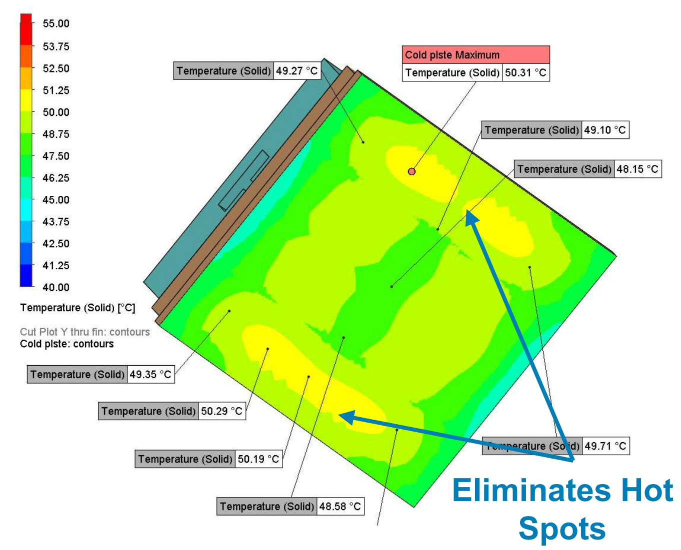


38.6% Improvement In Thermal Performance

254% Improvement In Cold Plate Temperature Variance

Customized ECAM Solution, Optimized Thermal-Hydraulic Performance





Max Baseplate Temp (°C)	Thermal Resistance, Rth (°C/W)	Temperature Variance, (°C²)	Pressure Drop (psi)
50.4	0.0138	1.13	1.16

Power: 800W
Coolant PG25 , 1.5 L/min, 40°C

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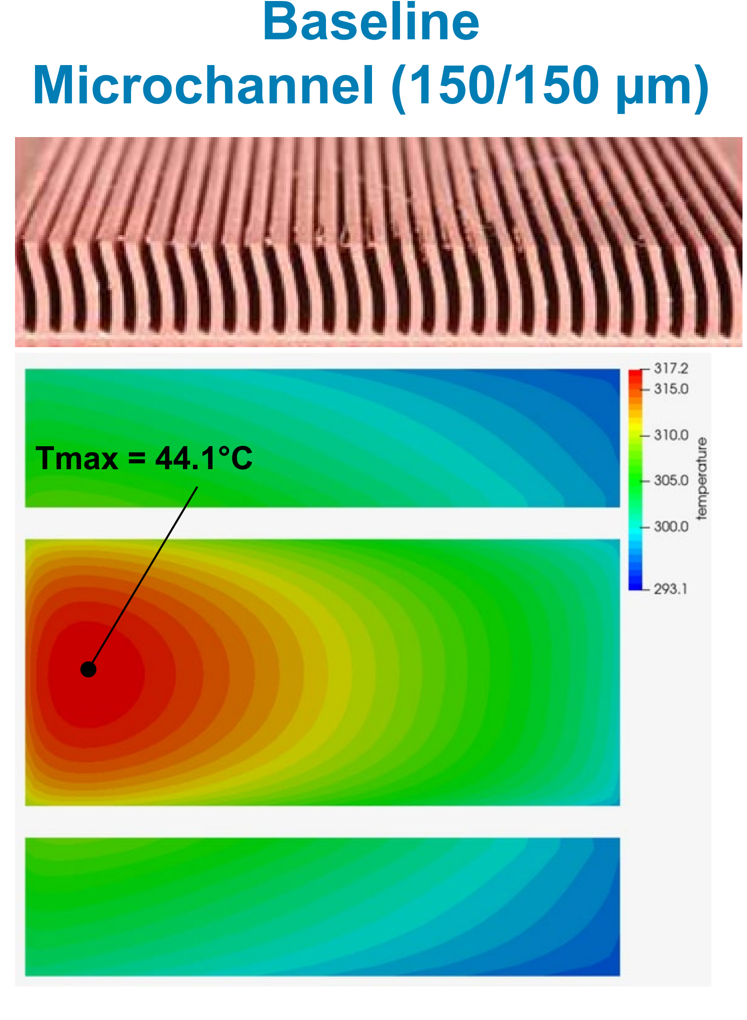
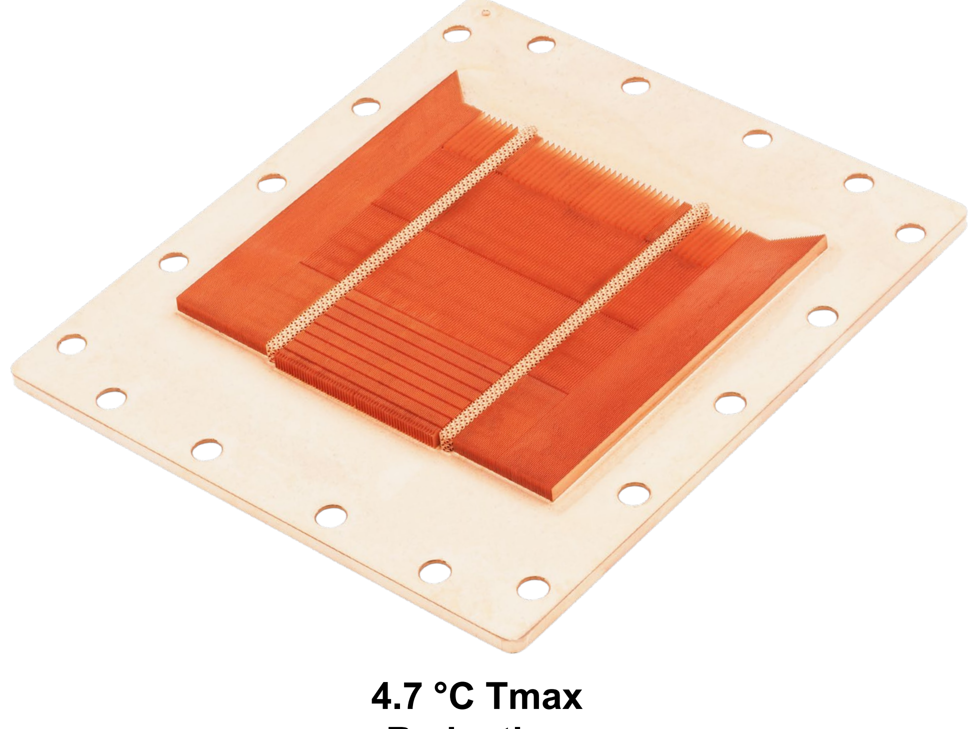
Performance Comparison vs. Straight Microchannels

Low Thermal Resistance Creates Options for Higher TDP vs. Reduced Operating Costs

Baseline Microchannel (150/150 µm)

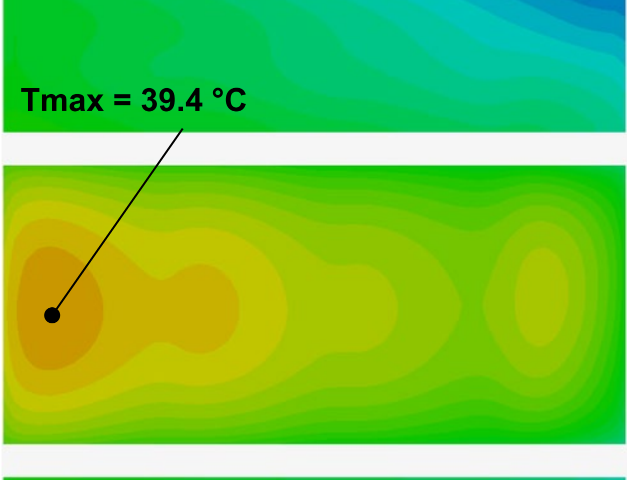


Power Map Optimized Design with Enhanced Heat Transfer Structures



4.7 °C Tmax Reduction

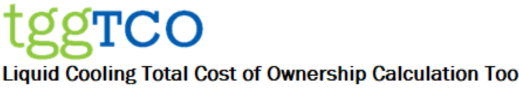
Custom ECAM Design



500 MW Data Center Example

Facility Water Temp: 25 °C
Annual energy costs
$370,353,000

~$70M
Annual Energy Savings



Facility Water Temp: 29.7 °C
Annual energy costs
$300,298,000

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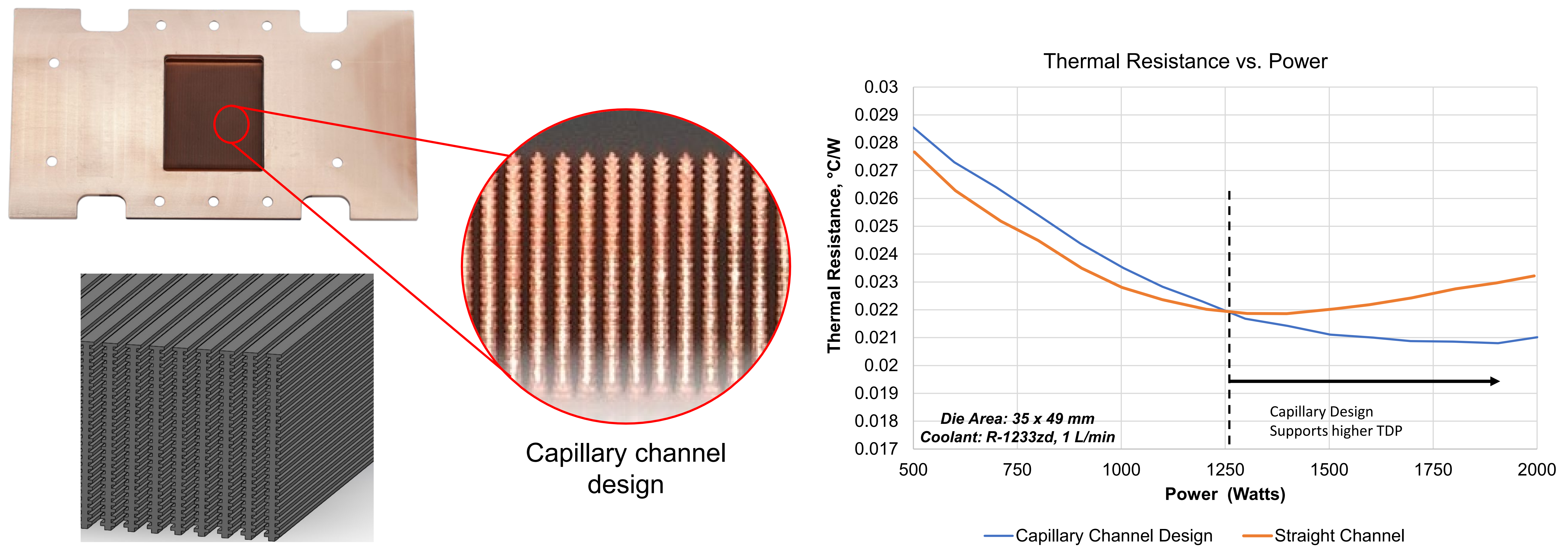
Two Phase Liquid Cooling: Capillary Feature Enhancements

ECAM Enables the Thermal Roadmap Beyond Single Phase Cooling



Integration Of Capillary/Wicking Structures To Enhance Performance Extends Serviceable TDP Beyond Straight Channels

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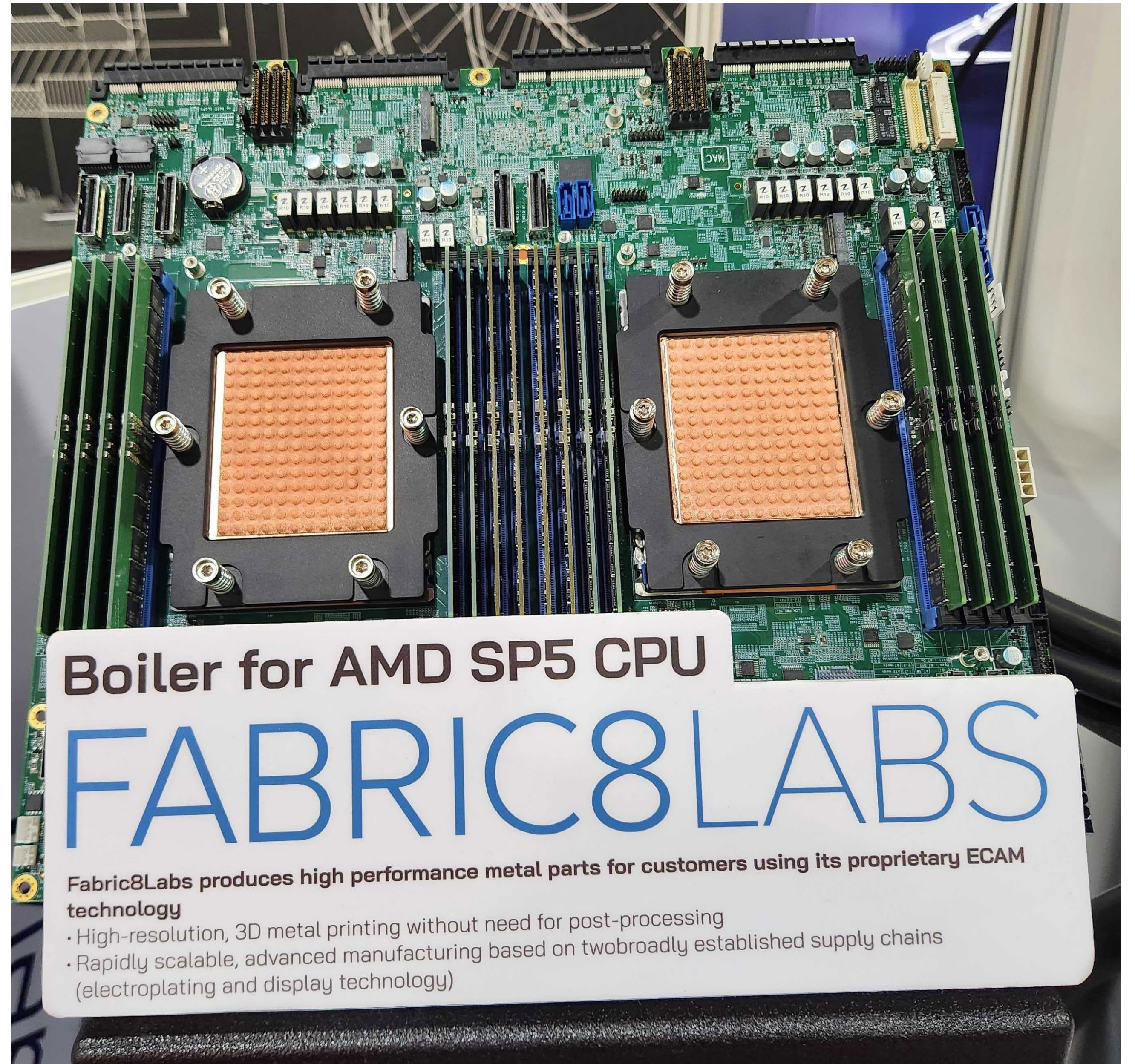
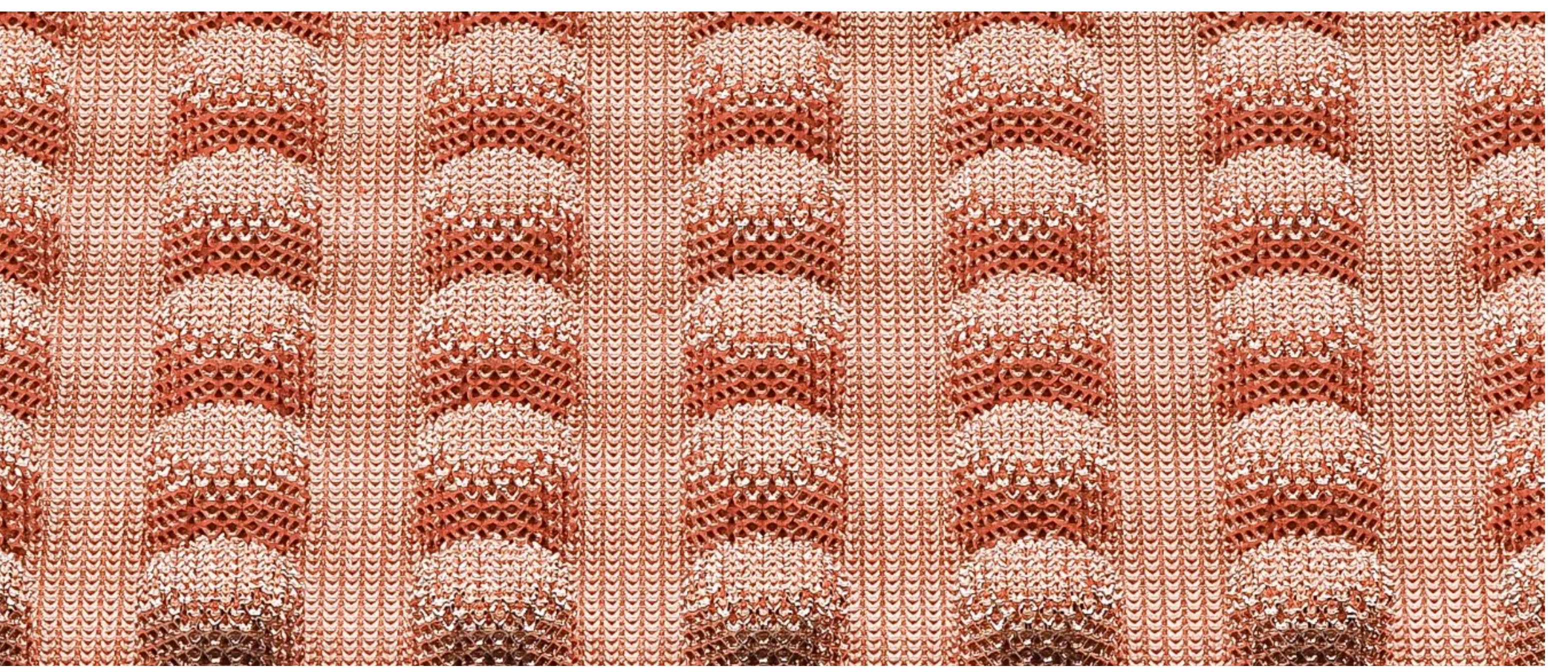
Two Phase Immersion Cooling

High Surface Area Designs Enhance Cooling Performance





2 mm diameter x 2 mm tall bumps with 0.6 mm tall 3D mesh

Performance Test Results, Tj Max

	Incumbent (Punch Hole)	Fabric8Labs (ECAM)	Improvement
400W TDP	81.6 °C	76.3 °C	5.3 °C

*CPU: **AMD EPYC** Genoa 3.7GHz/(96cores) (TDP=400W); 2 Phase Coolant：LC50*

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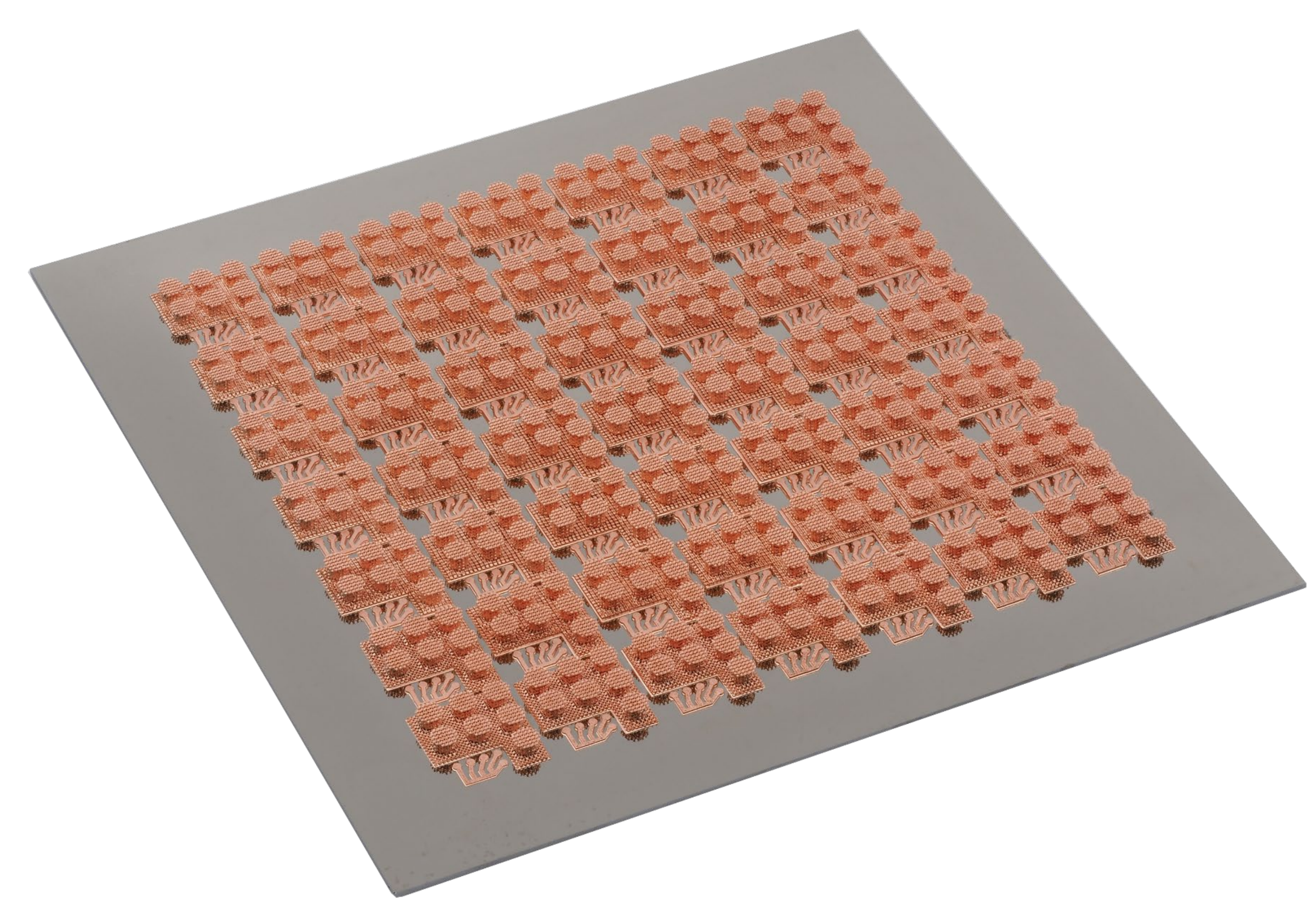
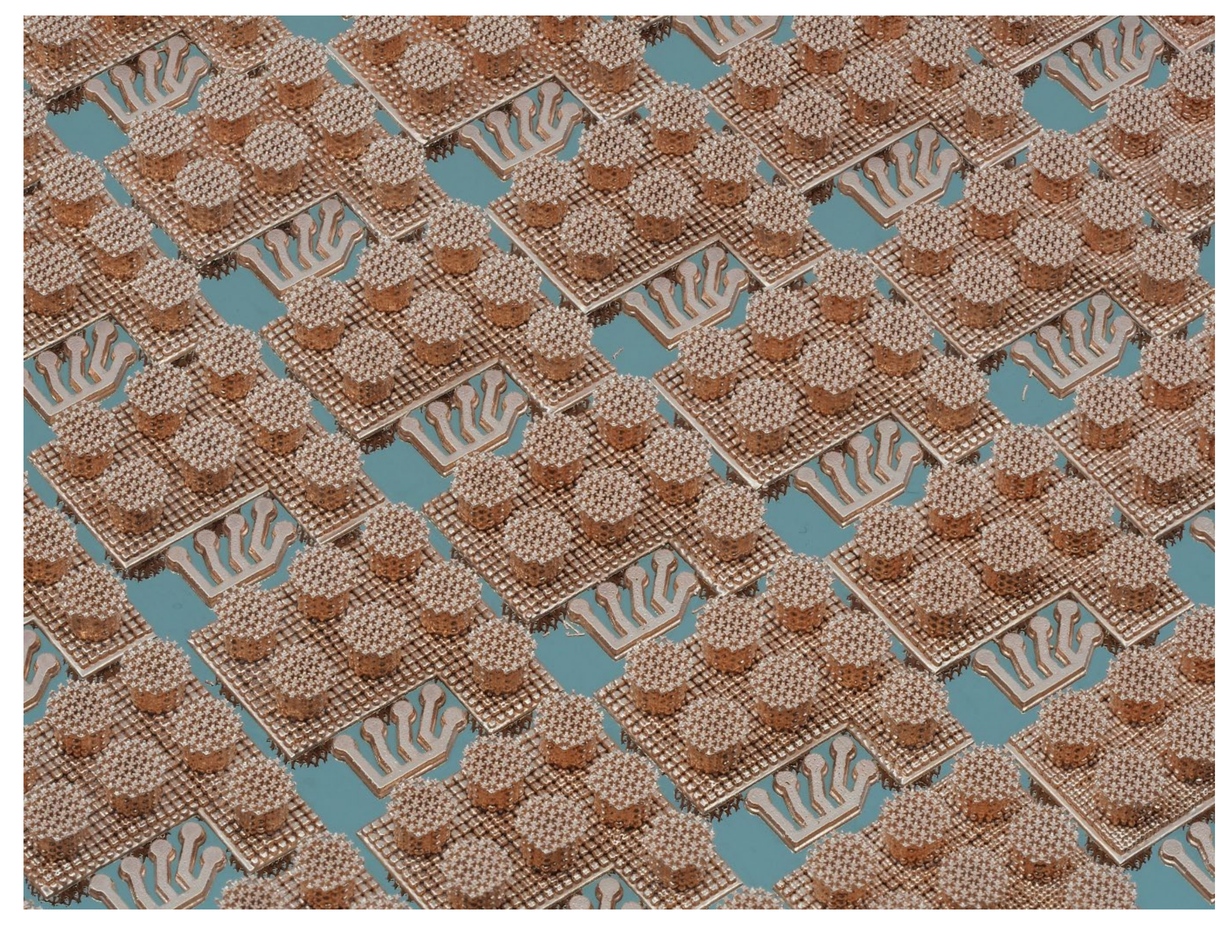
Potential for Wafer Scale Processing

Leverage EDA Software Tools to Produce Chiplet Optimized Cooling Structures on Wafer





Silicon Wafer Coupon with ECAM Printed Copper Structures

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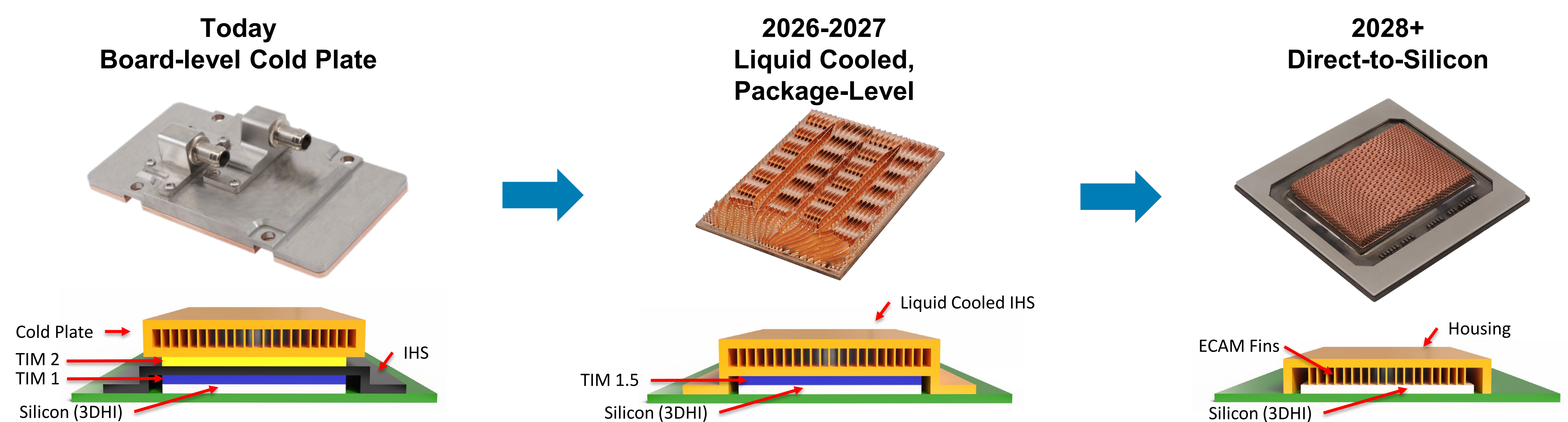
ECAM Thermal Solution Roadmap

Board-Level Cold Plates to Direct-to-Silicon Integration



Thermal interface materials (TIM 1&2) drive thermal resistance; Performance of ECAM delivers significant Rth improvement and temp uniformity

ECAM integrated heat spreader (IHS) brings liquid cooling into the package and removes TIM2

ECAM room-temperature process enables direct-printing to Si, removing TIM1

Thermal Resistance Improvement

+20-50%
Via structure, hotspot optimization, and substrate performance

+30-40%
Via removal of TIM2

+30-40%
Via removal of TIM1

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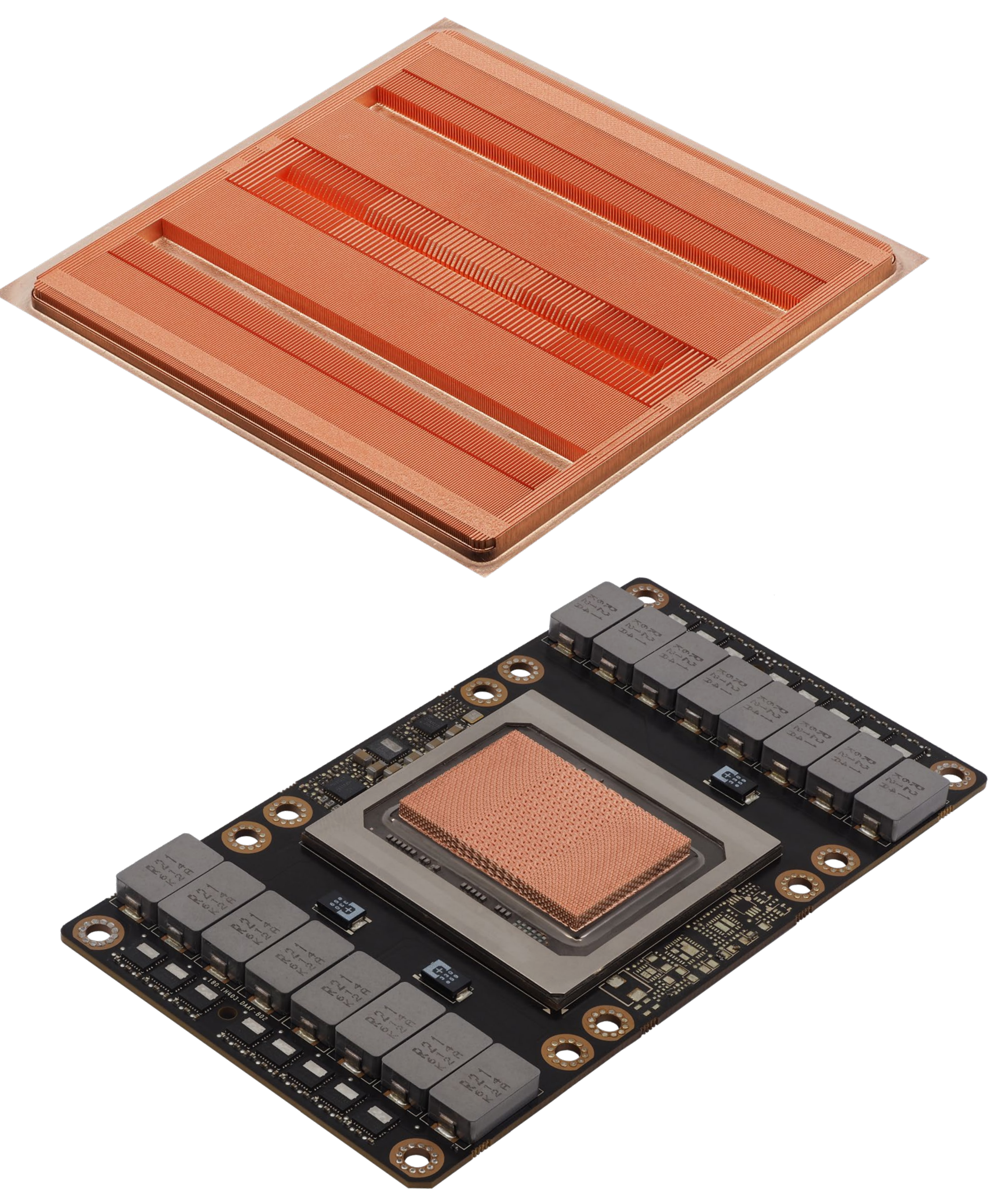

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