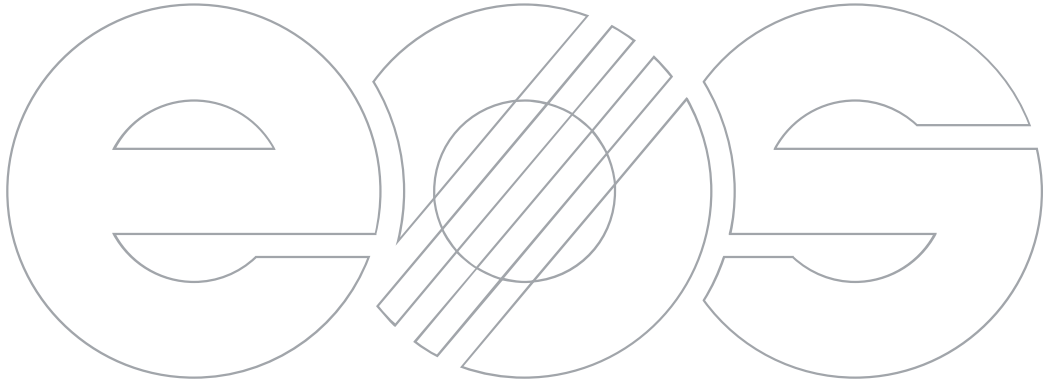
The role of Additive Manufacturing (3D Printing) in e-mobility and electrification

Webinar 17.3.2021

Olli Nyrhilä

EOS Finland



Content

- EOS
- EOS Metal Materials
- Some AM electification material considerations
- Case examples

EOS – Technology and Market Leader for 3D Printing Solutions

- **EOS** is the **world's leading technology** supplier in the field of **industrial 3D printing** of metals and polymers
- **Family-owned**, founded in 1989
- Headquartered in Krailling near **Munich,** Germany
- **Solution portfolio:** Additive Manufacturing (AM) systems, materials (plastics and metals), software, services and consulting
- Complete **end-to-end solutions:** from part design and data generation to part building and post-processing
- **EOS helps companies leverage competitive advantages in a variety of industries**, such as medical, aerospace, tooling, industry, lifestyle products and automotive

Marie Langer
CEO

David Leigh
CTO

Nikolai Zaepernick
Life Cycle Solutions

Glynn Fletcher
Regions & USA

Ruha Reyhani
CTrO

Florian Mes
CPO

EOS is committed to:
Innovation – Quality – Sustainability


EOS Mission
EOS is the leading provider of Additive Manufacturing solutions. Our systems and services are essential to the digital factories of the future.
EOS Vision
Additive Manufacturing is a key technology for advanced industrial production.

EOS Metal Materials
for Additive Manufacturing


Developing Metal materials and processes for EOS customers
Supporting EOS customers when metallurgical and analytical competences on metal powders, processes and material properties are needed

Competence Centre for Metals

Late 1980's

Development and metal powder sourcing group of Electrolux Rapid Development

1994

Started as EOS development partner

Beginning of commercial DMLS

Joint development of materials and processes for EOS metal AM systems

2000

EOS Finland founded

General Manager Olli Nyrhilä

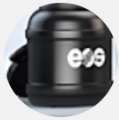
2021

EOS Finland know-how and competence has **essential role in EOS metal technology development**

Personnel: ~65 employees *(> 35% in R&D)*

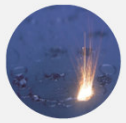
Competence Centre for Metals

Development of
EOS metal powder products



Metal powder manufacturing

Global sourcing of metal powders



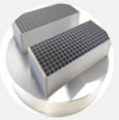
Development of EOS metal process
products for EOS metal systems

EOS Finland has several functions within EOS

Customized materials & processes

Quality management,
powder & metallurgical analytics

Medical product competence



Regulatory affairs & compliance

EOS Metal Materials Portfolio

Aluminium	Cobalt Chrome	Nickel Alloy	Tool Steel	Stainless Steel	Engineering Steel	Titanium	Refractory Metal	Copper
EOS Aluminium **AlSi10Mg**	EOS CobaltChrome **MP1**	EOS NickelAlloy **IN939**	EOS MaragingSteel **MS1**	EOS StainlessSteel **316L**	EOS CaseHardening-Steel **20MnCr5**	EOS Titanium **Ti64**	EOS Tungsten **W1**	EOS Copper **Cu**
EOS Aluminium **AlF357**	EOS CobaltChrome **RPD**	EOS NickelAlloy **IN718**	EOS ToolSteel **1.2709**	EOS StainlessSteel **316L VPro**		EOS Titanium **Ti64ELI**		EOS Copper **CuCP**
	EOS CobaltChrome **SP2**	EOS NickelAlloy **HX**	EOS Stainless-Steel **CX**	EOS StainlessSteel **17-4PH**		EOS Titanium **TiCP Grade 2**		EOS CopperAlloy **CuCrZr**
		EOS NickelAlloy **IN625**		EOS StainlessSteel **PH1**		EOS Titanium **Ti64 Grade 5**		
				EOS StainlessSteel **GP1**		EOS Titanium Ti64 **Grade 23**		
CUSTOMIZED OFFERING								
			EOS ToolSteel H13					EOS Bronze

EOS Finland machine park

In total over 20 EOS metal systems for research, development and constant re-qualification of EOS metal powders

1 EOS M400

2 EOS M400-4s

9 EOS M290s

Ti-alloy specific M290s and peripherals

Al-alloy specific M290 and peripherals

1 AMCM M290 1 kW

2 EOS M280s

1 EOS M270

5 EOS M100

EOS Finland machine park

- Several Melt Pool Monitoring and OT Monitoring units + non-released R&D hardware
- Furnaces for heat treatments in argon/nitrogen atmosphere
- Convection furnace for M4-platforms
- Vacuum furnace for M4-platforms
- EOS Laboratory with **extensive capabilities** for metallurgical and powder analysis

We are experts in metal AM technology

E-mobility and electrification requires high electical conductivity

Some general considerations about electrical conductivity and AM

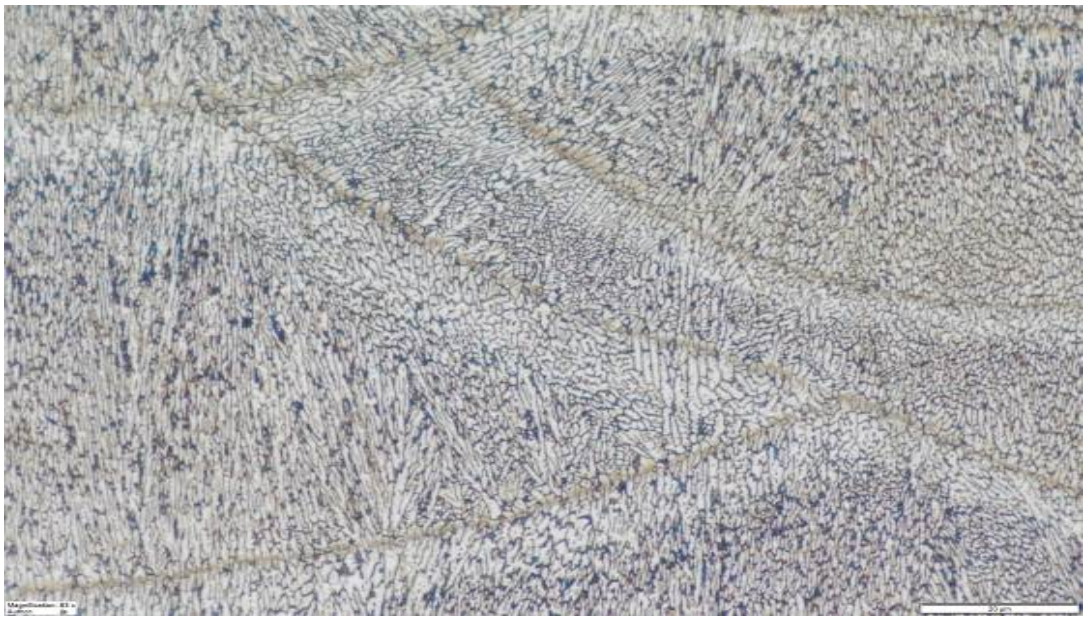
- Grain size effect on strength properties
    - Very small grain size of AM allows for less alloying for same mechanical performance as conventionally manufactured materials.
- Heat treatments can be used to improve on conductivity as well as other properties.
- High alloying typically leads to better mechanical properties but also poor conductivity
- Surface conductivity in antenna applications can be optimized by parametrisizing surfaces to have high density, while center of piece can be replaced with more porous bulk or lattice structure
    - Lightweighting for lower transportation and operating costs in space applications

Orientation dependency of external properties

Laser melting process comprises of extremely fast melting and re-solidification.

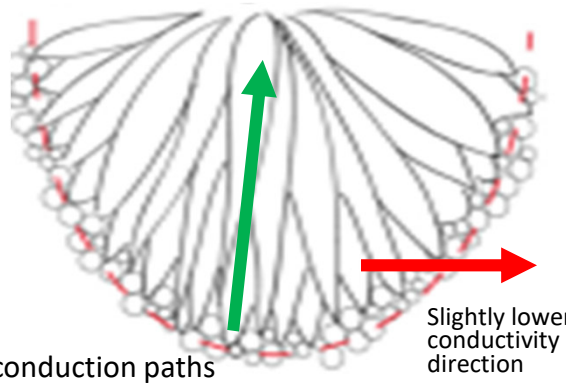
Due to the layerwise manufacturing method, the parts exhibit anisotropic properties depending strongly on the building direction. This is especially seen in mechanical properties, but other properties such as conductivity have dependency on build direction, too.

With heat treatment – more uniform microstructure and less orientation dependency can be gained.

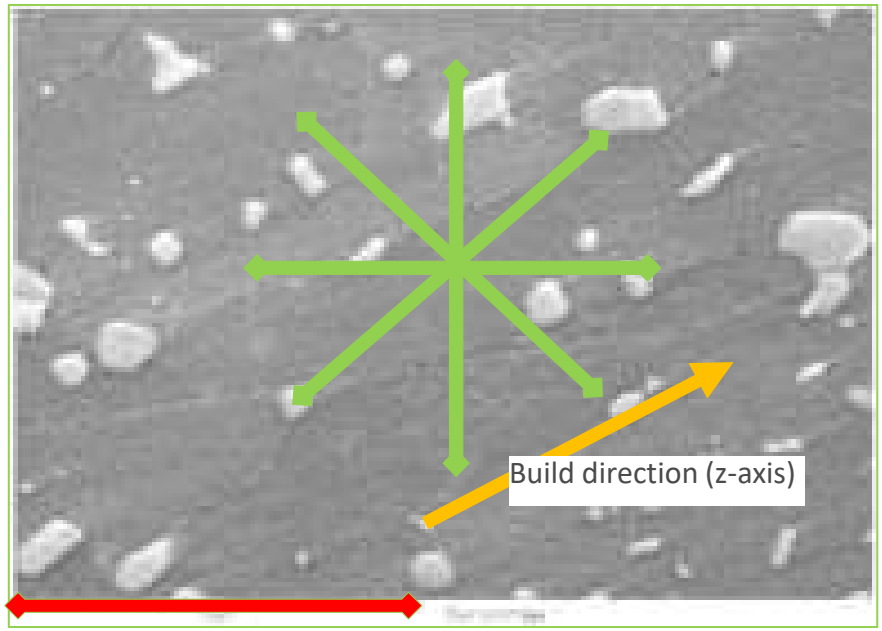


Al F357 alloy (as built), etched with Groesbeck's reagent. Scale bar is 20 µm.

Underlying aluminium grain structure that is found under silicon network



Same structure after heat treatment (SEM image)

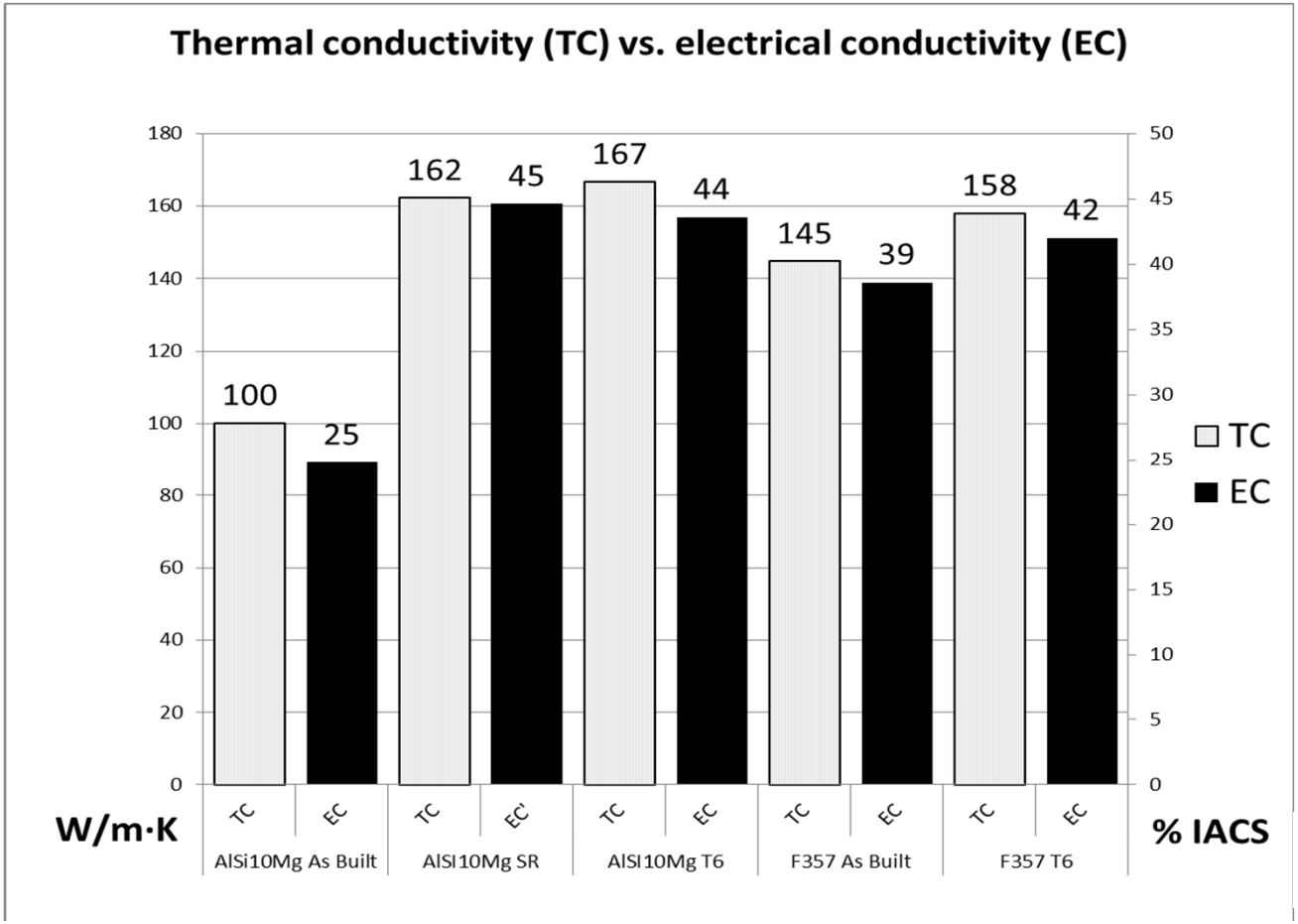


Scale bar 10 µm

Improved and more uniform conductivity in all directions after heat treatment thanks to microstructural changes

Spheroidization and break-up of silicon network leads to more free path for electronic conduction and reduces alloy supersaturation.

ALSi10Mg and F357/AlSi7Mg Aluminium Conductivity



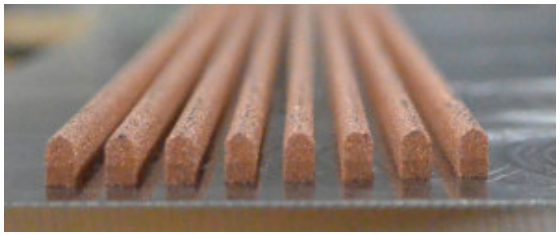
Strong correlation between thermal conductivity (TC) values and electrical conductivity (EC) values in

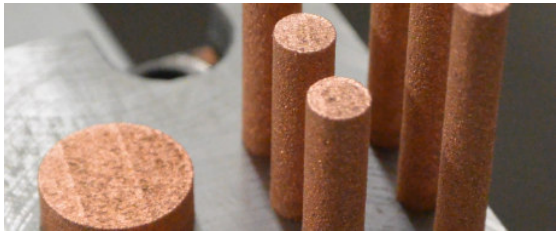
Stress relief and T6 heat treatments improve on conductivity when supersaturation of alloying is relieved through precipitate formation.

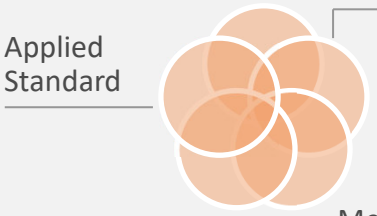
*IACS International Annealed Copper Standard, where scale value of 100 %IACS represents electrical conductivity of commercially pure copper.

Thermal Conductivity of Additively Manufactured Thermal Management Components.
Jukka Simola. EOS Finland Oy.
EuroPM2019, MECC Maastricht, October 15th 2019

In electrical applications
Conductivity is Key – and also the Challenge





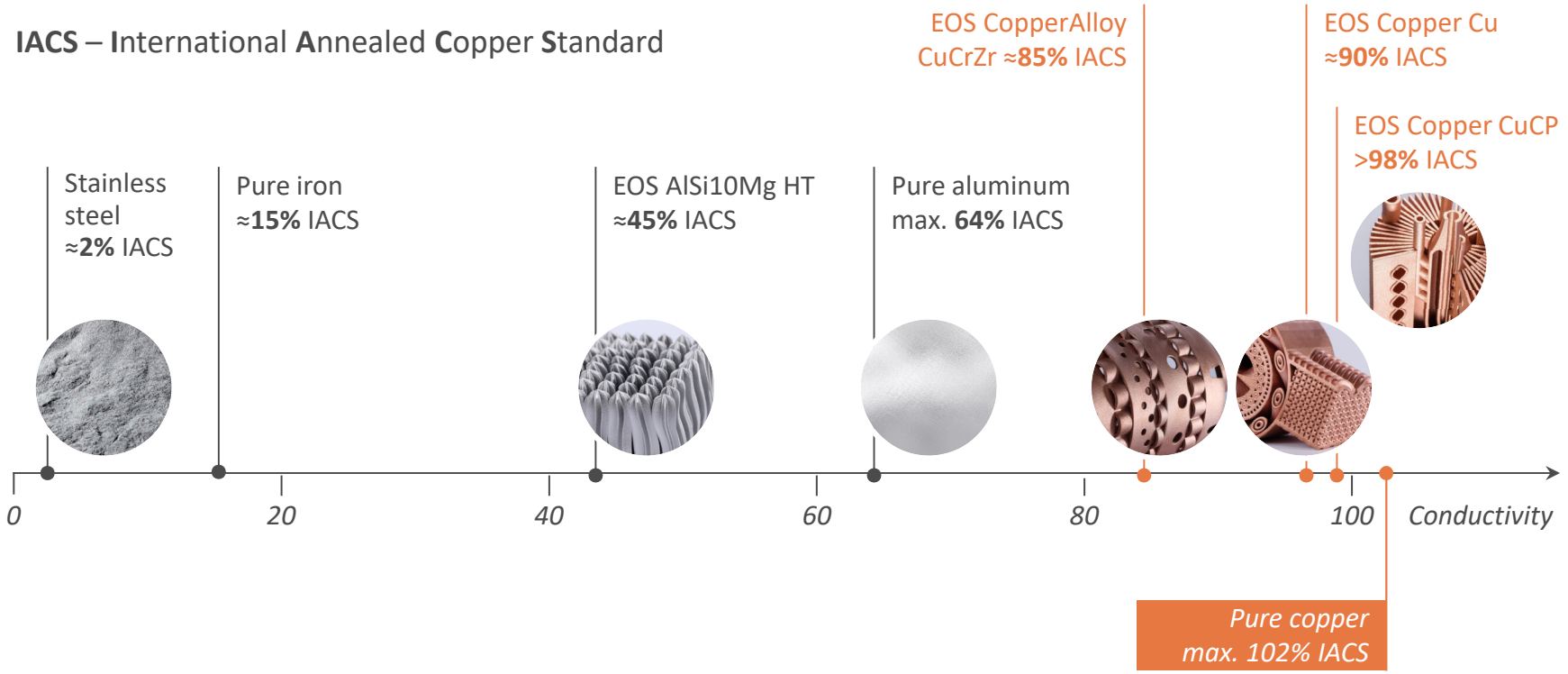


Electrical
Resistance (U/I)
Volume resistivity (Ωm) at ref. T t_0
Conductivity (S/m)
Conductivity (% IACS)

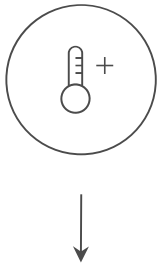
At EOS: Eddy current electrical conductivity measurement (ASTM E1004 – 17)

Conductivity is Key – and also the Challenge

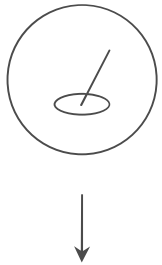
IACS – **I**nternational **A**nnealed **C**opper **S**tandard



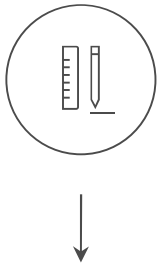
Challenges with Conductivity



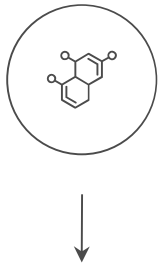
Heat escaping from the melting process



Melt pool size



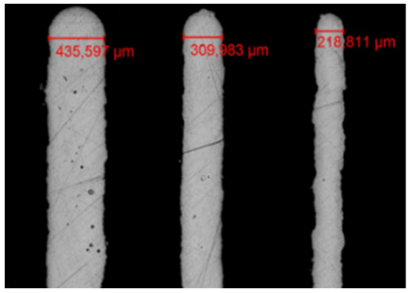
Part & support design



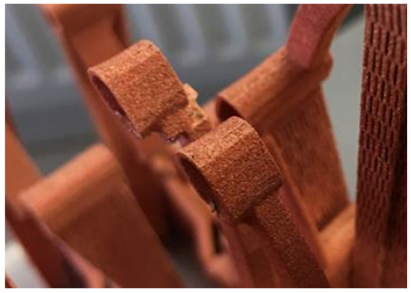
Oxidation

Challenges with Conductivity

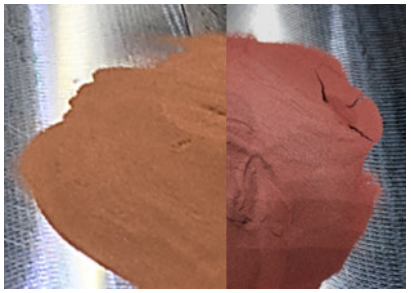
Heat can build up in specific areas and escape in other areas



Part precision control needs special attention

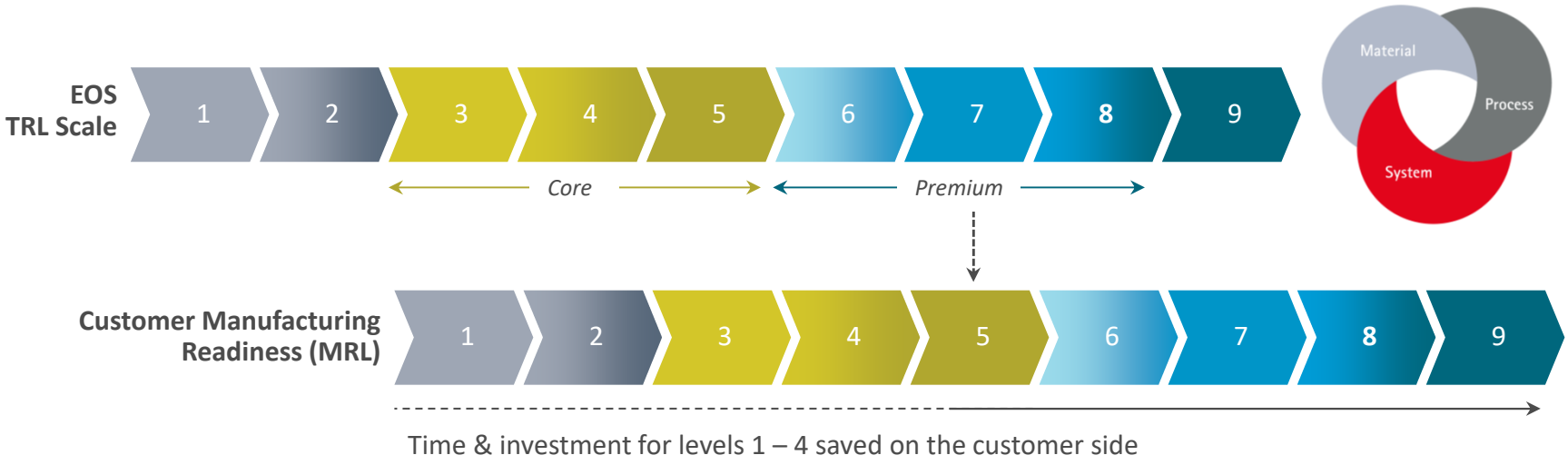


System robustness & precision is highlighted



Oxidation leads to discoloration – a natural tendency for copper – but not critical

EOS Technology Readiness Levels Translate to Manufacturing Readiness Levels



EOS copper solutions are at TRL 3, work is in progress to advance them to higher levels

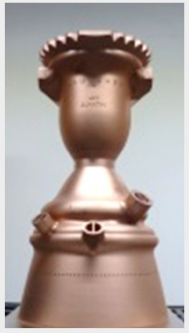
Different Copper Alloys for Different Applications

Pure Copper

Conductivity	■■■■■■■■■■
Productivity	■■■
Mechanics	■■■

CuCrZr

Conductivity	■■■■■■■■
Productivity	■■■■■■■■■
Mechanics	■■■



CuNi2SiCr

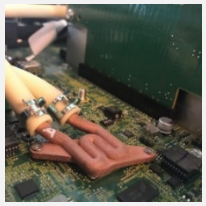
Conductivity	■■■■
Productivity	■■■■■
Mechanics	■■■■■■■■

Image sources: 3druck.com on Protiq; for Launcher engine AMCM; antenna from Polymertal; Cooler by Cloud & Heat, AM Metals; Cooler by Stratasys Direct Manufacturing; stator by AM Metals; CuNi Cooler by Modelltechnik and AM Metals; Kjellberg Finsterwalde with AM Metals;

First Applications Commercialized using DMLS® Technology

Coolers / Heat Exchangers

- Low leakage risk
- Miniaturization



Electric Motors

- Smaller series
- Higher energy densities

Nozzles

- Optimized flow
- Longer lifetime

Antennas / RF Communication

- Miniaturization
- High efficiency

Electrical Contacts

- Higher currents
- Integrated active cooling

Inductors

- Customization
- Digital production chain

Image sources l.t.r.: Cloud & Heat – built by AM Metals; AM Metals; AM Metals; Polymertal; Kellberg Finsterwalde and AM Metals; Protiq, a Phoenix Contact Company, press release with EOS;

Pure Copper: Performance Increase up to 45%

- Start-up for electric motor production by additive manufacturing
- Lot size 1 for fast prototyping
- Large serials for improved performance

3D printed hair pin “winding” for traction motor

Source: Additive Drives

CuCrZr – Collaborating for Success

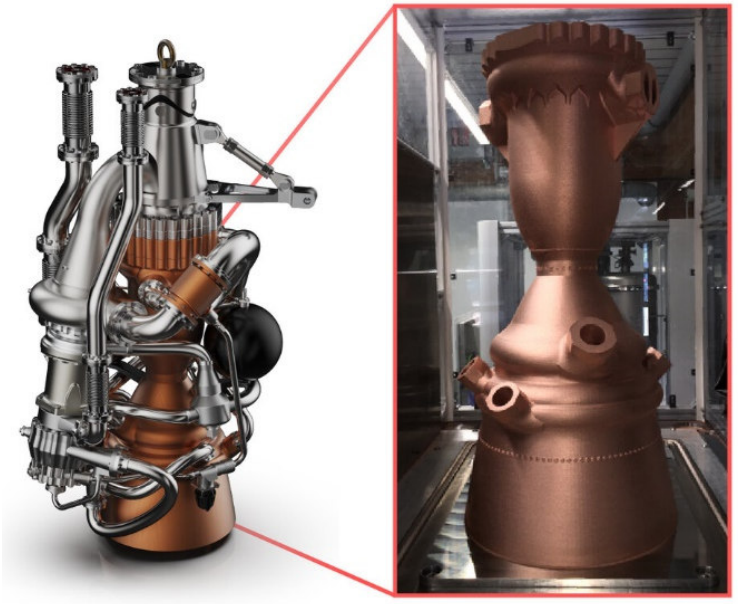
LAUNCHER
launcherspace.com

LAUNCHER E-2

3T

AMCM

EOS



CuNi2SiCr: Cooler in Serial Production

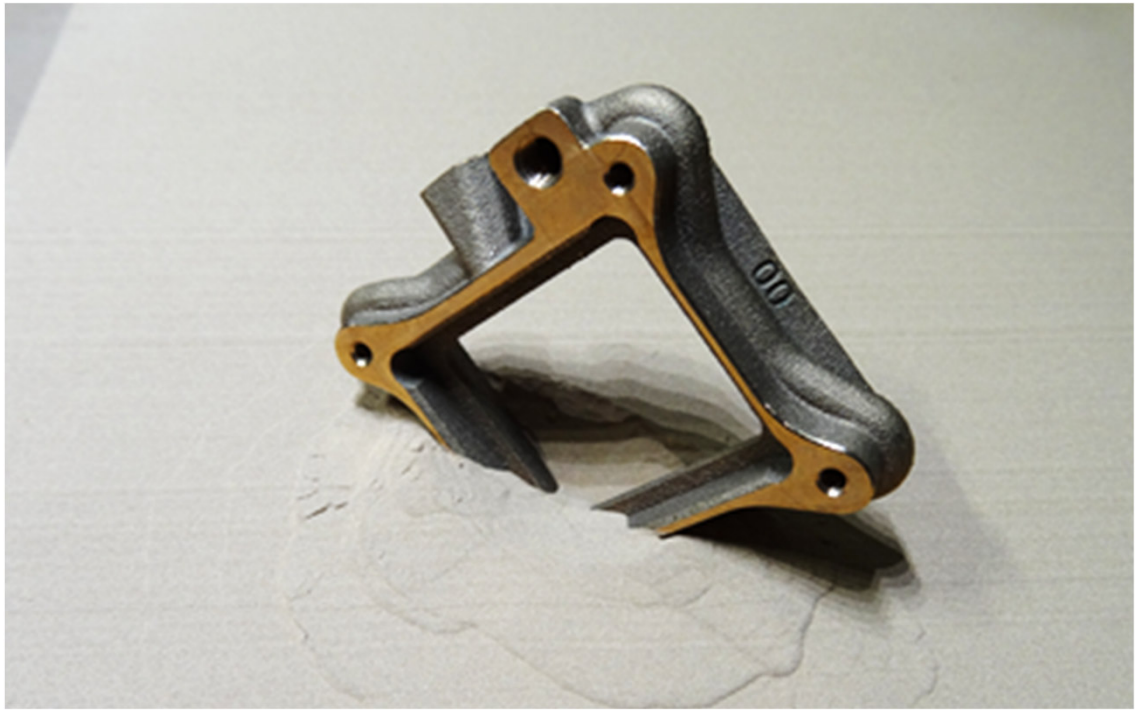
- Made for medical devices and without weld seams
- Less scrap by solving the leakage problem
- Better cooling by factor 3
- Simplified assembly and better economics

production by

MODELL TECHNIK
Rapid Prototyping GmbH

engineering by

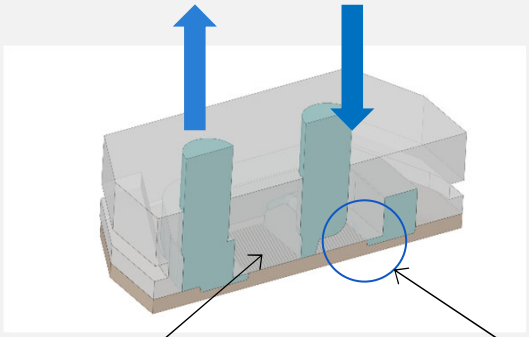
AM METALS



Source: ModellTechnik Rapid Prototyping GmbH

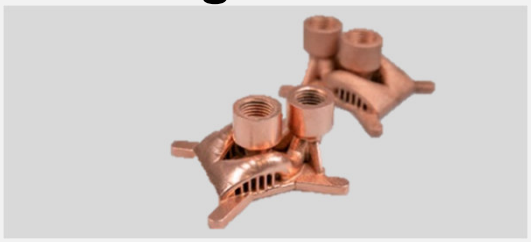
Innovating a Gaming CPU Cooler with 3D Printing

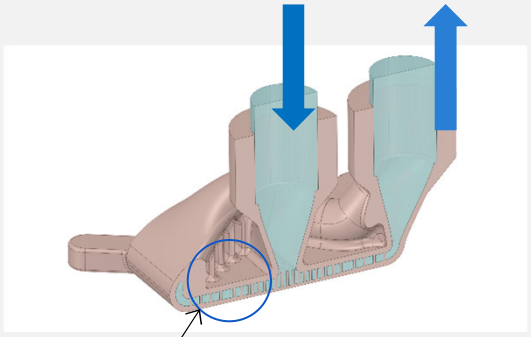
Conventional Design



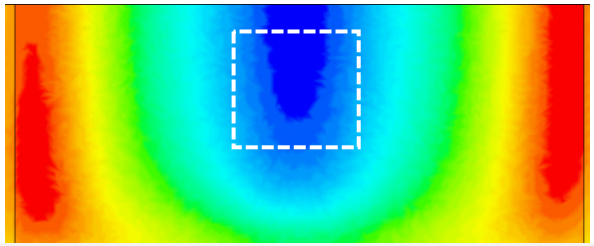
0.3mm Fin

AM Design

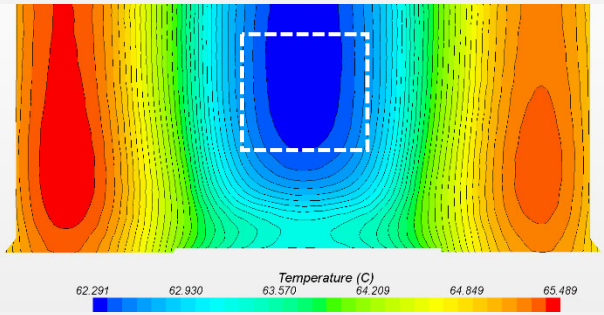




Impingement cooling



Temperature distribution on base plate (Conventional Design)



Temperature distribution on base plate (AM Design)

Source: TheSys, AM Metals, EOS

New EOS alloy types under development

1) EOS High purity aluminium
$RP_{0.2}$ ~65 MPa, up to 62 %IACS electrical conductivity, thermal conductivity up to 230 W/mK

2) EOS Low alloy, high conductivity aluminium,
$RP_{0.2}$ 150 MPa, electrical conductivity up to 50-53 %IACS, thermal conductivity 195-205 W/mK

Designed for waveguides for telecommunication, thermal management components, electronics casings etc.

* %IACS International Annealed Copper Standard scale, where value of 100 %IACS represents electrical conductivity of commercially pure copper.

https://www.beamler.com/3d-printing-capabilities/materials/aluminum/

Thank you!