

FEMS 2025 EUROMAT

18th European Congress and
Exhibition on Advanced Materials
and Processes

Granada,
14 – 18 September 2025



Universidad de
Castilla-La Mancha



Solar reactive sintering applied in AM and PM to process multi-material components

Abraham Sánchez Romero¹, Gloria P.
Rodríguez², Ana Romero¹, Antonio Cañadilla¹

¹ INAIA-EIIA, Universidad de Castilla-La Mancha, Toledo, Spain

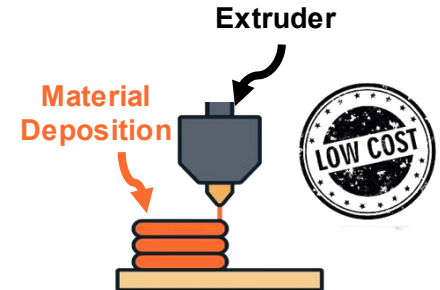
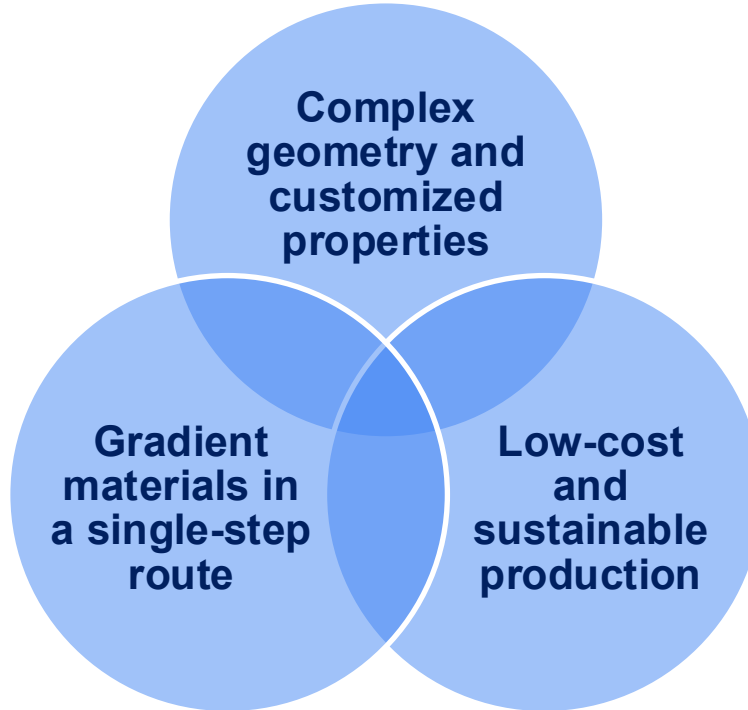
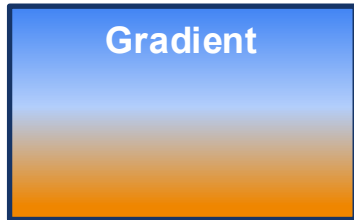
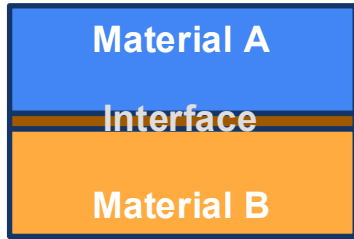
² INEI-ETSII, Universidad de Castilla-La Mancha, Ciudad Real,
Spain

Abraham.Sanchez@uclm.es



Opportunities

Additive Manufacturing



Cu-Al applications

High hardness wear
coatings



Marine corrosion-
resistant
components

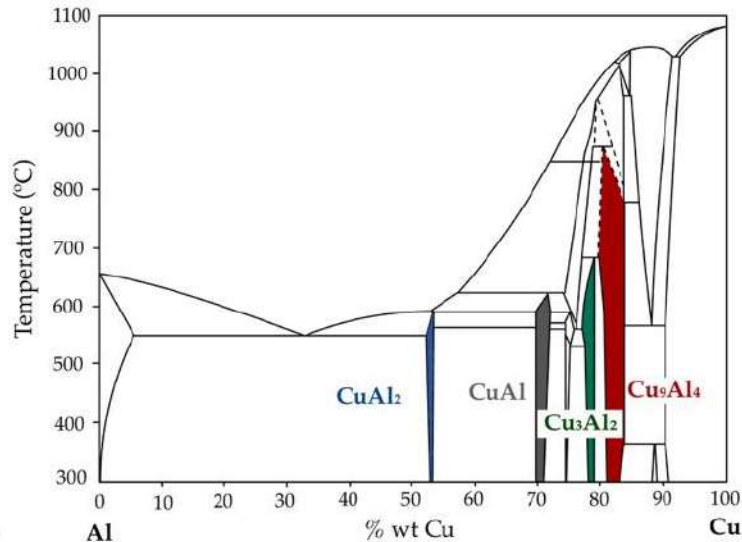


Heat resistant and
high conductivity
components

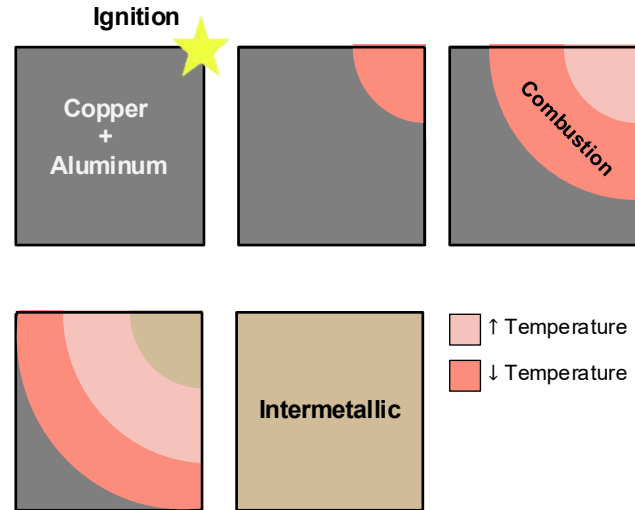


Reactive Sintering

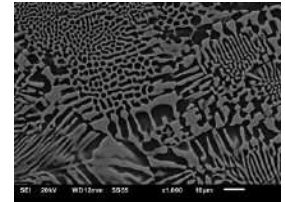
Intermetallic Synthesis



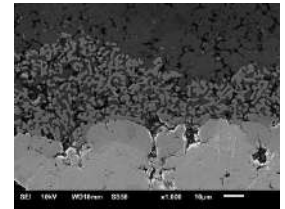
SHS Reaction



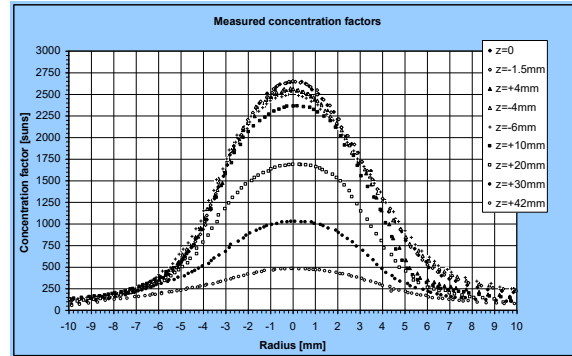
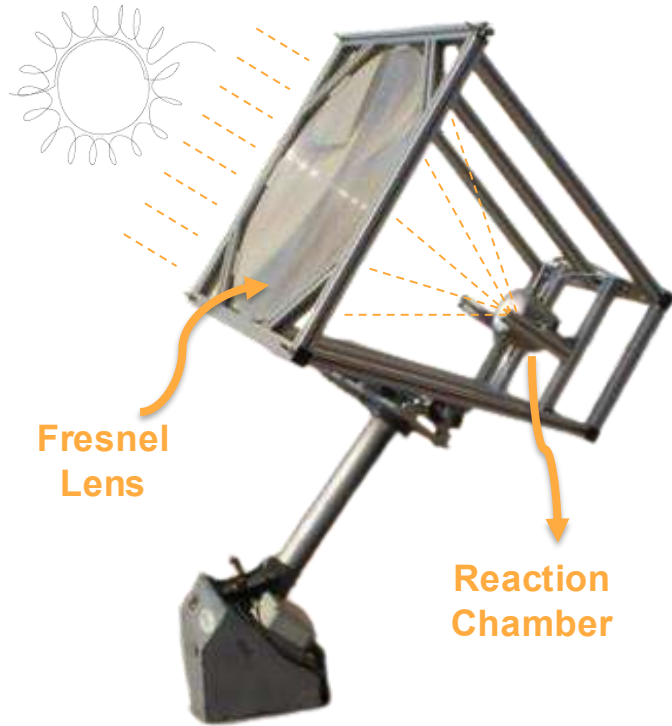
Intermetallics



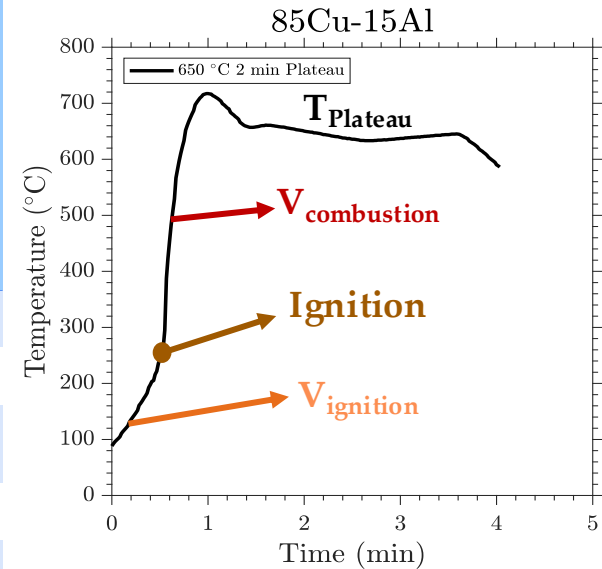
Diffusion layer



Concentrated Solar Energy (CSE)



Diameter	900 mm
Focal distance	757 mm
Focal Surface	20 mm ²
Concentration factor	2644
Power density	260 W/cm ²



Challenges

Achieving high enough heating rates to trigger the SHS reaction.

Ensuring reactive sintering occurs in the brown parts after printing.

Controlling the ignition and propagation of the reaction to avoid defects.

Forming a thin diffusion layer with strong bonding between dissimilar materials.

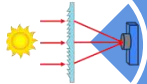
Reaching a balance between hardness and brittleness, as intermetallics tend to be hard but fragile.



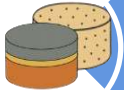
Goals



Manufacturing of copper/aluminum multimaterials by Powder Metallurgy and Additive Manufacturing



Solar activation of Self-Propagating High-Temperature Synthesis reactions



Synthesis of intermetallics and formation of diffusion layers

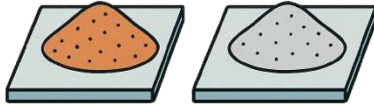


Use of low-cost FDM polymer printers for metal printing



Powder Metallurgy

Materials



	Copper	Aluminum
Density (g/cm ³)	8.74	2.70
Purity (%)	99.5	
Particle size (μm)	<45	

Manufactured systems

All mixtures are expressed in % wt

	Single layer	Multi-layer
Pure Systems	Cu	Cu/Al/Cu
	Al	
Mixture Systems	85Cu-15 Al	Cu/85Cu-15Al/Cu
	70Cu-30Al	Cu/70Cu-30Al/Cu
	50Cu-50Al	Cu/50Cu-50Al/Cu



Powder Metallurgy

Methodology

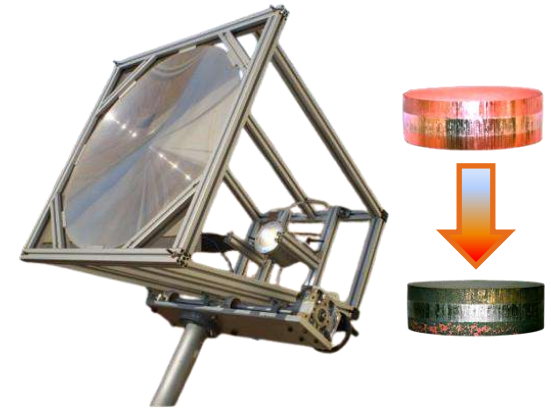
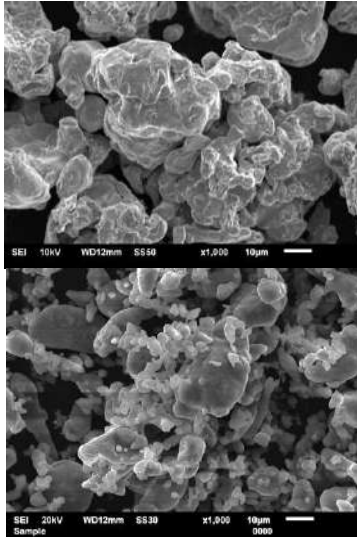
Mixing

Pressing

Sintering

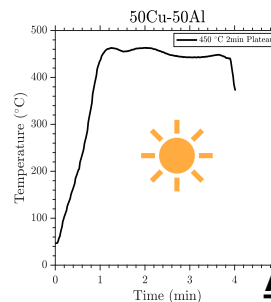
Copper

Aluminum



Results via PM

Single layer



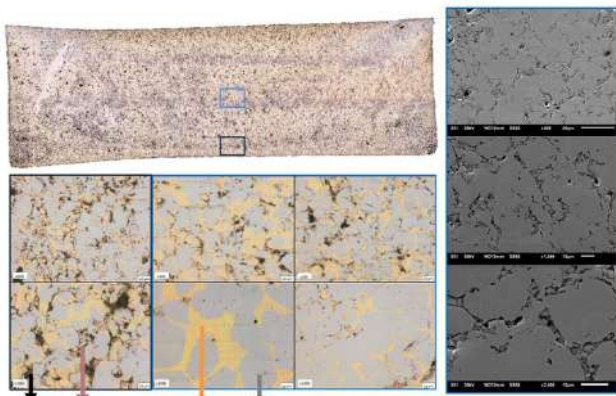
Copper 800 °C 2 min



Aluminum 450 °C 2 min

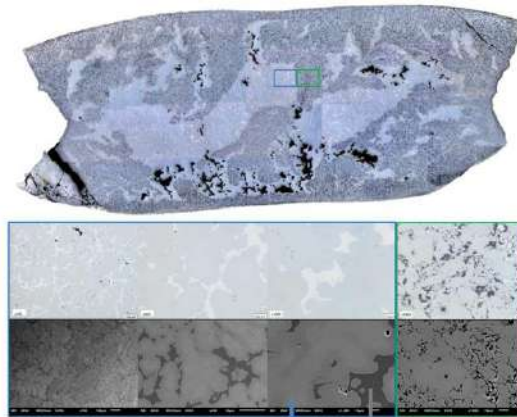


85Cu-15Al 650 °C 2 min



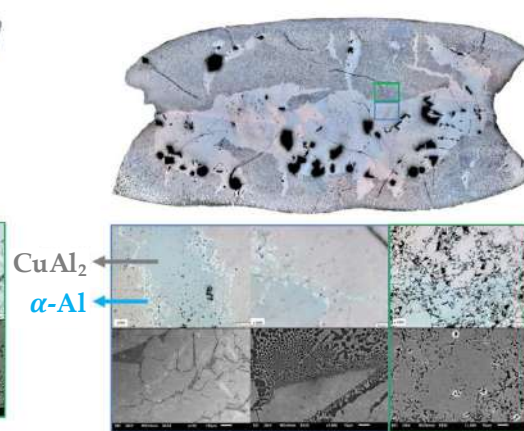
CuO Cu α-Cu α-Cu

70Cu-30Al 700 °C 2 min



CuAl CuAl₂

50Cu-50Al 450 °C 2 min

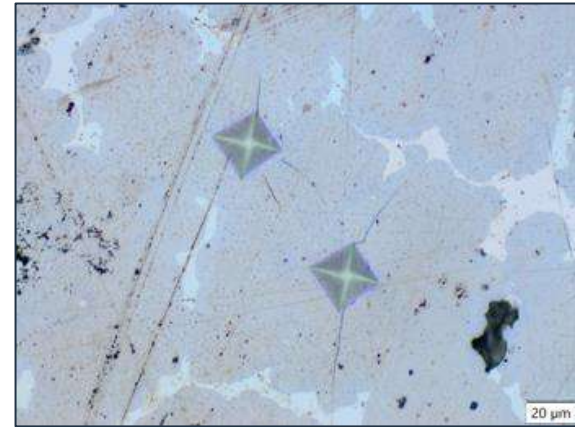
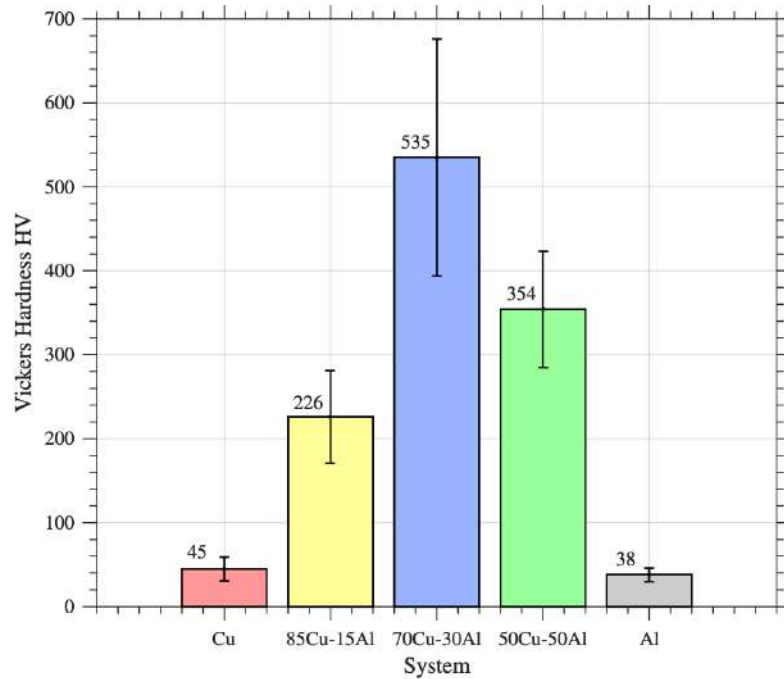


CuAl₂
α-Al



Results via PM

Hardness in single layer samples

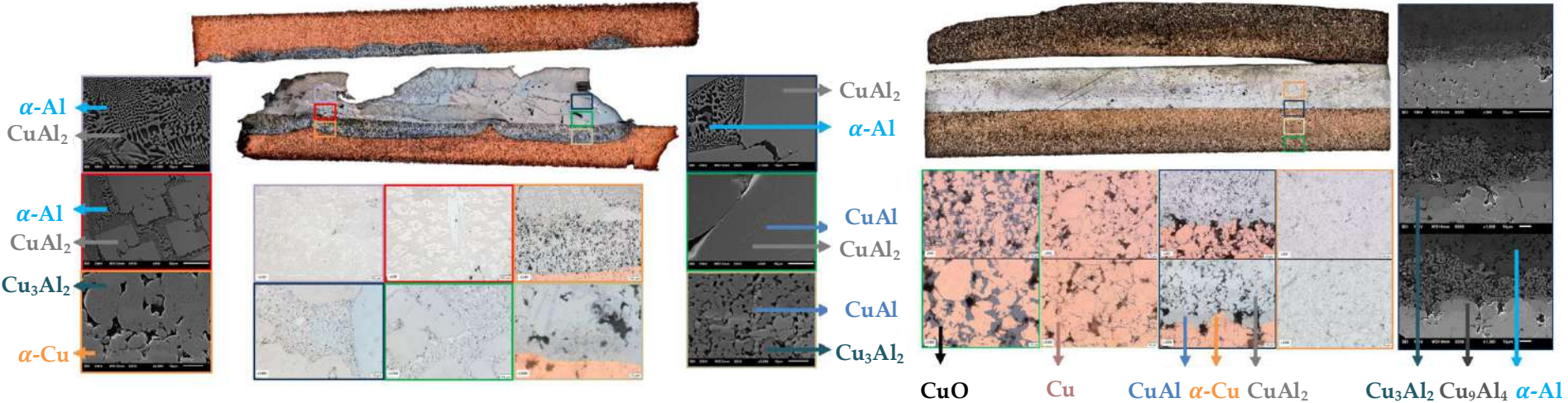


The matrix prevents crack propagation



Results via PM

Cu/Al/Cu diffusion layer

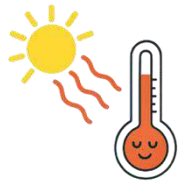


↑↑ Temperature = 850 °C



- Delamination
- High formation of intermetallics
- Highly exothermic reaction

↓ Temperature = 400 °C



- Better quality of the union
- Formation of a diffusion layer
- Sintering of the central layer



Results via PM

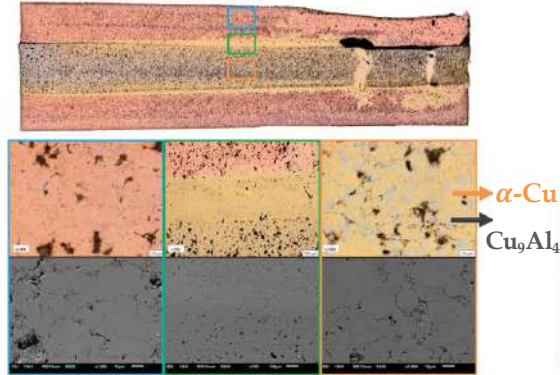
Multi-layer diffusion layer

Temperature
Heating rate

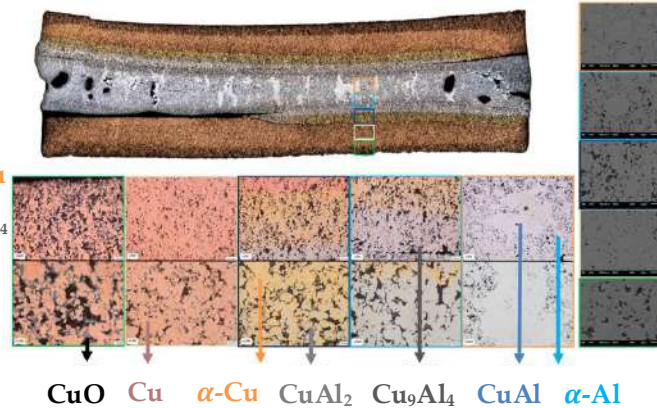
Time



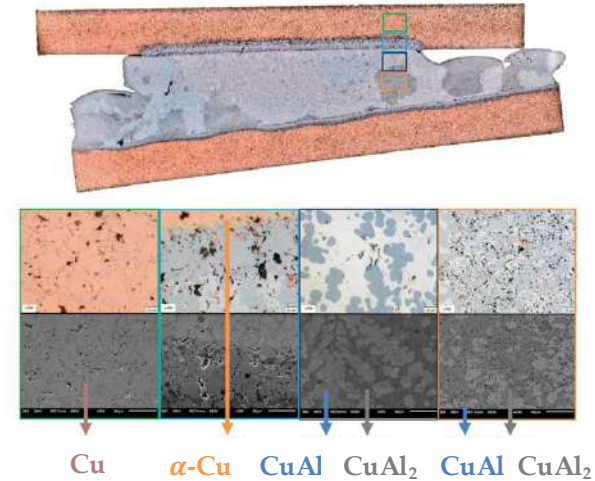
Cu/85Cu-15Al/Cu



Cu/70Cu-30Al/Cu



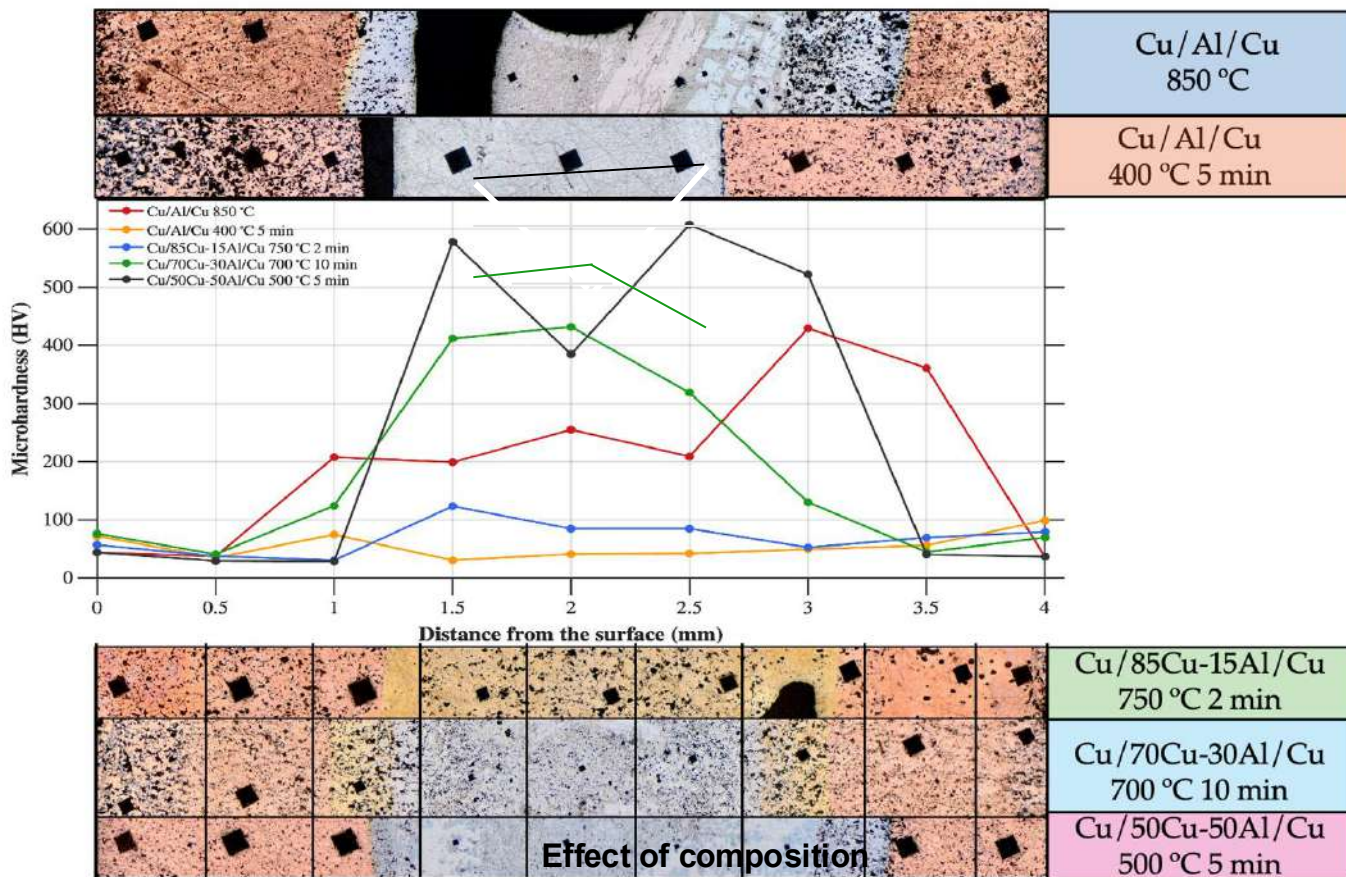
Cu/50Cu-50Al/Cu



Results via PM

Diffusion layer hardness

Effect of temperature



Additive Manufacturing

Materials

Virtual Foundry

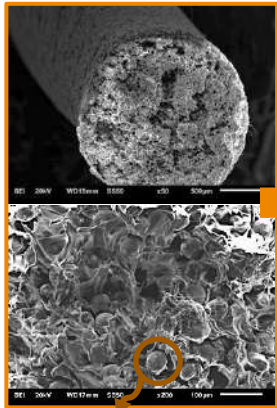
Manufactured systems



	Copper	PLA
%wt	89	11
	Aluminum 6061	PLA
%wt	67	33



Single layer	Multi-layer
Cu	Cu/Al/Cu
Al	



Metallic Powder

Printing



Debinding



Sintering



Additive Manufacturing

3D
PRINTINGAFTER
DEBINDINGSOLAR
SINTERING

Previous solar works on pure copper parts

A. Cañadilla, G.P. Rodriguez, A. Romero, M.A. Caminero, O.J. Dura, **Sustainable production of copper components using concentrated solar energy in material extrusion additive manufacturing (MEX-CSE)**, *Sustainable Materials and Technologies* **2024**, 39, e00799.
<https://doi.org/10.1016/j.susmat.2023.e00799>.

A. Cañadilla, A. Romero, G.P. Rodriguez, G. Matula, L. Krzeminski, B. Tomiczek. **Manufacturing copper complex parts using an innovative Printing-Debinding-Solar Sintering (PDSS) process**, *Journal of Manufacturing Processes* **2025**, 134, 851-865.
<https://doi.org/10.1016/j.jmapro.2025.01.001>.

Results via AM

Multi-layer

Cu/Al/Cu



Green



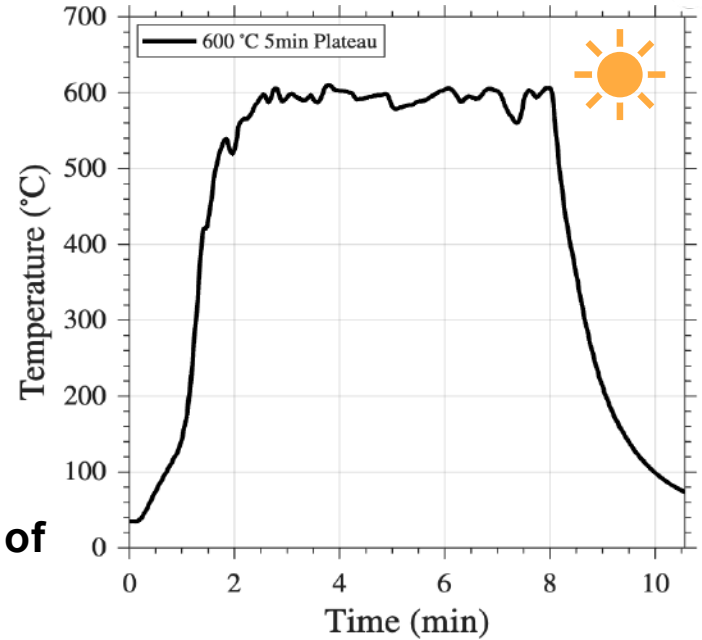
Brown



Sintered



In the process of
optimizing



Conclusions



Feasibility of using CSE in the solar sintering step in PM and AM



Processing of multi-material metal components via reactive solar sintering in PM

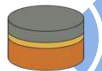


Using low-cost polymer printers for metal printing and solar sintering

Powder Metallurgy



Heating rate, temperature and composition are the main factors for controlling the SHS reaction.



Formation of intermetallic diffusion layers with the presence of a gradual intermetallic transition in PM

Additive Manufacturing



Acknowledgments

- **“Programa Investigo” initiative (JCCM-2024, co-funded by the FSE+)**
- Scientific Research and Technology Transfer Project, JCCM, 2024–2026 (SBPLY/23/180225/000201)
- Ministry of Science and Innovation, Knowledge Generation Projects 2022, PID2021-122491OB-I00
- Support for Consolidated Research Groups at UCLM, Vice-Rectorate for Research, UCLM Internal Research Plan, 2023-GRIN-34105 (2023–2025)



Financiado por
la Unión Europea
NextGenerationEU



GOBIERNO
DE ESPAÑA

MINISTERIO
DE TRABAJO
Y ECONOMÍA SOCIAL



Plan de Recuperación,
Transformación
y Resiliencia



Castilla-La Mancha



Thank you!

Abraham.Sanchez@uclm.es