

This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

SAND2018-9010C

# Composite Cu-C and Cu-W Thermal Concentrator Design Using LENS



PRESENTED BY

Tim Price, Ph.D., Andrew Kustas, and Shaun Whetten

SFF 2018 – Austin, Texas

August 16, 2018

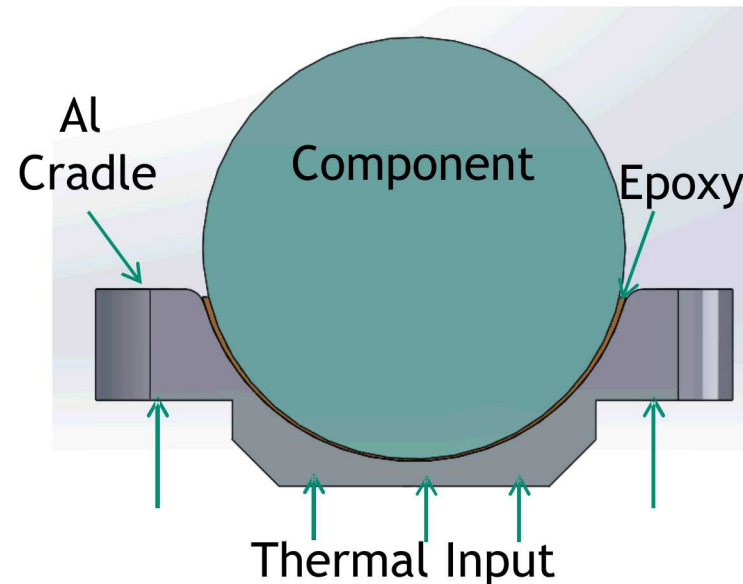
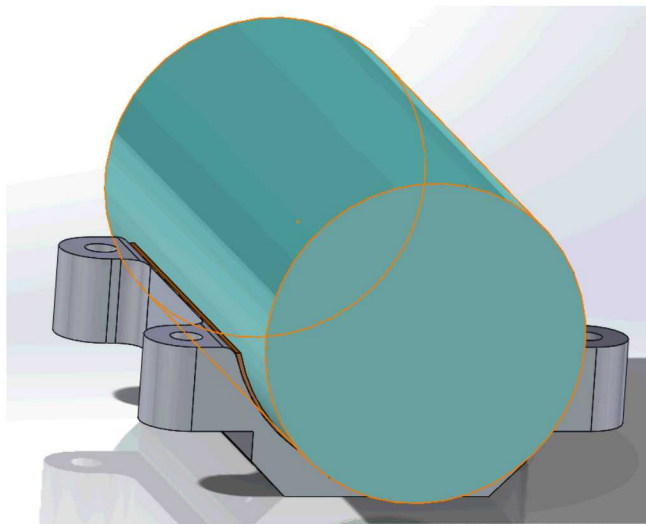
Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

# Multi-Material Thermal Concentrator Introduction

Objective: Maximize thermal energy transfer rate into a component

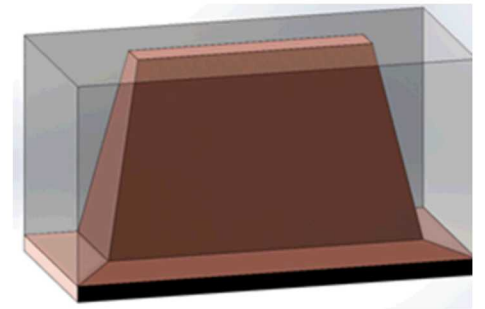
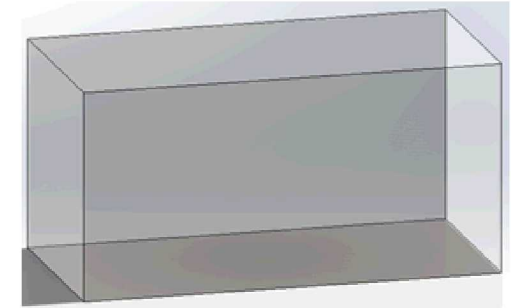
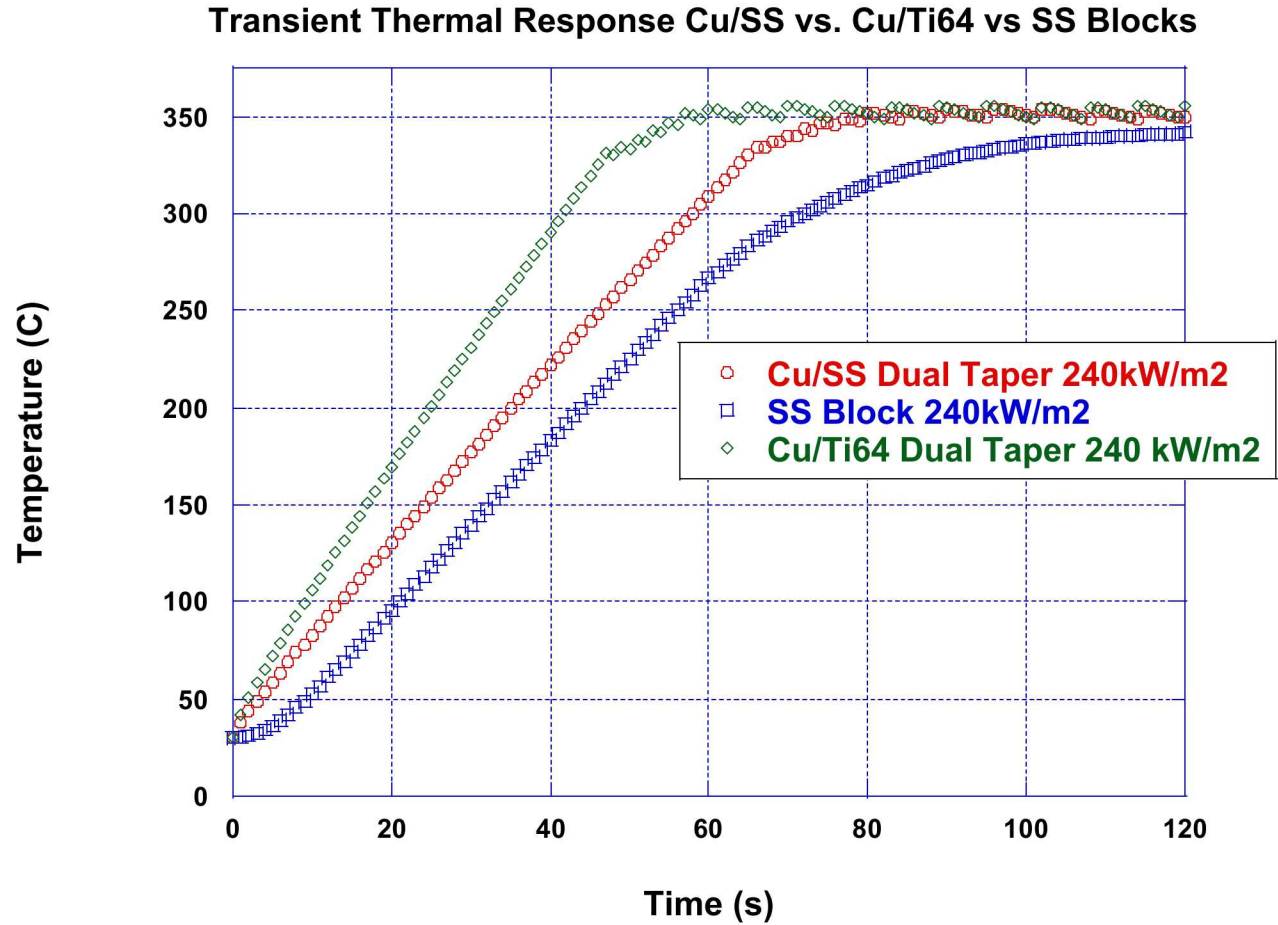
Existing structures are solid SS or Al, traditional manufacturing

Multi-material AM is appealing as a process and design enabler



## Previous Work

- 2017 work developed thermal concentrator blocks
- FEA and thermal experiments confirmed thermal performance
- Presented at SFF 2017



## 4 Multi-Material Thermal Concentrator – Problem

Problem: Our current LENS system shows incomplete Cu melting and poor metallic interfaces

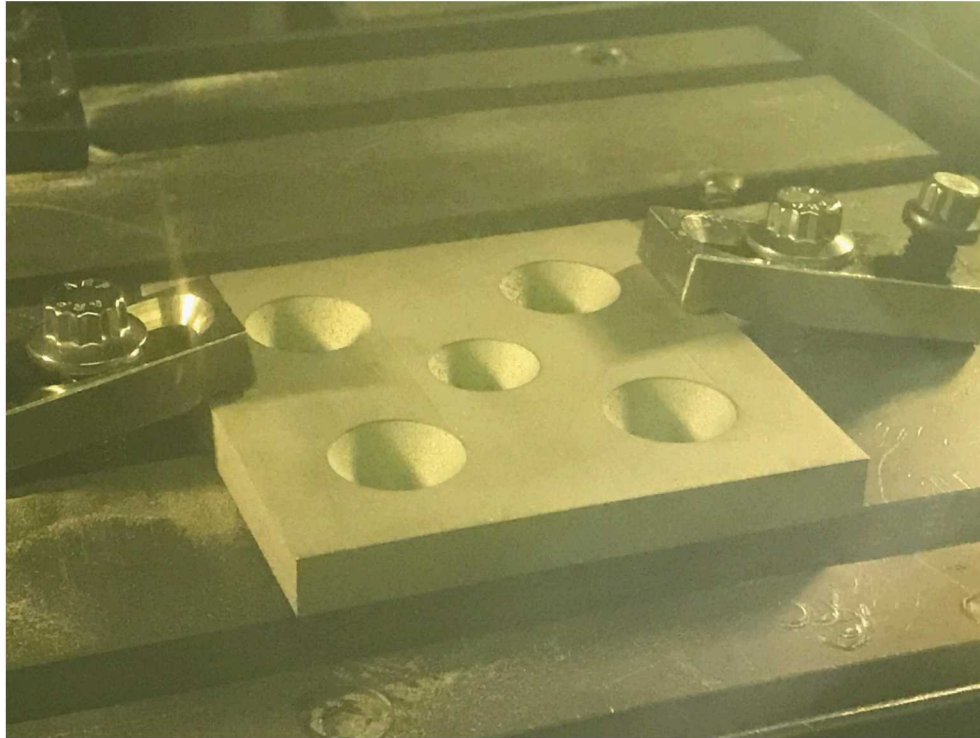


## Multi-Material Thermal Concentrator – Hypothesis

Hypothesis: Mix LENS powder with C or W to act as melting nuclei to enhance metal interface



## Process: 3D printing of Copper with LENS



### Processing parameters:

Laser powers: 400W

Build velocity: 720 mm/min

Atmosphere: <100 ppm O<sub>2</sub>; <10 ppm H<sub>2</sub>O

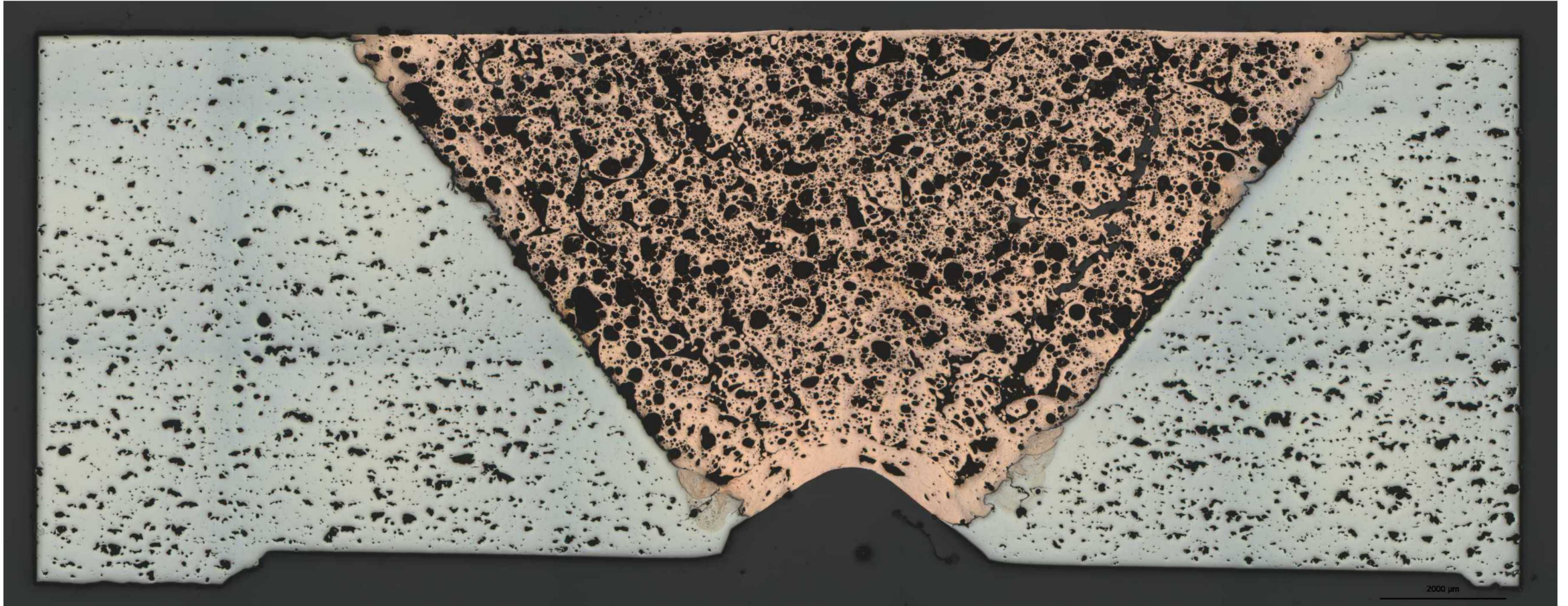
## 7 Experiment Summary

3 Experiments were performed with different powder compositions

- Cu-C Un-Mixed
- Cu-W Un-Mixed
- Cu-C Mixed (ball mill 5-10 mins)

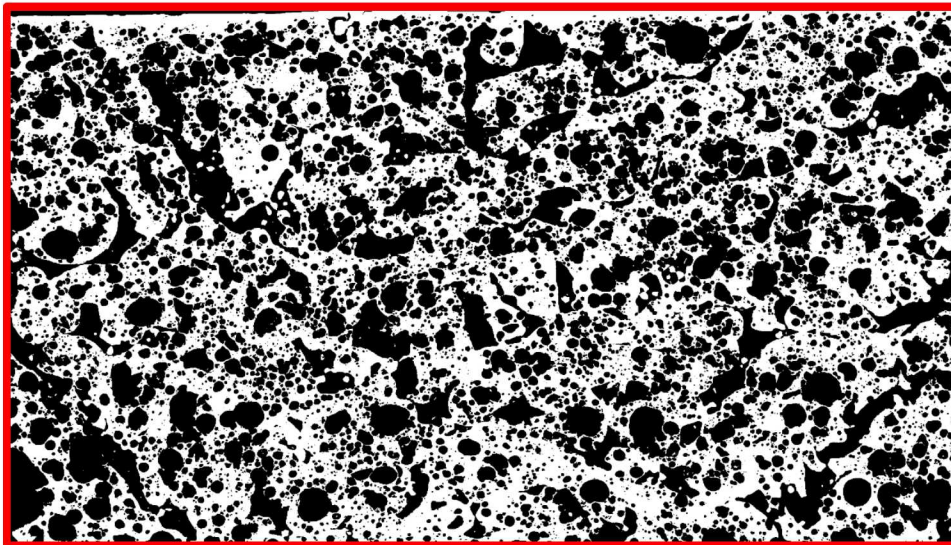
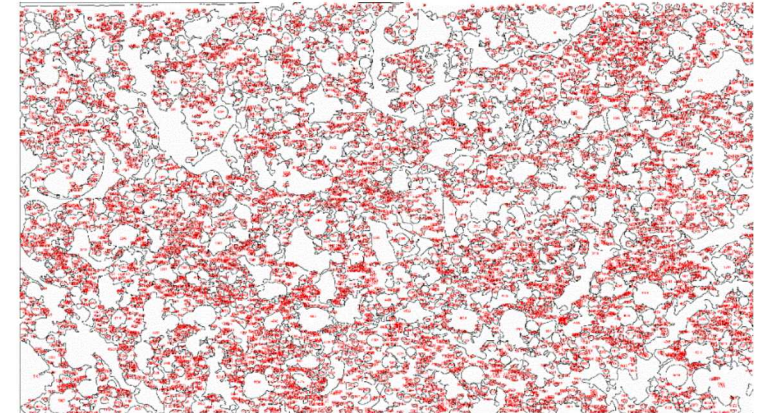
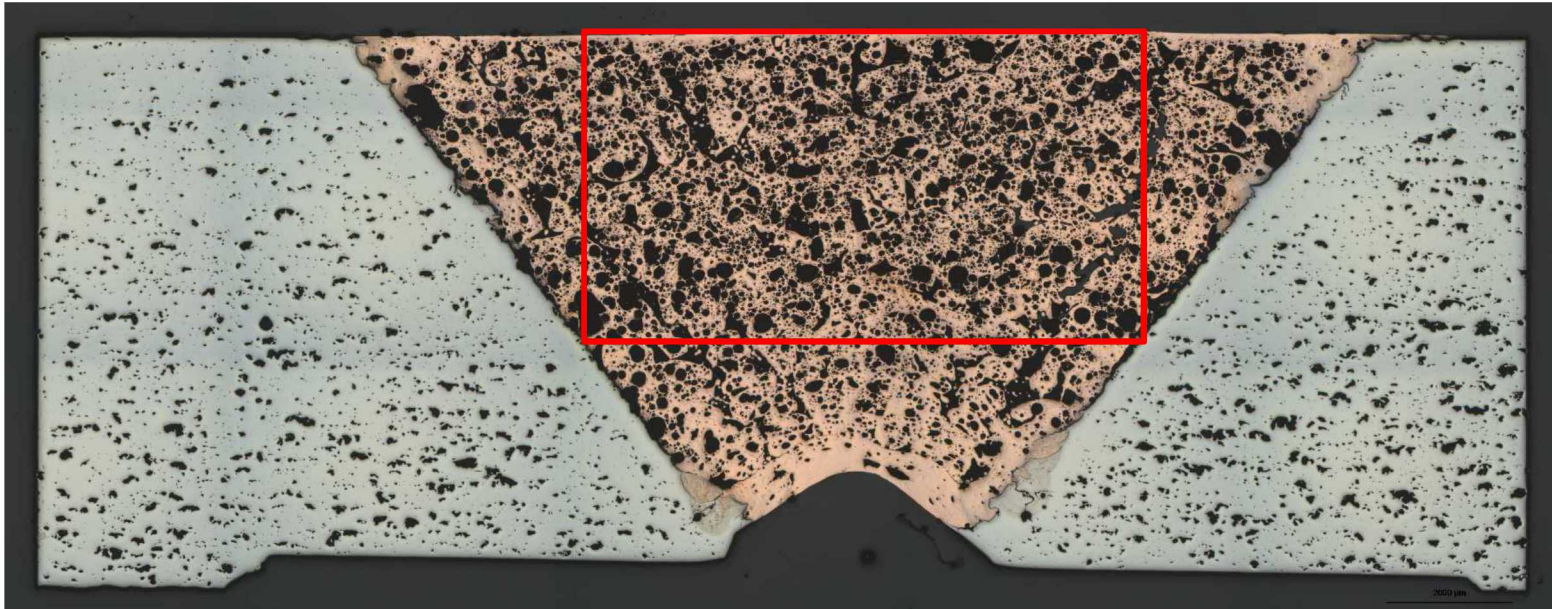
Test wells were cross sectioned and polished to check for wall bonding and porosity

# Cu-C LENS composite - unmixed



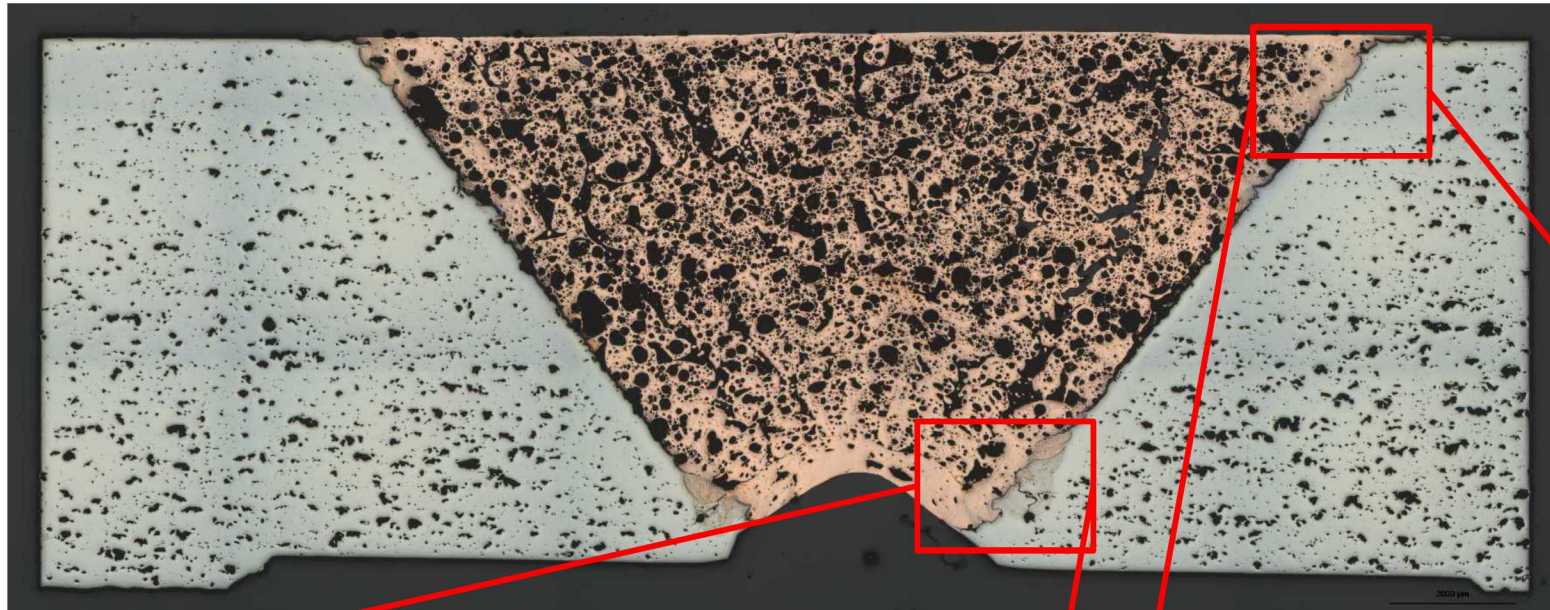
Note high porosity in SS304L and Cu-C, likely resulting in increased thermal resistance

# Cu-C LENS composite – unmixed

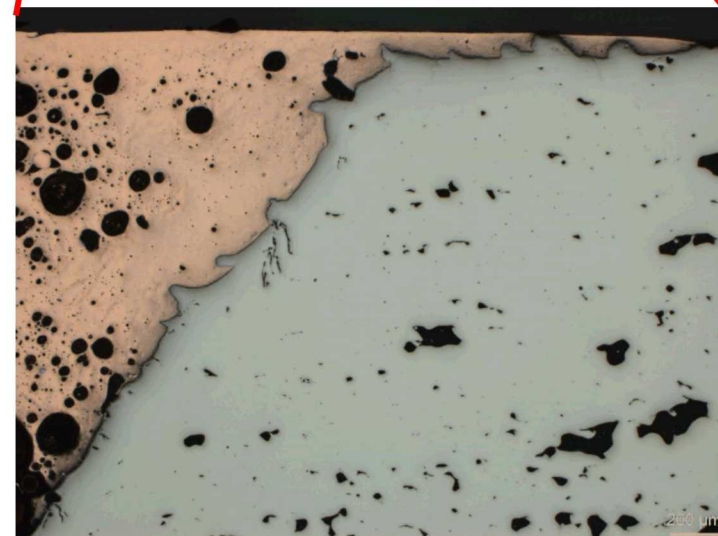
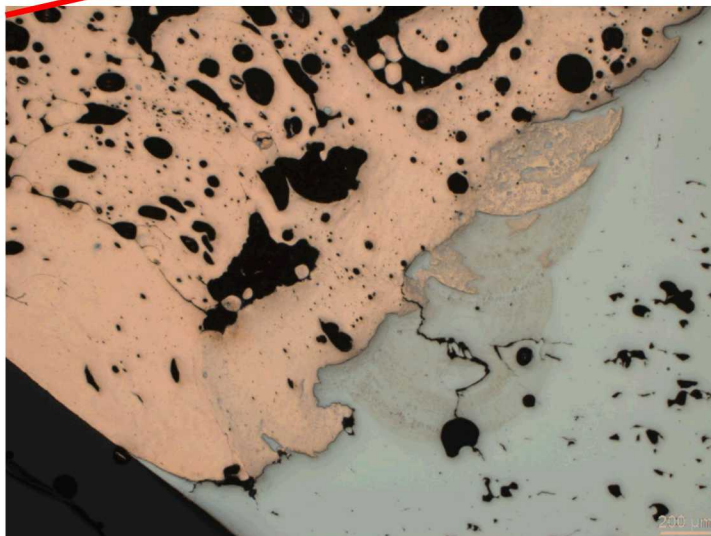


Void number = 6294; 150/mm<sup>2</sup>  
% Area Porosity = 52.2

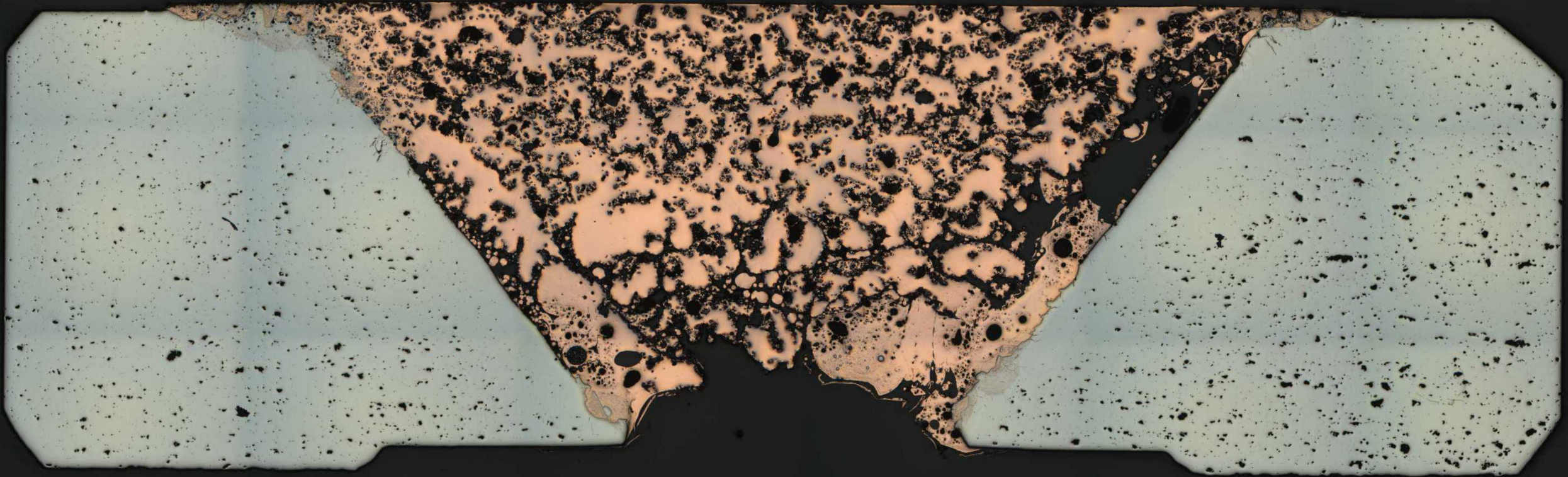
# Cu-C LENS composite – unmixed



Interface quality shows promise – rigid Cu-SS304L interfaces observed.

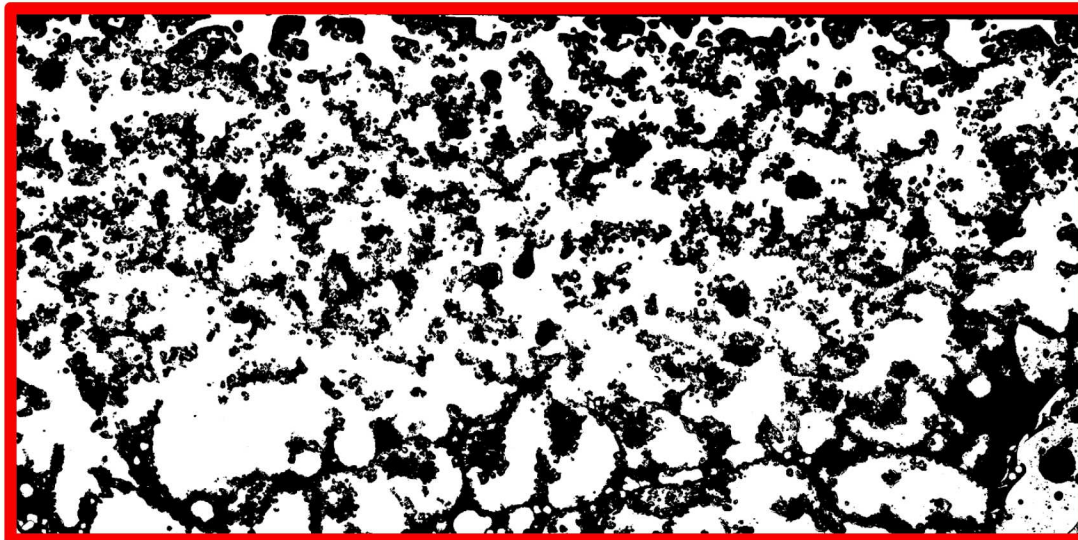
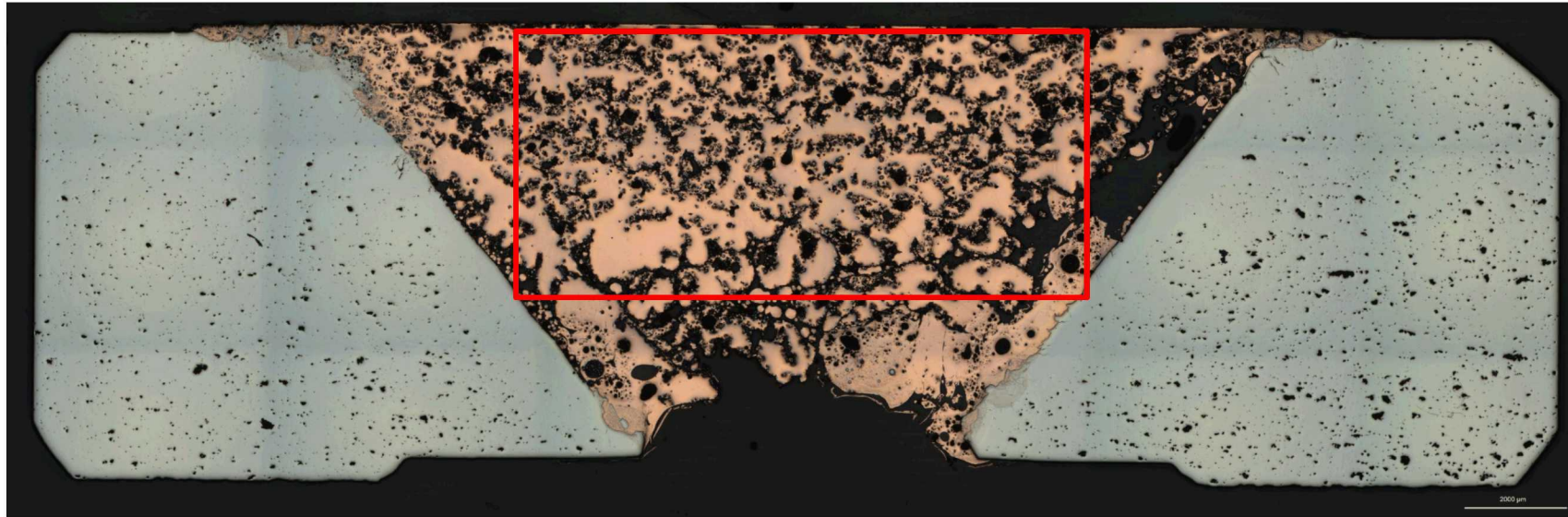


# Cu-W LENS composite – unmixed



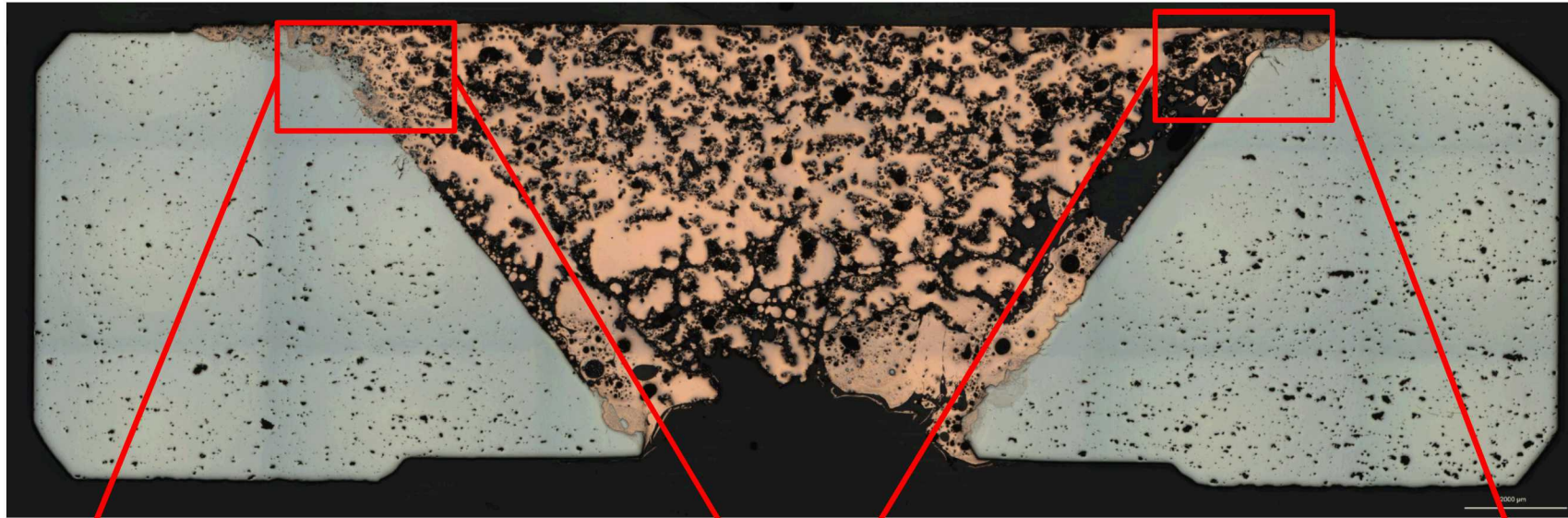
2000  $\mu\text{m}$

# Cu-W LENS composite – unmixed

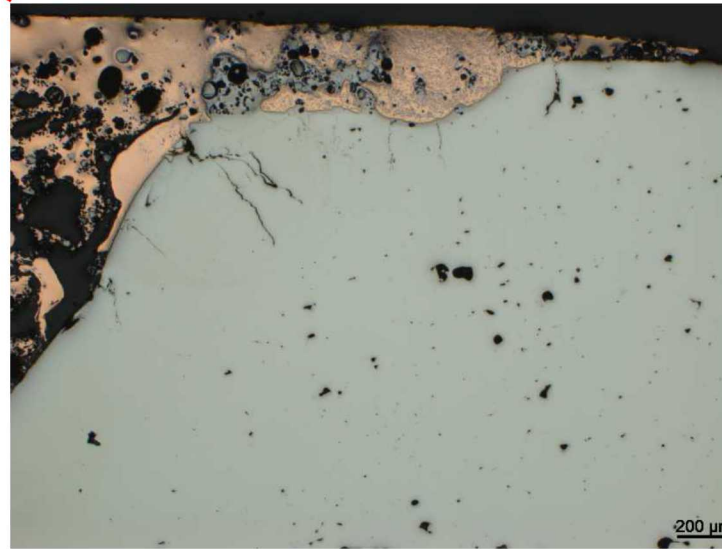
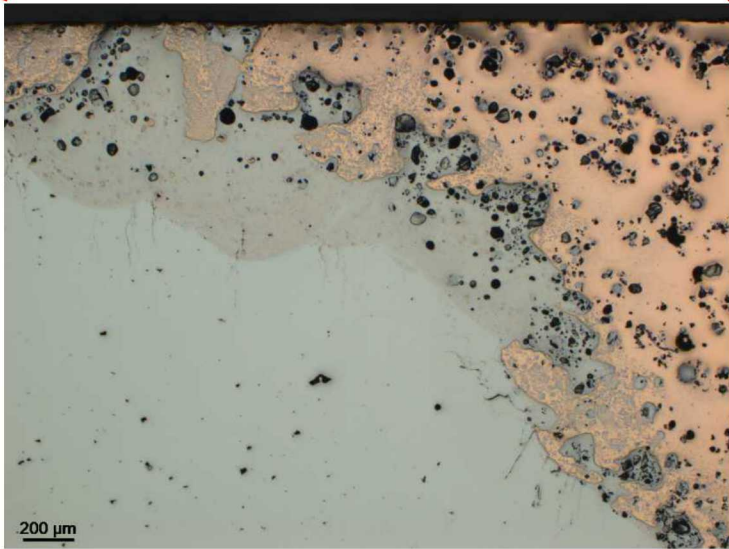


Void number = 1608; 30/mm<sup>2</sup>  
% Area Porosity = 41.7

# Cu-W LENS composite – unmixed

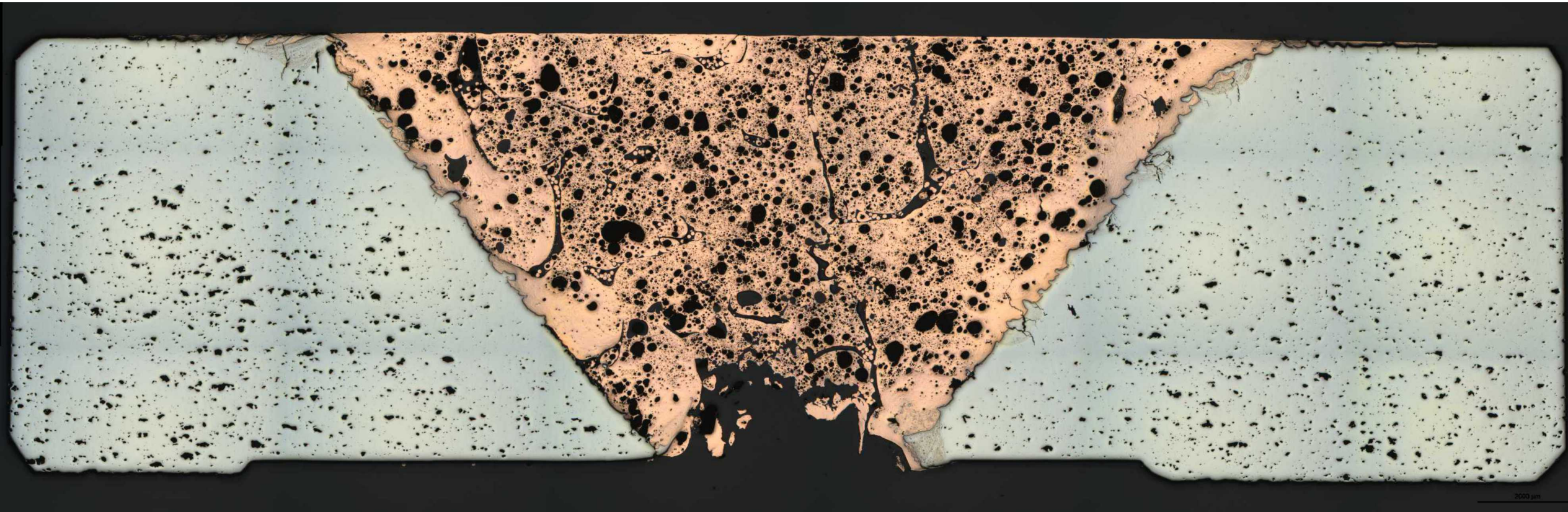


Interface quality again promising. Fine tungsten particles shown uncompromised following melting.

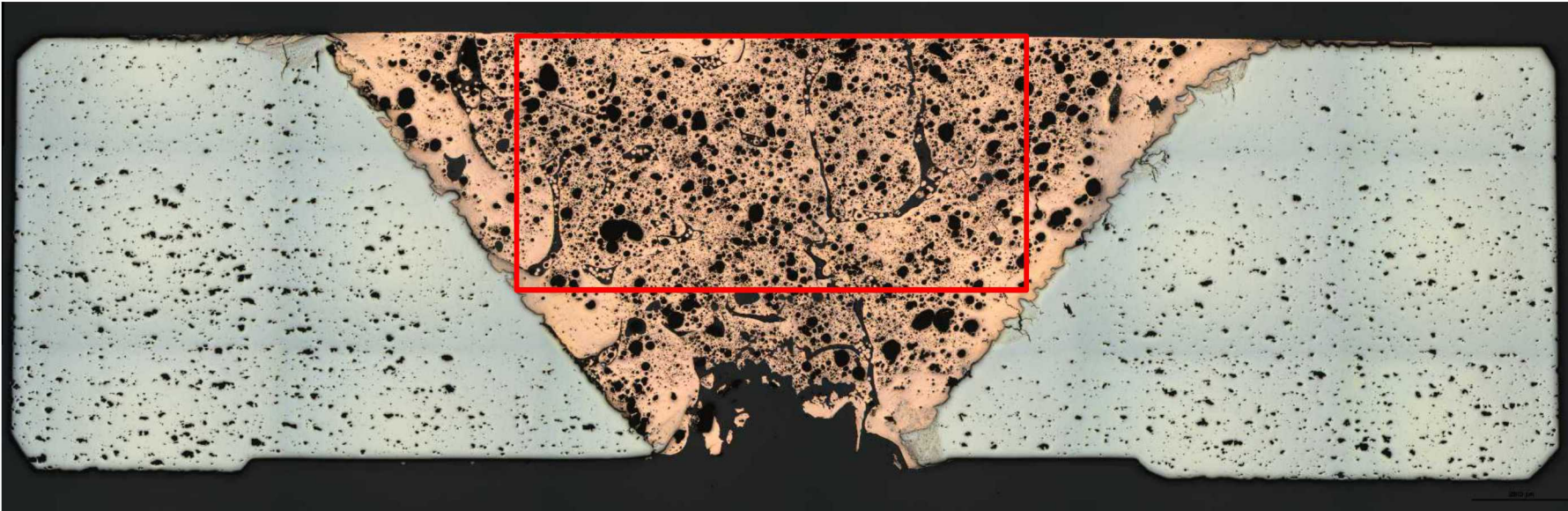


Significantly coarser average pore size and larger high-density regions.

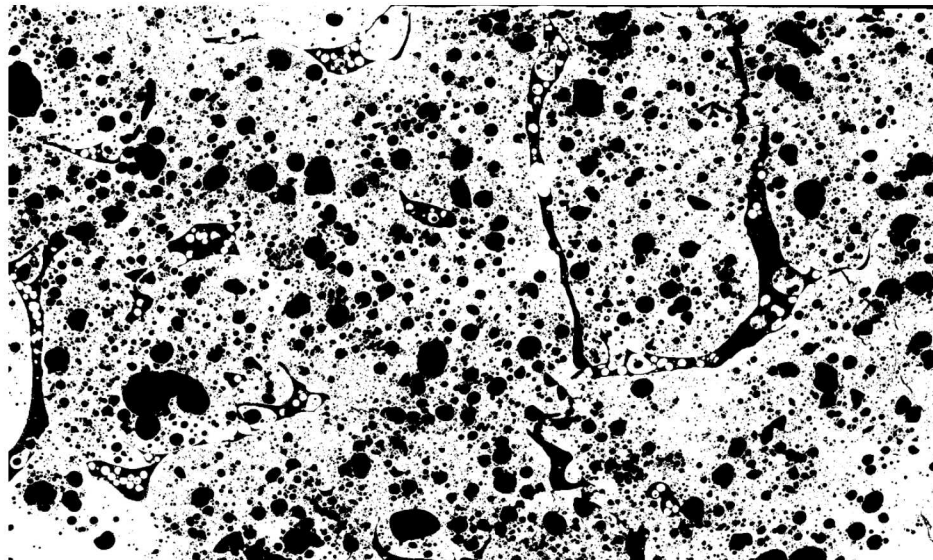
# Cu-C LENS composite again – mixed



# Cu-C LENS composite again – mixed



Significantly improved interface quality and significant porosity reduction (**> 15%**) when Cu is mixed/cladded with graphite.



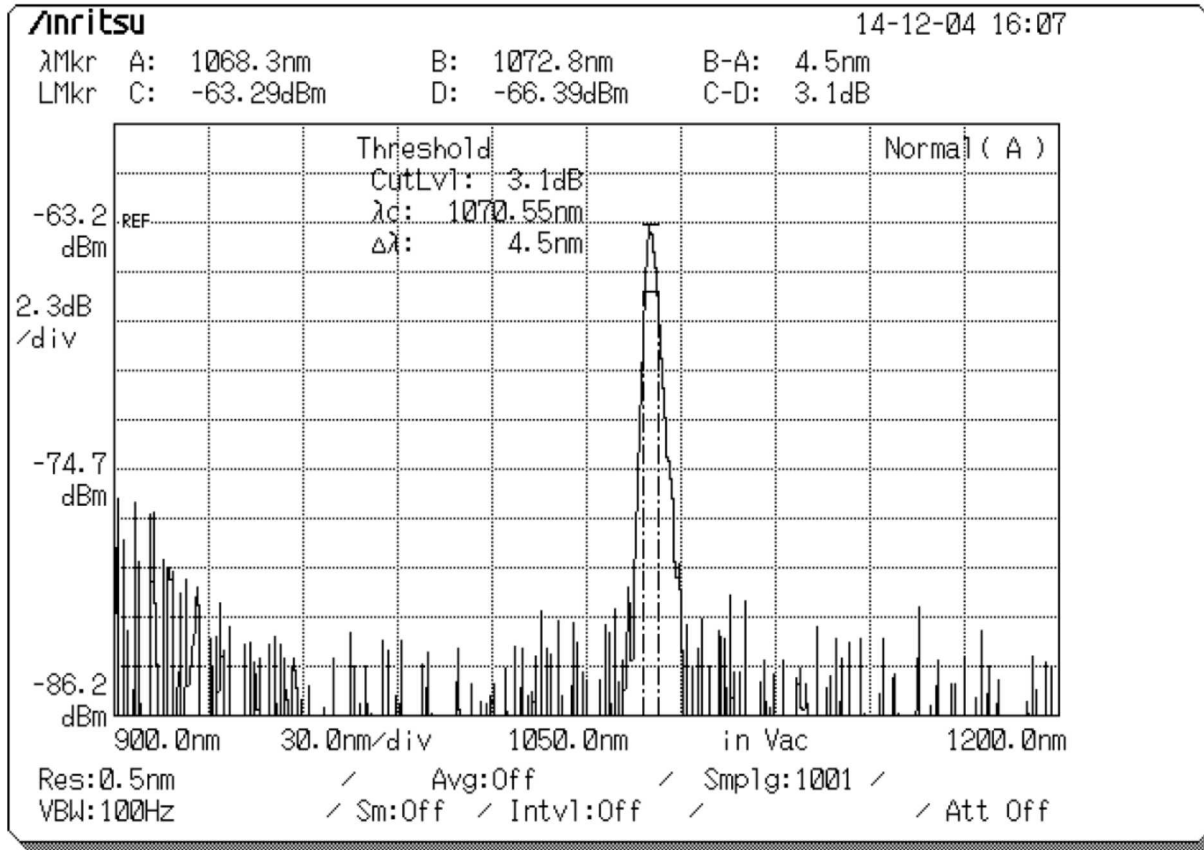
Void number = 14817; 240/mm<sup>2</sup>  
*% Area Porosity = 36.2*  
*(carbon solubility in Cu?)*

# Cu-composite porosity summary

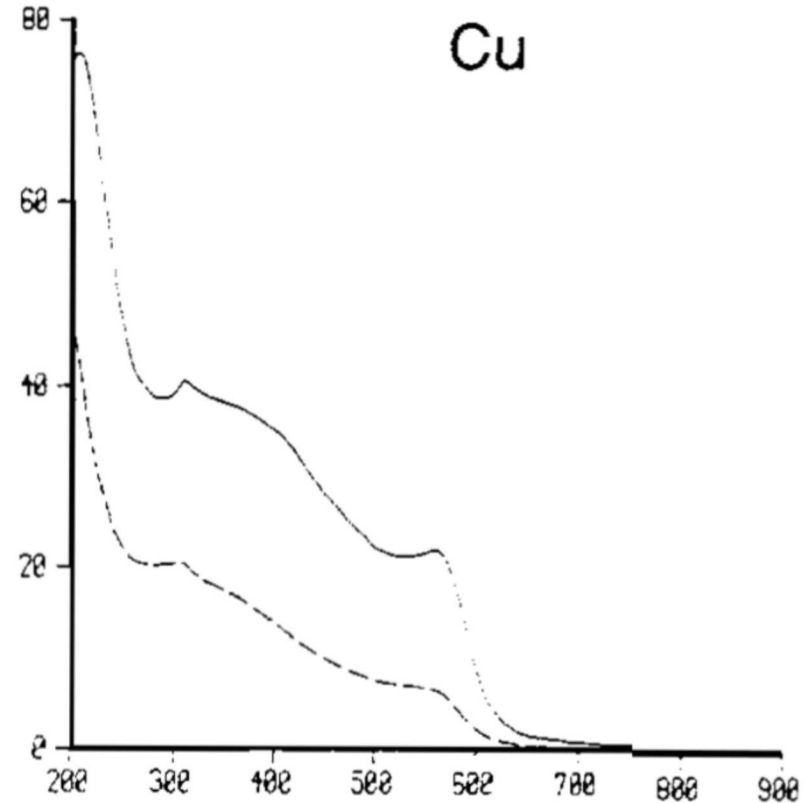
Material Combination	Void Number	%Area porosity
Cu-C (unmixed)	6294	52.2
Cu-W (unmixed)	1608	41.7
Cu-C (5-10 min. mixing)	14817	36.2

Mixing/cladding of Cu powder showed drastic reduction in porosity – three proposed directions for future work.

# What Happened?



Output Spectrum at maximum output power



Liquid Cu has higher laser absorption at our laser spectra,  
vaporizes Cu leading to voids.

From: Ultraviolet-Visible Absorption Spectra of the Colloidal Metallic Elements,  
Creighton and Eadon, J. Chem. Soc. Faraday Trans. 1991

- Possibly pulse to start laser and maintain melt pool throughout laser path
- Evaluate the Cu-C ball milled powder to evaluate characteristics
- Use a better matched laser (Blue Laser ~ 450nm)
- Plasma based wire feed shows promise (S. Whetten)

Special thanks to Dave Keicher for his valuable service and insights



Thank You!

---

Tim Price, Ph.D. [tprice@sandia.gov](mailto:tprice@sandia.gov)