CASE STUDY | MULTI-MATERIAL ADDITIVE MANUFACTURING

Accelerated Development of Multi-Materials for L-PBF

Thermo-Calc Solutions used a predictive ICME approach to define the processing space and identify lower-risk conditions in only days, reducing the dependency on costly trial-and-error testing during materials development.

Days
to predict a viable process window

200+ trials
estimated for traditional route

1-2 years
estimated traditional timeline

200k+ €
estimated cost savings

The Challenge

Multi-material additive manufacturing enables lighter, more efficient components by combining different material properties within a single part. However, joining dissimilar materials during laser powder bed fusion (L-PBF) remains a significant challenge.

Successful processing requires balancing alloy chemistry and process conditions to achieve strong bonds while limiting brittle intermetallic phases, thermal stresses, and defects. Finding this balance experimentally alone is often slow, expensive, and difficult to scale.

This was a key focus of the MADE-3D project, which explored how multi-material additive manufacturing can be used to create components with locally tailored properties. In particular, the project investigated Al-Cu material combinations for L-PBF applications in high-power electronics and automotive systems.

The Approach

Thermo-Calc Solutions developed and applied an Integrated Computational Materials Engineering (ICME) approach to evaluate how alloy chemistry and L-PBF process parameters influence the quality of aluminum-copper interfaces (Figure 2).

The workflow used alloy compositions and manufacturing parameters as inputs (1) to predict intermixing and material behavior during printing (2). These predictions were then used to assess the risk of brittle phase formation and processing defects across a range of L-PBF conditions (3), helping identify promising parameter combinations for experimental validation (4).



Common Issues with Multi-Material L-PBF Processing

- Cracking from brittle intermetallic phases
- Highly sensitive process windows
- Weak bonding and premature failure

The ICME Workflow

Developed by Thermo-Calc

1: INPUT
- Manufacturing parameters
- Alloy compositions

2: PREDICT
- Dilution / intermixing
  Core metric

3: EVALUATE
- Materials constraints

4: OUTPUT
- Actionable, viable process window

Figure 2: The ICME approach developed by Thermo-Calc Solutions and used to identify a viable process window in days, with experimental verification completed in weeks.

A Process Map to Guide Experimental Trials

The ICME approach modeled dilution and intermixing between the two materials during L-PBF. The resulting local compositions were then used to predict the extent of intermetallic formation under different processing conditions.

The analysis produced a process map within days that identified promising processing window capable of producing sound interfaces with limited cracking while avoiding other unwanted processing defects, as labeled in Figure 3.

The process map enabled researchers to target experimental trials within promising regions of the processing space, focusing validation efforts, and reducing the time required to establish suitable processing conditions to mere weeks.

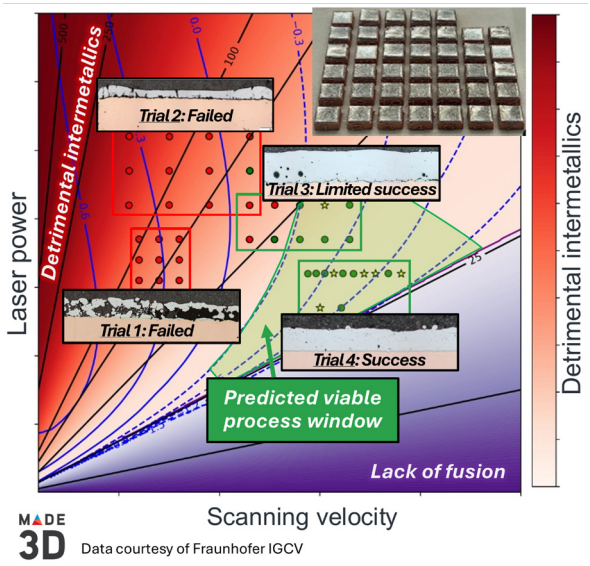


Figure 3: The Process Map for Al-Ci developed by Thermo-Calc that allowed researchers to successfully join Al-Cu using targeted experimental trials in Trial 4.

The Result

This work significantly reduced development time of multi-material processing by L-PBF and led to noticeable savings and improvements related to:

- **Faster development**
  From years to months by focusing on validation work.
- **Higher reliability**
  Reduced failed builds and repeated tests
- **Cost savings**
  Used fewer experiments to define process windows.
- **Improved sustainability**
  Limited scrap and energy consumption.

The work enabled the production of demonstrator components for cooling high-powered electronics within the MADE-3D project. When compared with traditional single-material components, these multi-material components achieved weight reductions of up to 60% and a 30% increase in cooling efficiency.

KEY RESULT

Days to identify a viable process window, weeks to verify results

The predicted window enabled researchers to focus experiments on conditions found in the trial 4 region and verify the results within weeks.

Traditional Development Estimate

The customer indicated that a conventional route could require:

200+	1-2	€ 200k+
trials	years	cost

Software: Thermo-Calc

Database(s): TCAL, TCCU

Solutions Package: Customized R&D Service

Bring us your multi-material AM challenge!

Talk to an experiment about ICME-based process mapping tailored to your material and application.

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