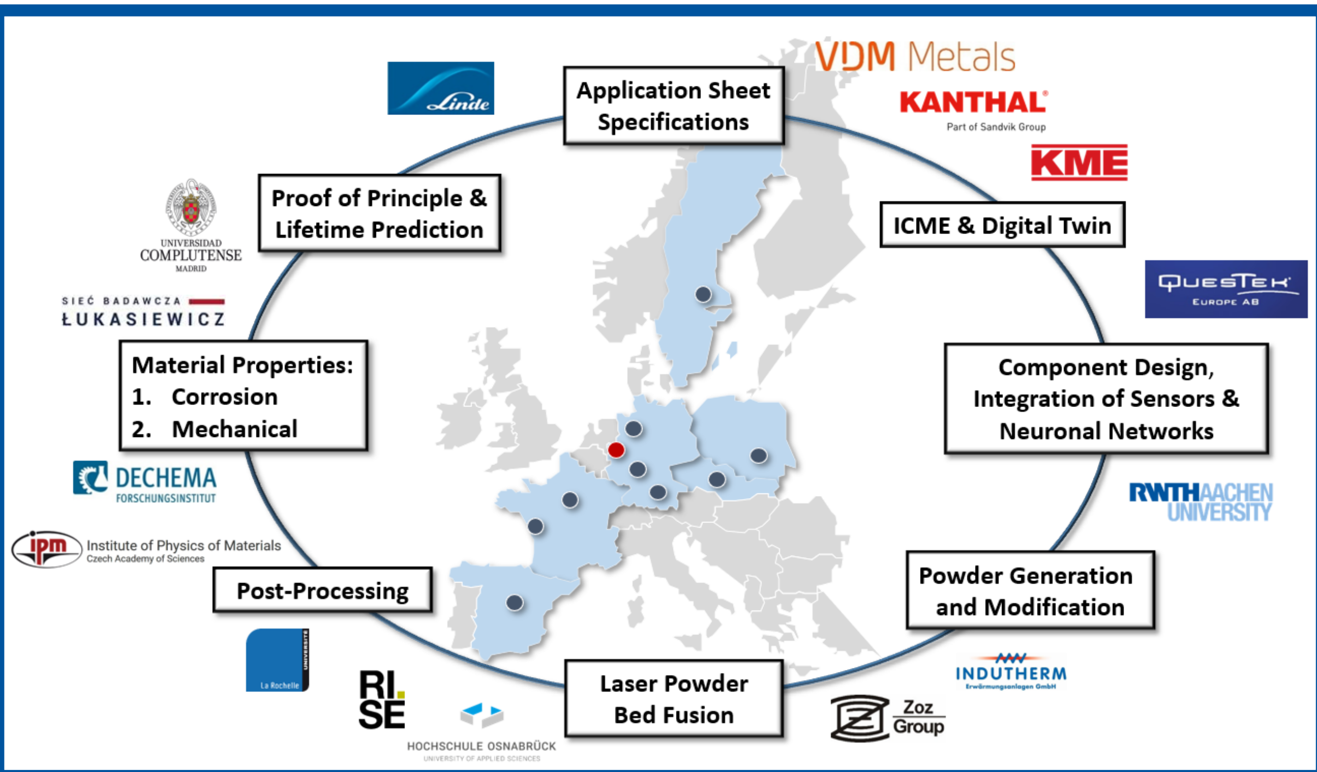
JUNE 2022

topAM BRIEFING

Developing ODS high temperature alloys tailored for AM



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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958192.

WP1 Application and specification sheet

WP1 has already been completed and the deliverable of the specification sheets for the ferrules and the gas burner tip were submitted on time. These specification sheets describe the materials' property goals, target environments and the component geometries. These are confidential deliverables and thus cannot be publicly posted.

WP2 Optimal computational design for LPBF based on ICME

With a range of nanoparticle candidates (oxides, nitrides, etc.) for dispersion strengthening and different processing methods (freeze granulation, mechanical alloying, internal oxidation and gas atomization reaction synthesis - GARS) for powder modification, WP2 has developed a particle selection methodology, which considers the specialties of each processing method and prioritizes the alloy design requirements for the three alloys considered in the project. The integration of multi-scale, multi-physics experimental and computational methods has been enabled in the ICME framework, which provides a sustainable path towards alloy development compared with traditional trial-and-error-based approaches. The WP2 activities and framework flow are shown below in Figure 1.

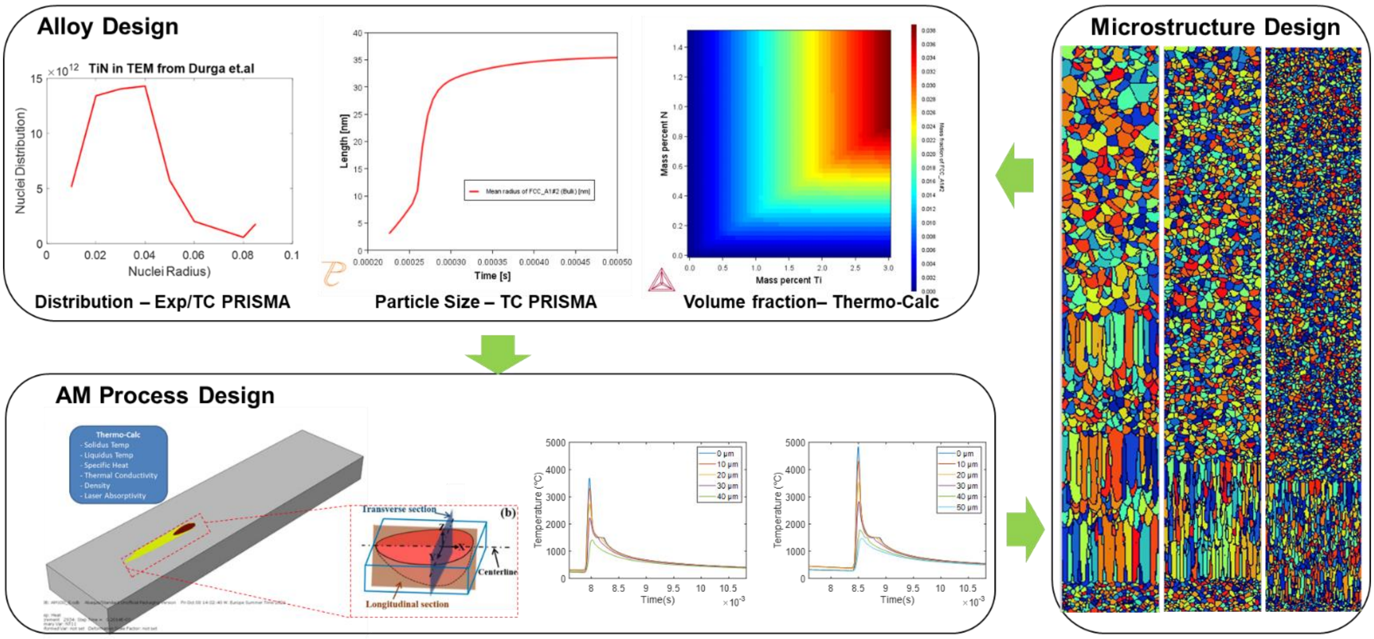

Figure 1. Summary of WP2 activities and process flow.

WP3 LPBF component design

For integrating the fiber Bragg grating (FBG) sensors in the component for improved monitoring of the components, two strategies have been developed: integration during and after the LPBF process. Initial experiments have been successfully performed for the integration of the FBG sensors for both strategies. To protect the FBG sensors from the high amount of heat during the LPBF process, a steel tube is introduced for sensor integration. The main challenges that were faced for integrating the sensors post-LPBF process are the removal of metal powder from the sensor channels and improving their surface roughness to not damage the sensor during placement into the channels. The results from these trials can be seen in Figures 2 and 3.

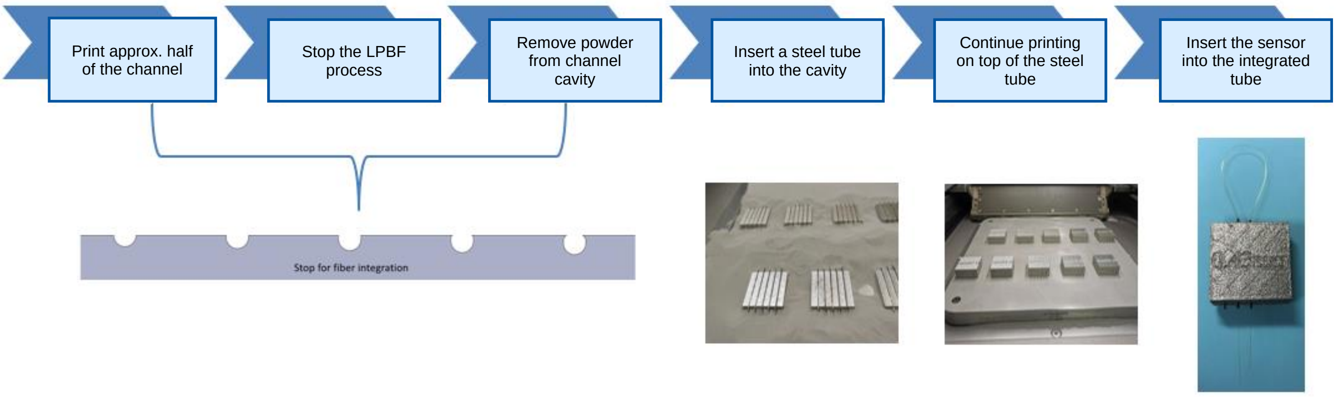

Figure 2. Sensor integration during the LPBF process using steel tubes.

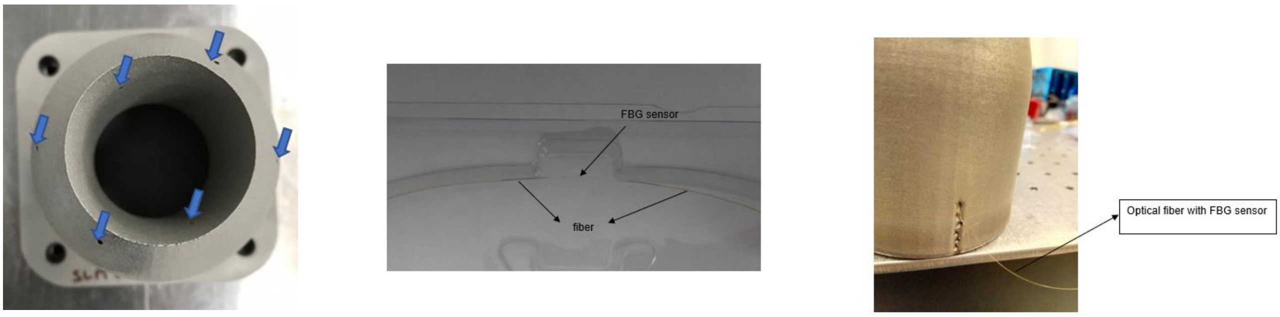

Figure 3. Sensor integration on a scaled-down gas burner tip component. Six sensor channels were designed and post-processed for sensor positioning.

WP4 Powder production and modification

Full characterization has been performed on all of the baseline alloy powders, from particle size distribution (PSD) to flowability to morphology and chemistry, including transmission electron microscopy (TEM) as shown in Figure 4. The as-atomised alloy 400 powder showed almost no dislocations in the interior and a fairly homogeneous chemical distribution.

Powder modification trials using freeze granulation and mechanical alloying (starting from <15µm and 15-53µm powder, respectively) have been conducted for the 3 different alloy systems using yttria nanoparticles with variation in vol% and nanoparticle size. Apart from obtaining a homogeneous distribution of the ODS particles, the control of PSD and/or flowability of such modified powders is a challenge and requires further optimisation. Process parameter studies on internal oxidation/nitridation have been carried out for the different base alloys via two alternative approaches, namely post-atomisation in a fluidised bed reactor using 15-53µm powders, as well as in-situ during atomisation. Promising process parameter windows have been identified and the next trials are scheduled using modified alloys with specific contents of alloy additions like Y, Zr or Ti to obtain a sufficiently high vol% of ODS particles.

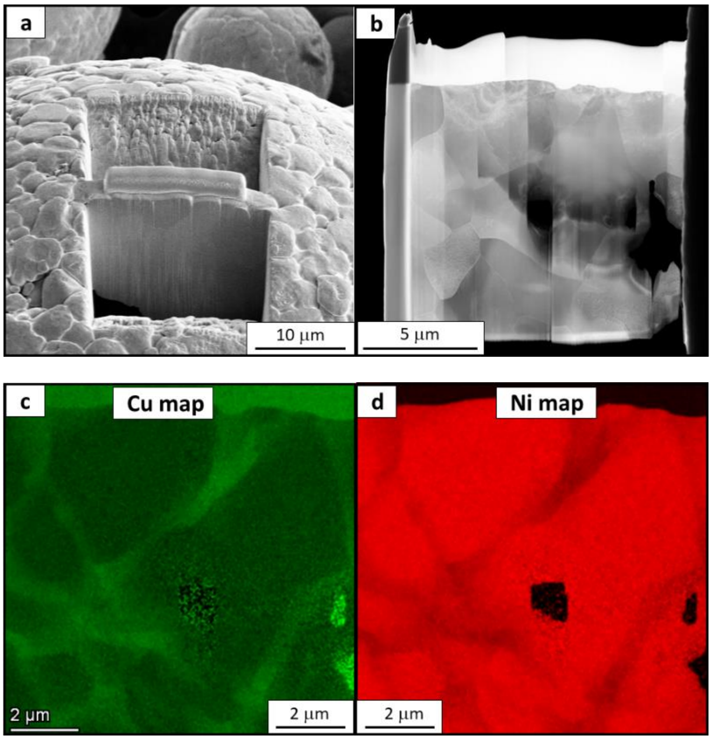

Figure 4. TEM analysis of an alloy 400 powder particle: a) visible surface solidification structure, b) a partially prepared FIB lamella showing sub 5µm grains, and c) Cu and d) Ni chemical distribution maps showing slight chemical segregation of Cu to the grain boundaries.

WP5 LPBF and Post-Processing

For alloys 400 and 699XA, LPBF process parameters have been optimized to reach high densities. Test specimens from these alloys have been manufactured by LPBF. Fatigue, creep, tensile and corrosion tests are being carried out on the AM produced specimens, with one example included in Figure 5. The microstructure of the AM produced parts are under investigation, as shown in Figure 6.

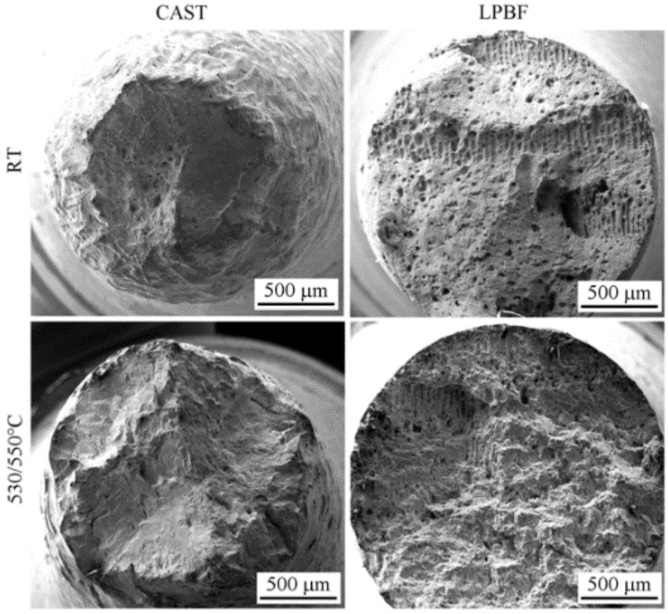

Figure 5. Tensile fracture surfaces of cast (left) vs. LPBF (right) alloy 400 at RT and >500°C.

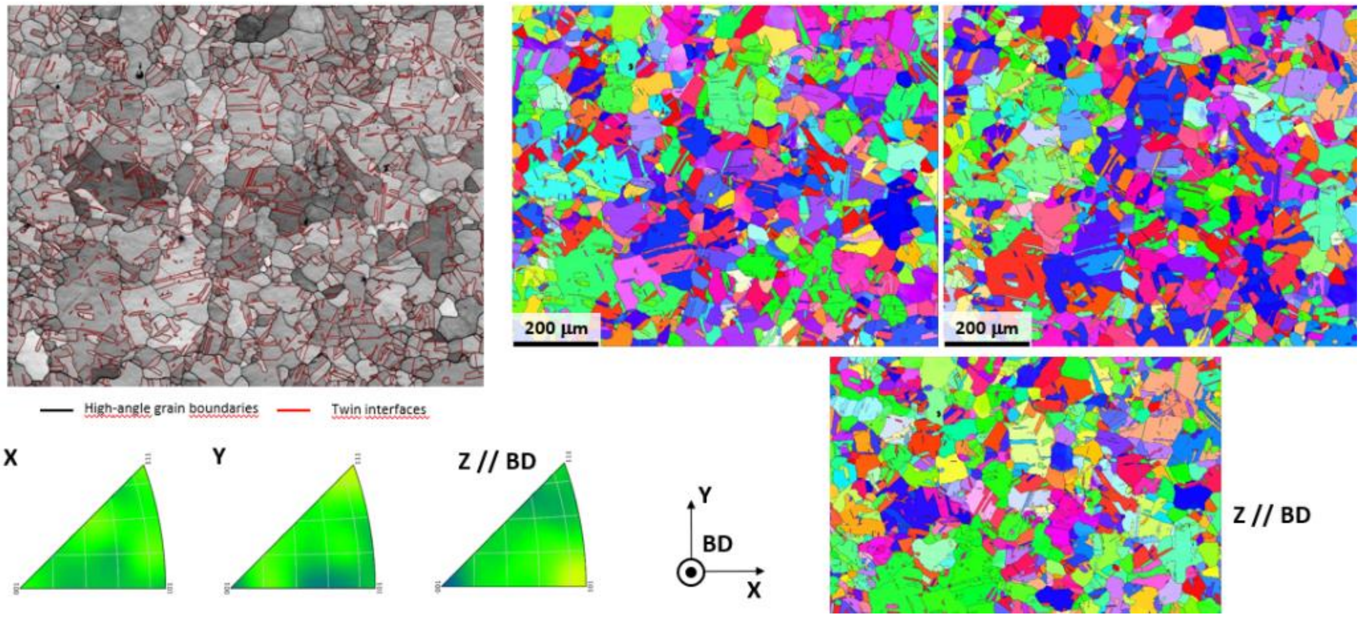

Figure 6. Microstructure (electron backscatter diffraction – EBSD) of alloy 699XA produced by LPBF and heat treated.

WP6 Material properties

After the first high temperature tests under steam, steam + H_2, air, molten salt and metal dusting atmospheres, the nickel and Ni-Cu alloys show promising results. No spallation, cracks or delamination were observed during the exposure times and temperatures for the three alloys. More detailed characterization activities will be performed for a deeper understanding of the internal oxidation observed in the Ni-Cu alloy 400. With respect to mechanical properties, the Ni-base alloy 699XA has shown a well-mastered AM-LPBF material preparation with excellent mechanical properties including well balanced strength-to-ductility interplay from room temperature to the application temperature and very good creep resistance as shown in Figure 7. The thermophysical tests have shown better thermal capacities and thermal conductivities values for additive materials versus literature data.

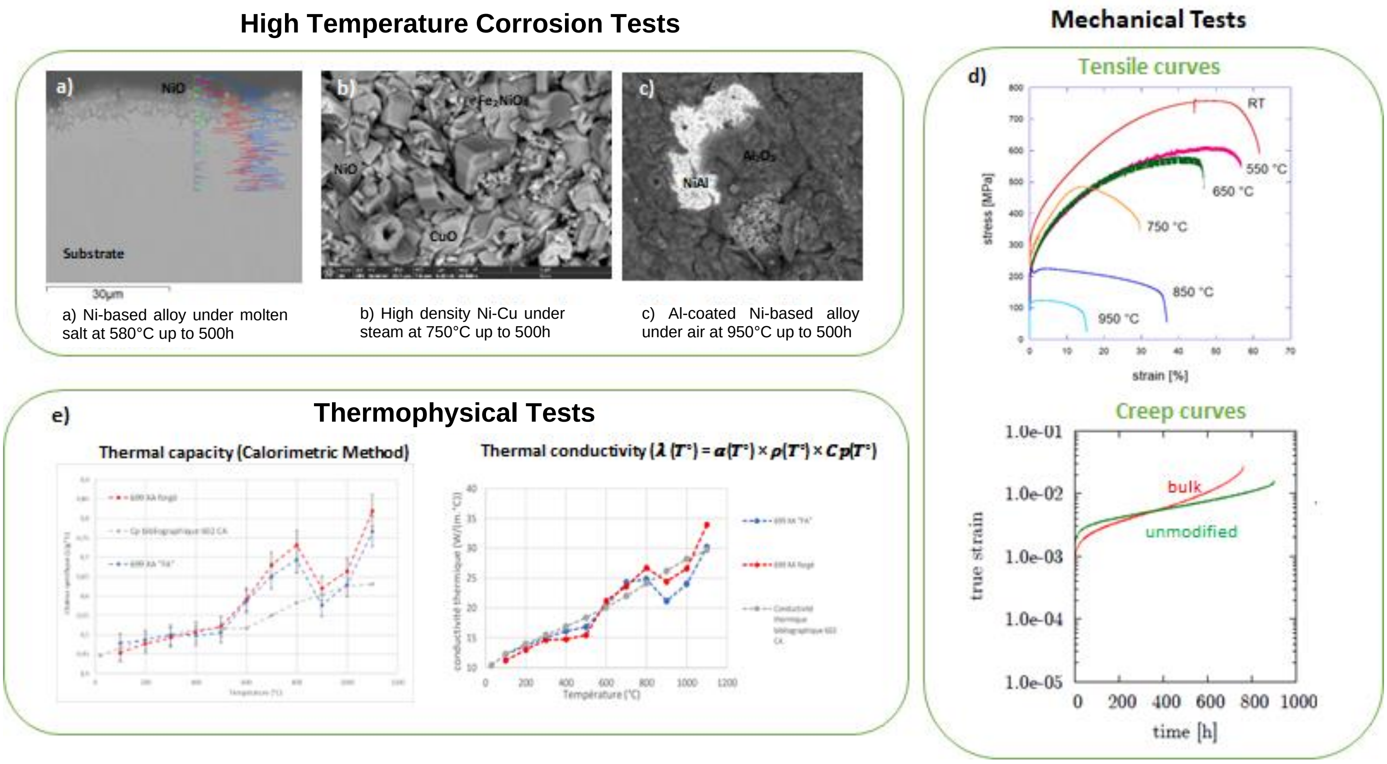

Figure 7. Examples of material property characterization: a), b), c) high temperature corrosion tests; d) mechanical tests; and, e) thermophysical tests.

WP7 Proof of principle

Planning for the proof of principle validation at the end of the project is already underway, including the LPBF builds and the testing facilities for each condition. These activities are scheduled for later in the project after the major results of the other WPs have been compiled.

Note: the other non-technical project work packages, WP8 Dissemination, communication, exploitation and WP9 Technical coordination and project management, are on target but are not discussed in this briefing.

How to get more involved:

You can follow the latest topAM project activities on LinkedIn (topAM Project) and Twitter (@topAMproject)! These are the best locations to stay up-to-date on the project's communication and dissemination activities. Email emma.white@dechema.de to be added to the LinkedIn topAM project group. Also our project website is regularly updated at https://www.aspire2050.eu/TopAM.

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