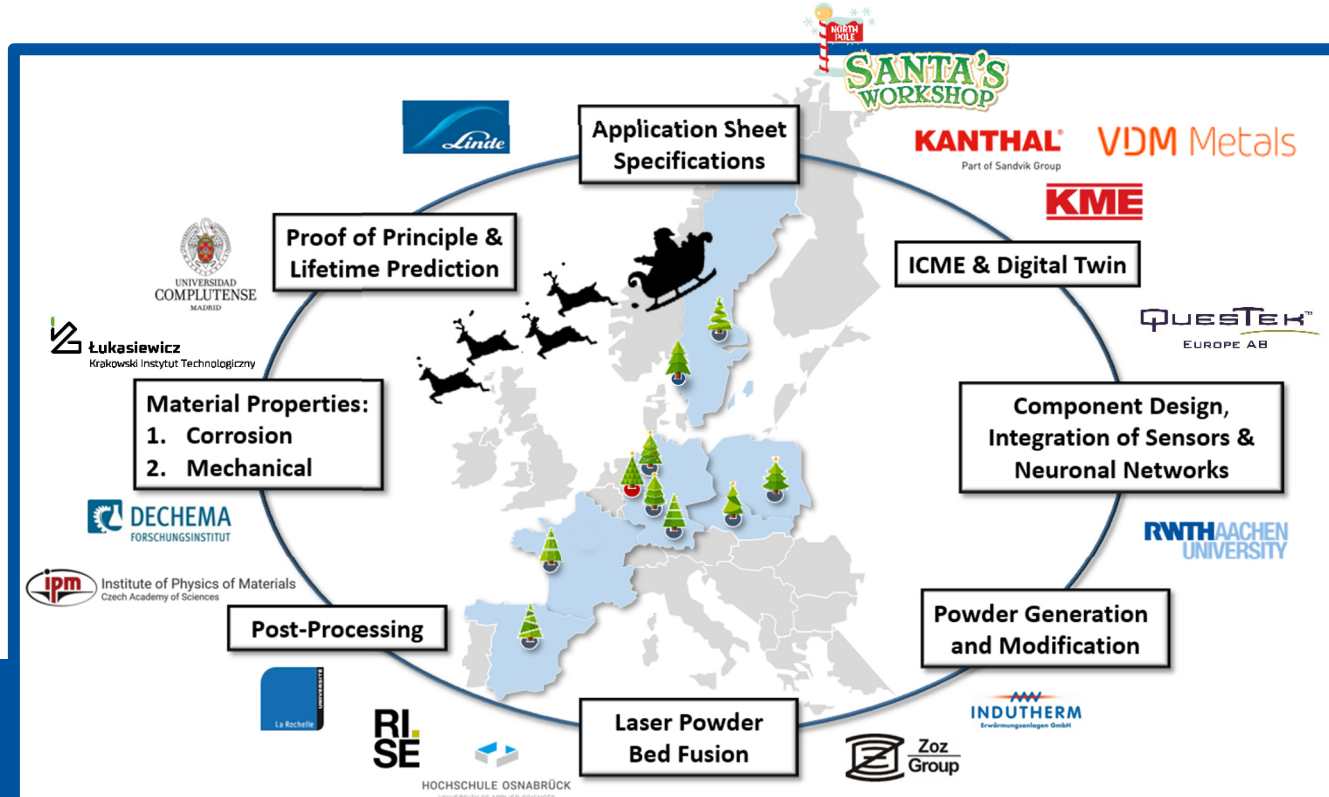




topAM BRIEFING

Developing ODS high temperature alloys tailored for AM



This topAM Briefing covers the latest project results including: modelling of the dispersoids, powder modifications, AM production of samples, and materials properties of the modified alloys. Follow topAM on LinkedIn (topAM Project), Twitter (@topAMproject), and at <https://www.aspire2050.eu/TopAM>.



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

WP2 Optimal computational design for LPBF based on ICME

Using the developed ICME framework for creep property modelling, the creep life can be predicted for alloys with different precipitate distributions (*i.e.*, size and volume fraction) and at different testing conditions (*i.e.*, stress, temperature). Figure 1 below exemplifies the predicted creep life of alloy 699XA with different γ' -phase distributions, under 125 MPa stress at 750 °C. The predicted creep life has been compared with the

creep testing result of an unmodified alloy 699XA, and will be compared with the creep life of a modified alloy 699XA that is currently under creep testing. It is predicted that the modified alloy 699XA will exhibit 1.5X the creep life of the unmodified counterpart, which is primarily attributed to the increment of precipitate volume fraction.

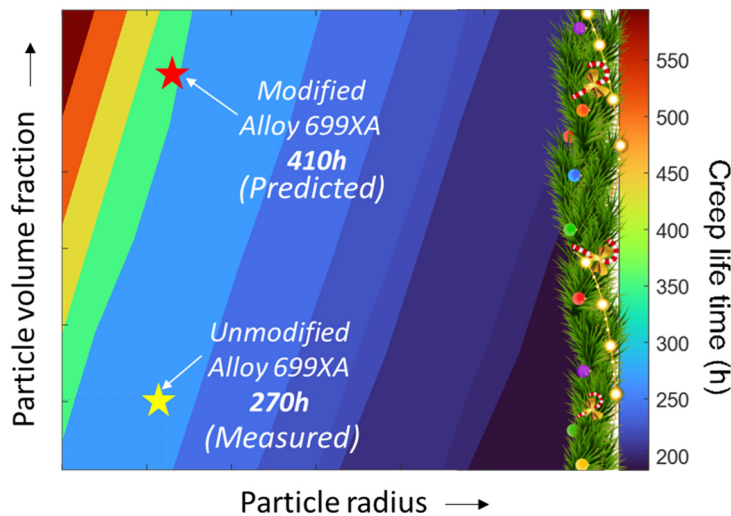


Figure 1. Mapping of predicted alloy 699XA creep life at 750 °C and 125 MPa condition as function of particle volume fraction and particle size, with stars representing the modified and unmodified alloy 699 XA.

WP3 LPBF component design

In WP3, there is good progress in the development of the multiphysics optimization tool using the continuous adjoint approach by extending the capabilities of OpenFOAM. The capabilities of the standard optimization solver of OpenFOAM are extended by the

inclusion of the heat transfer equation. Currently, a new objective function is being implemented to optimize a given geometry for minimizing/maximizing the heat flux (Figure 2).

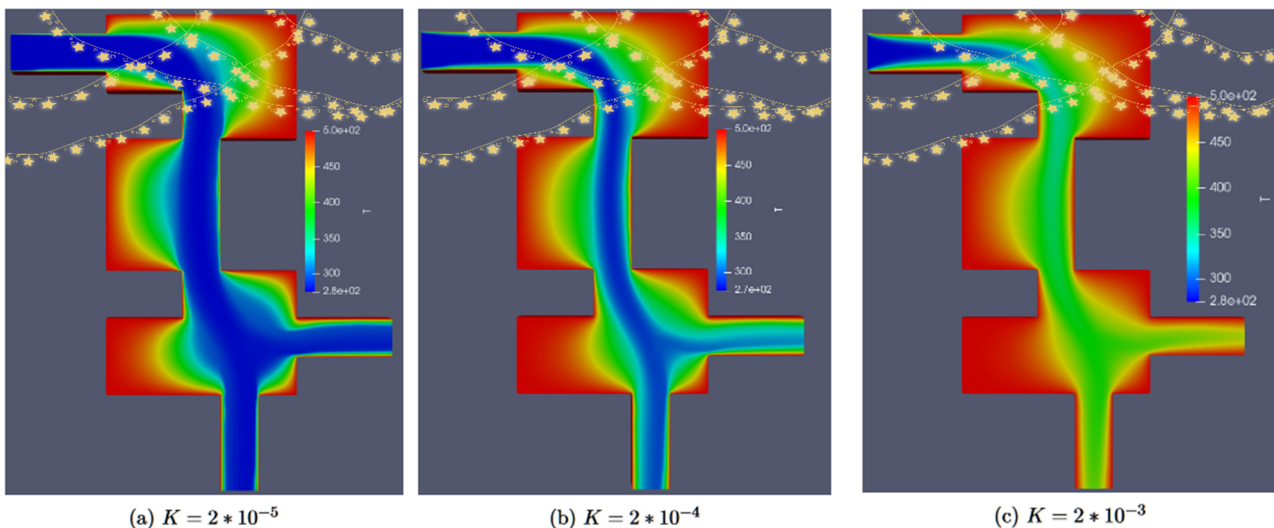


Figure 2. Temperature distribution within a topology-optimized heat sink for a coupled thermal-fluid problem with one inlet (at the top) and two outlets (at the bottom) as the thermal diffusivity is varied.

WP4 Powder production and modification

Work on the different powder modification routes has progressed towards down-selecting the final powders/modifications. Using a fluidized bed reactor and different reactive gas, La Rochelle has succeeded in incorporating nano-dispersions of oxides and of nitrides in the alloys studied in the project: alloys 100 (Fe-based, Figure 3), 699XA (Ni-based) and 400 (NiCu-based). The powder dimensions and sphericity were maintained and their flowability ensures

adequate printability as demonstrated at RWTH Aachen University and the University of Applied Sciences in Osnabrück. The mechanical and oxidation resistance is demonstrated to be superior to conventional counterparts. This has led to La Rochelle filing a patent on “fluidization fabrication process of alloy metal powders strengthened with ceramic nano-dispersions.”

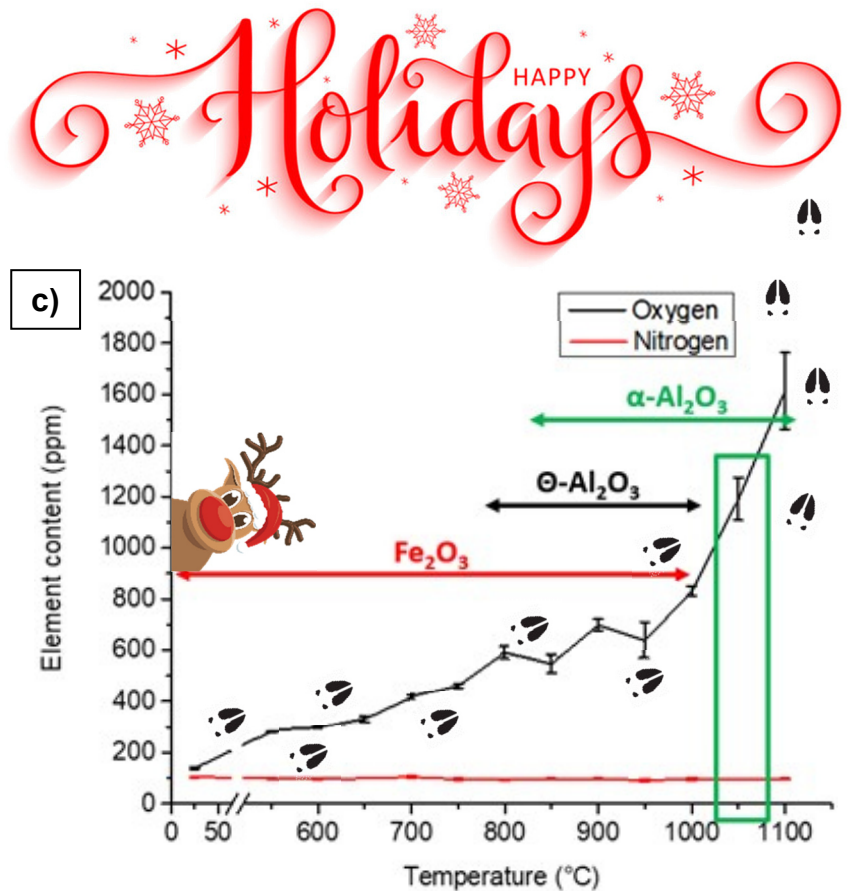
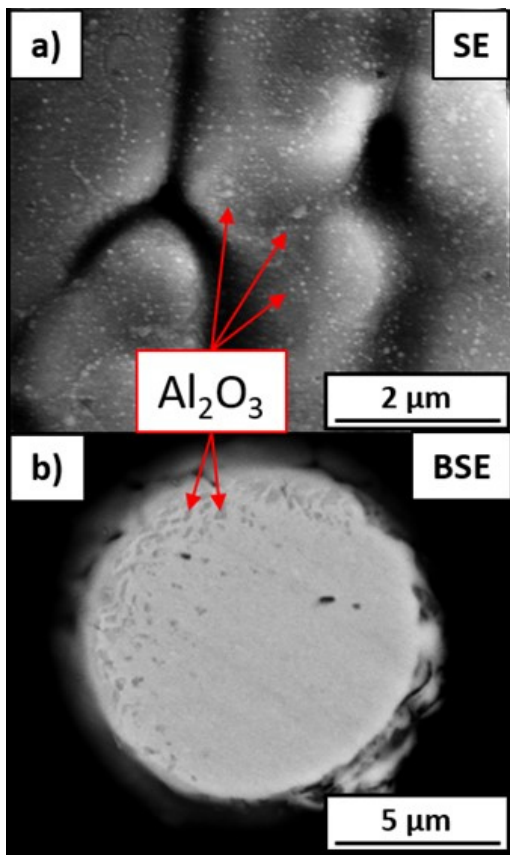


Figure 3. AM100 powder with post-internal oxidation in a fluidized bed reactor: (a) SEM-SE of the external surface, (b) SEM-BSE showing the internal dispersion of oxides and, (c) LECO analysis showing an increased incorporation of oxygen with increasing process temperature. The resulting oxide phases were identified by Raman spectroscopy.

WP5 LPBF and Post-Processing

Ongoing research is focused on determining the optimal powder modification methods, both in-situ and ex-situ. Notably, in-situ modification employing internal oxidation and nitridation has demonstrated promising outcomes for alloys based on Ni and Ni-Cu. Recent findings from the mechanical evaluation of a Ni-based alloy, subjected to in-situ nitridation, have shown promising results, particularly in terms of high-temperature performance. The powder underwent

nitridation during atomization at Indutherm in Germany and was subsequently printed and manufactured at RWTH Aachen University in Germany. Mechanical performance analysis conducted at the IPM Research Centre in the Czech Republic revealed a substantial improvement, with a 9-15 times increase in the minimum strain rate compared to conventionally manufactured alloys as shown in Figure 4.

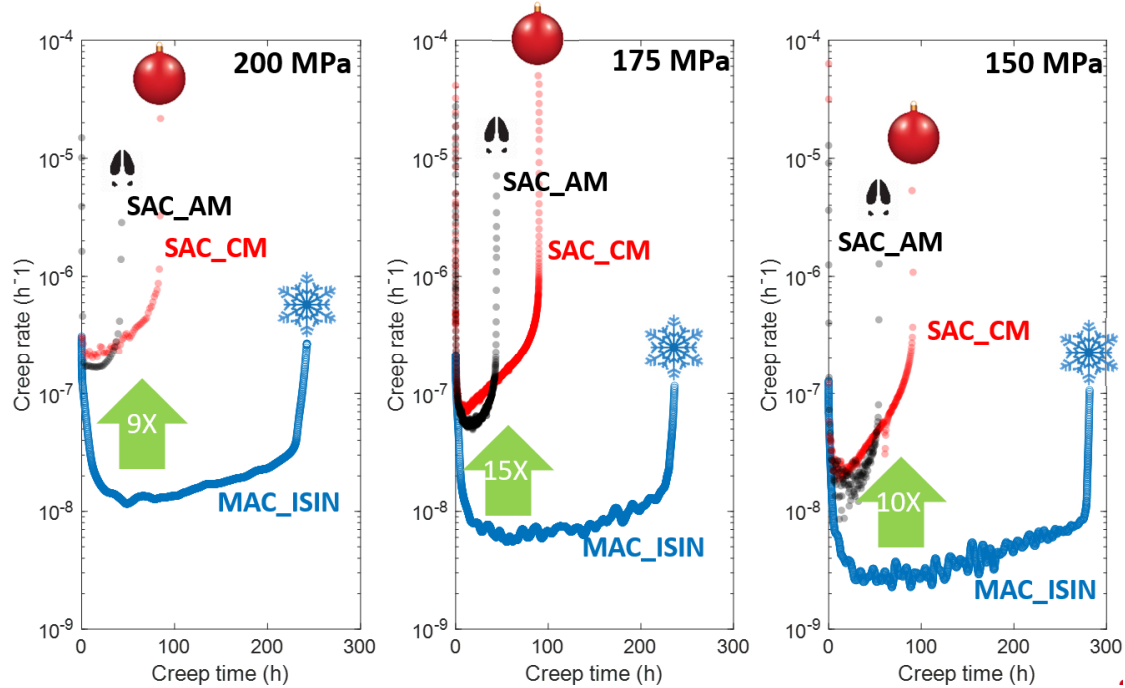


Figure 4. The creep performance of printed in-situ internally nitridated modified alloy composition 699XA is compared to the conventionally and additively manufactured standard alloy composition.

WP6 Material properties

Some of the long term tests of the modified AM materials have been started and data compilation is ongoing. At 750 °C the creep properties of the various modified 699XA alloys are clearly superior (Figure 5, left). The modified 699XA compositions do not show a large benefit in terms of fatigue performance (Figure 5, right), with the exact mechanism(s) still under investigation. These mechanical property results are

being used to determine the most promising modification(s) for each alloy family to be tested in some of the long term exposures, for the proof of principle (WP7), and for feedback into the alloy modelling (WP2). As the property results become available they are also being compared with the target performance indicators (TPIs).

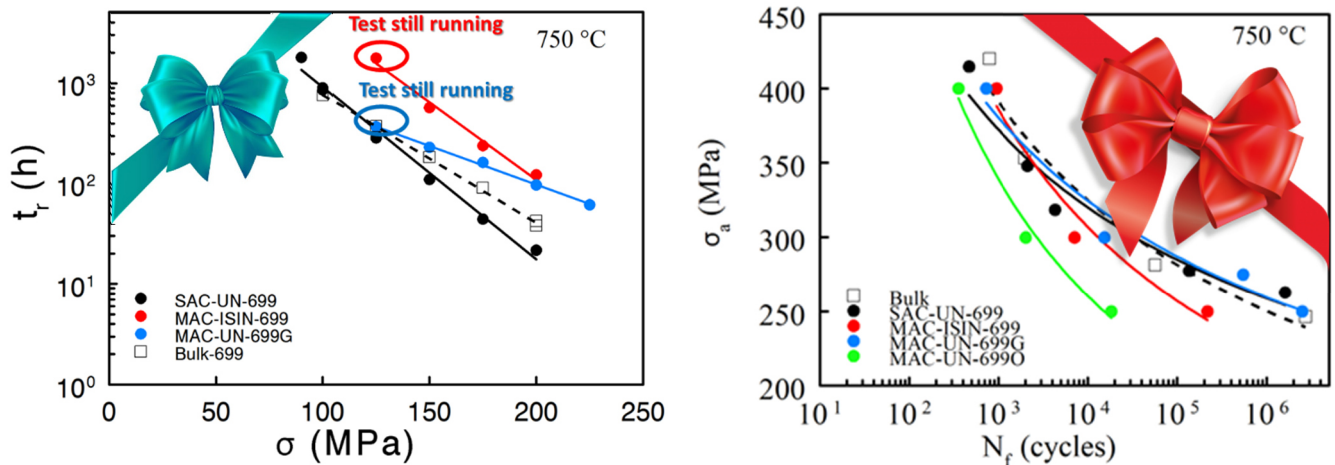


Figure 5. Creep properties (left) and fatigue performance (right) of the modified 699XA alloys at 750 °C.

WP7 Proof of principle

In the tertiary stage of creep, cavities typically form at the grain boundaries, especially in regions subjected to transverse stress (1-3), as depicted in Figure 6a. The creep lifetime prediction of the ODS nickel alloys

was implemented through the constrained cavity growth model. The model was specifically applied to the alloy MA754 (Ni-based ODS alloy) to simulate the tertiary creep region (1). The evolution of the cavitated

grain boundary fraction (f) is illustrated during the tertiary creep stage in the ODS alloy MA754, subjected to a 200 MPa tension with an initial cavity radius of 1000 nm and a cavity spacing of 6000 nm. The model showed a good agreement as seen from plotting the normalized strain (ϵ/ϵ_f) and the normalized time (t/t_f) in Figure 6b. The comprehensive analysis ensures the reliability and precision of the applied model, providing valuable insights into the tertiary

creep behavior of ODS nickel alloys, particularly emphasizing the case of Ni-based ODS alloys under specific loading conditions. Internal preparations are underway for the final burner test/proof of principle. The next steps are the final burner design, which first requires input for mechanical properties (WP6). After the design is finalized, printing of the burner can proceed for testing.

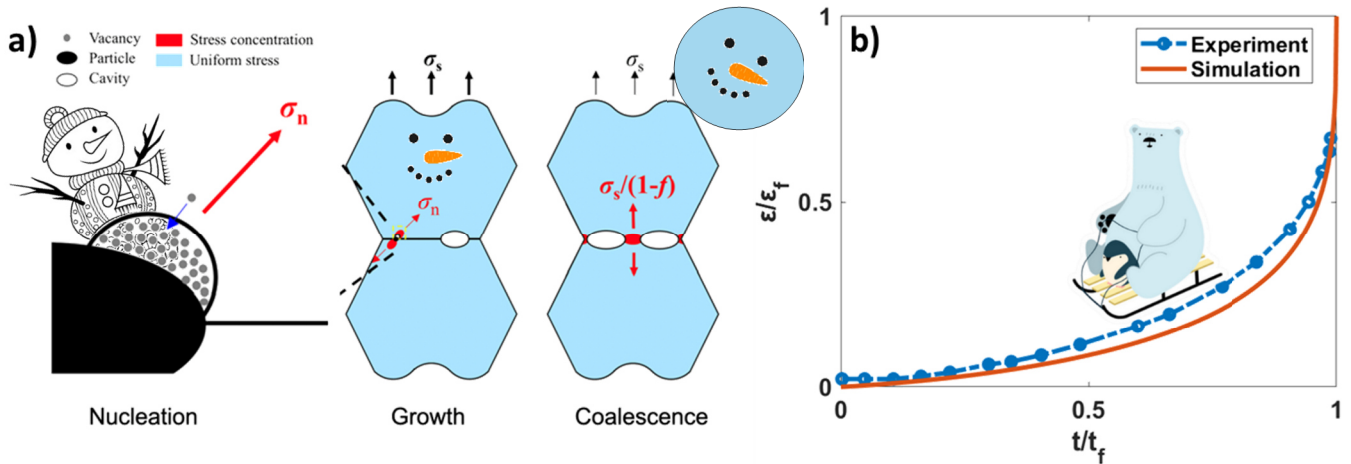


Figure 6. Constrained cavity growth model. (a) Creep cavity formation in the grain boundaries transverse to the applied stress (1). (b) Validation of the simulation on the evolution of creep strain with time for the model alloy MA754.

WP8 Dissemination, communication, exploitation

The topAM LinkedIn and Twitter accounts have been very active this year with around 22,200 total views of the LinkedIn posts at the end of November. Papers continue to be published and presentations of the topAM partners have been well received at

international events. The first patent coming from topAM results has been filed by University of La Rochelle. Additionally the topAM anthem premiered during the General Assembly meeting in Krakow, Poland. The lyrics are below and the audio will be available online shortly.

Verse 1:

In the heart of innovation, where science takes its flight,
A project named topAM shines with all its might.
Nanoparticles, tiny wonders, dancing in alloy's grace,
They fortify the structures, in the toughest high temp case.

Chorus:

topAM, topAM, in the laboratory's glow, We forge a future where strong materials show.
With ODS particles, we'll reach new heights, In the world of strength, we'll shine so bright.

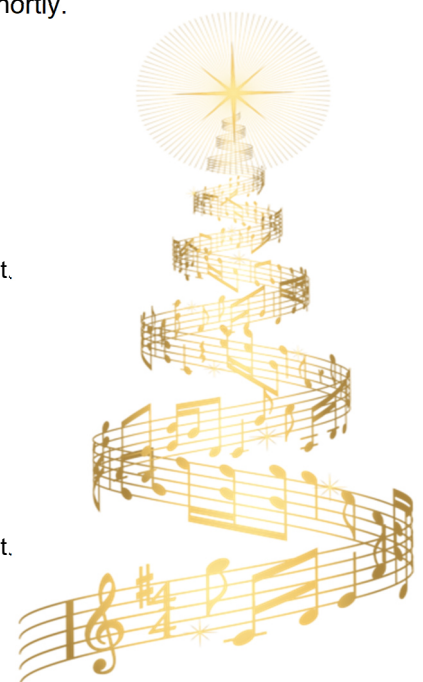
Verse 2:

In reactors and turbines, where temperatures soar,
ODS particles endure, we'll need them more and more.
From jet engines soaring, to nuclear's embrace,
Our materials will stand firm, in every kind of space.

Chorus:

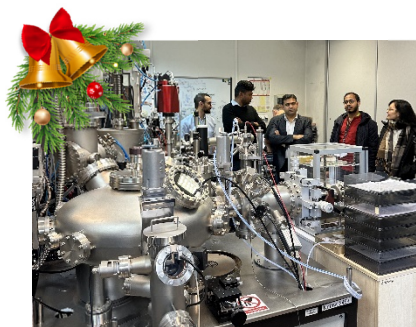
topAM, topAM, in the laboratory's glow, We forge a future where strong materials show.
With ODS particles, we'll reach new heights, In the world of strength, we'll shine so bright.

Credits: Lyrics (Mathias Galetz, ChatGPT), Composer (Anne Petrie)



General Assembly Meeting, Oct. 2023, Krakow, Poland

The topAM October General Assembly meeting in Krakow, Poland, hosted by Sieć Badawcza Łukasiewicz - Krakowski Instytut Technologiczny, was a scientific and cultural delight. The discussions were fruitful and the partners were treated to extensive laboratory tours, highlighting KIT's capabilities. The evening group dinner showcased excellent Polish food and history.



From all of us to all of you...



Happy Holidays

