About ICARUS

ICARUS, an ambitious synergy of European organizations, has developed a state-of-the-art **thermodynamic methodology** towards identifying the elements and the relative chemical composition necessary for enabling a nanocrystalline state to occupy a **relative minimum of the Gibbs free energy,** thus achieving **reasonable stable nanostructure**.

This approach was integrated with multiscale and thermodynamic (Nano-Calphad) modeling, in order to implement a High-Throughput Screening (HTS) tool opening a **new horizon for the exploration of multinary thermal stable nanocrystalline alloys**, exhibiting **high-performance tailored properties**. The most promising nanocrystalline materials identified were synthesized by mechanical alloying and physical vapor deposition. The mechanical alloying by ball milling technique- applied in the frame of ICARUS- appears as a very promising method for the production of thermodynamically stable nanocrystalline alloys.

The project was funded under the European Commission's **Future and Emerging Technologies (FET)** program and its team of experts comprises eleven highly-competent partners from seven European countries, forming a consortium of leading researchers and industrial organizations.

Shedding light on the thermodynamic stability of nanocrystalline alloys

Design by EASN-TIS

Consortium

Universidad de Burgos · ICCRAM International Research Center in Critical RAw Materials for Advanced Industrial Technologies · ENEA Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

CSGI · University of Patras Laboratory of Technology & Strength of Materials

ADVAMAT · MBN · Admatis Advanced Materials In Space

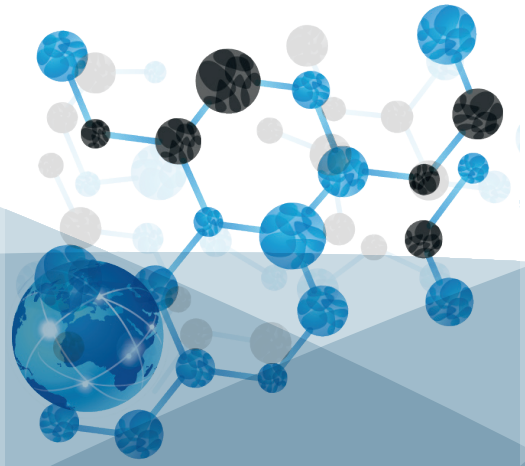
BRIMATECH · AAC aerospace & advanced composites · easn Technology Innovation Services

Community contribution:	€ 2,698,062.50
Start Date:	September 1st, 2016
Duration:	36 months
Coordinator:	Universidad de Burgos-ICCRAM
Contact person:	Prof. Nicolas A. Cordero
	ncordero@ubu.es

Connect with ICARUS

icarus-alloys.eu

ICARUS



Innovative Coarsening-resistant Alloys with enhanced Radiation tolerance and Ultra-fine grained Structure for aerospace application

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 713514.

Achievements

ICARUS developed an innovative theoretical methodology to describe the thermodynamics of multicomponent polycrystalline metal alloys and identify new thermodynamically stable nanocrystalline alloys. Classical and statistical thermodynamics were combined in a general theoretical scheme that enables the exploration of the Gibbs free energy surface under different possible approximation scenarios. The resulting model predicts the existence of thermodynamically stable multicomponent nanocrystalline alloys and provides a tool for identifying them based on the available physical and chemical information.

State-of-the-art

ICARUS is now proving that not only thermodynamically stable nanocrystalline alloys can be actually fabricated but also delivers a tool, the HTS tool – which can be further upgraded– allowing for the systematic exploration of the thermodynamics of multicomponent metal alloys.

Technique

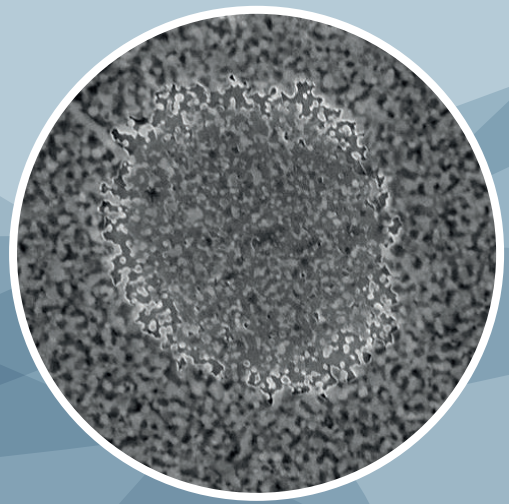
The innovative approach starts from the classical regular solution model. In particular, the Gibbs free energy of the alloy is related to the local configuration and energy of chemical bonds in grain boundaries. The model obtained, although within specific constraints and limitations, is quite general and can be tailored to the different case studies.

Alloys' Properties

To validate the thermodynamic model and provide a proof of concept several nanocrystalline alloys were fabricated and tested during the course of the project while the mechanical, chemical, environmental and specific properties of W-Cu, W-Al and Ti-Al were determined. These nanocrystalline alloys meet specific property goals such as:

- Excellent thermal cycling & outgassing
- High-compression strength
- High hardness
- High modulus of elasticity, yield strength and ultimate tensile strength
- Good electrical properties
- Good thermal behavior & dimension stability

While the alloys developed have a broad application spectrum, ICARUS focused on the needs and requirements in two areas, namely aeronautics and space.



Electron microscope photo of W-Cu nanostructure

Market Analysis

A market needs analysis focused on demand for new materials in the space and aeronautics domains was carried out. The above properties are particularly interesting for space applications where dimensional stability, excellent thermal cycling and low outgassing are required.

ICARUS nanocrystalline materials exhibit higher modulus of elasticity, higher yield strength and ultimate tensile strength (approximately two times higher than their commercial counterparts). Their enhanced material properties and inherent reduced density (10% reduced density) would lead to their extensive use in various aeronautical parts driving to the overall aircraft weight reduction.