POSTDOCTORATE OFFER IN MATERIALS SCIENCE

Composition fluctuations:
toward a new strengthening mechanism for metallic alloys

Employer description

The Institute of Chemistry and Materials Paris East (ICMPE) is an academic research laboratory of CNRS (French national scientific research center) and Créteil university, in the field of materials science. Its multidisciplinary research activities are focused on materials for energy as well as sustainable processing. The team “Design of alloys and microstructure” has a long expertise on structural metallic alloys.

Background

Lighter structure is a major leverage to improve energy efficiency and to decrease the environmental impact. It requires to increase ever more the mechanical resistance of metallic alloys, while maintaining their ductility, which remains a challenge. Lately, this objective has been reached by creating a network of composition fluctuations within a high entropy alloy (HEA), in other words a compositionally complex alloy, forming a solid solution.

Indeed, in a previous ANR project (2018-2022), for the very first time, we processed by Spark Plasma Sintering (SPS),of a mixture of CoCrFeMnNi HEA and pure Ni, a chemically architectured metallic alloy [1]. We identified the processing parameters to fully densify the desired microstructure. More precisely, this material is composed of spherical domains of HEA, surrounded by Ni matrix and a network of areas with chemical gradients in between. These gradients are continuous chemical variation while keeping the same crystalline structure and this, on a width of around 10 µm. The volume fraction being significant, it is called an interphase. Mechanical testings have shown that chemical architecturation induces an additional strengthening. Finite element modelling has identified the composition fluctuations as the strengthening element [2].

Objectives and methodology

The objective of this project is to determine whether composition fluctuation is a new strengthening mechanism, applicable to all types of metallic alloys while maintaining ductility. To do so, two approaches will be followed: (1) applying composition fluctuations to other metallic systems, (2) understanding the underlying plastic deformation mechanism. Depending on the candidate profile, one of this two approaches could be emphasized.

The first approach will rely on massive thermodynamic calculations, to detect large solid solution domains, as already performed at ICMPE for HEA [3]. We will select different crystalline structures and chemical compositions. Those alloys will be processed in order to incorporate the chemical compositions. To do so, the experimental protocol which was established for HEA will be used.

Microstructural characterization (mainly Scanning Electron Microscopy coupled with Energy Dispersive Spectroscopy and Electron Backscattered Diffraction, X-ray diffraction) and mechanical testing (nanoindentation, compression and/or tensile tests) will be performed to measure the properties and identify the structural and microstructural parameters that control them.
The second approach will mainly use transmission electron microscopy to characterize the dislocations structures. Post-deformed samples as well as in-situ experiments will be performed. Some preliminary FIB sample preparation and TEM characterization of undeformed samples have already been done.

Practical informations

- Place: ICMPE, Thiais (East of Paris)
- Supervision: Mathilde Laurent-Brocq, with a support of Régis Poulain
- Duration: 1 year, starting between 01/10/2023 and 01/12/2023
- Gross salary: 33,6 k€/year

Candidate profile

Required:

- PhD in metallurgy, with experience in experimental work.
- Autonomy, rigor, initiative and efficiency.
- Capacity to write scientific publication

Additional:

- Experience in TEM analysis of dislocations and/or SPS and/or Calphad calculations
- Knowledge in high entropy alloys

➔ Application: please send a CV to Mrs Mathilde Laurent-Brocq mathilde.laurent-brocq@cnrs.fr

Bibliography

[1] Laurent-Brocq, M., Mereib, D., Garcin, G., Monnier, J., Perrière, L., and Villeroy, B., *Chemical architecturation of high entropy alloys through powder metallurgy.* Journal of Alloys and Compounds, 2020. 835: p. 155279.
[2] Mereib, D., Monnier, J., Perrière, L., Villeroy, B., and Laurent-Brocq, M., *Chemically architectured alloys: How interphase width influences the strengthening.* Journal of Alloys and Compounds, 2022. 904: p. 163997.
[3] Bracq, G., Laurent-Brocq, M., Perrière, L., Pirès, R., Joubert, J.-M., and Guillot, I., *The fcc solid solution stability in the Co-Cr-Fe-Mn-Ni multi-component system.* Acta Materialia, 2017. 128: p. 327-336.