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Thesis Proposal

Multi-Components Refractory Metallic Alloys with a High Mixing Entropy: Formulation, Microstructural Evolution and Behavior under large Deformation

This PhD project is part of a research both fundamental and applied for complex multicomponent alloys so-called "high-entropy alloys" – alloys whose name underlines their inherently high mixing entropy. While it has often been – rightfully – thought that preparing metallic alloys containing elements with a quasi equiatomic composition would lead to the formation of brittle intermetallic phases (and thus detrimental to the mechanical behavior of materials), it seems now well established that unique solid solutions are formed when four or more elements are used in equal atomic proportions. The mixture of several different major components allows hope for highly unusual microstructures and therefore physical, chemical and mechanical properties.

Even though the formation conditions of these solid solutions are not formally known for now, the resulting materials have generally very stable microstructures as a function of temperature, up to 1400°C for the most refractory grades, excellent mechanical properties, a resistance that can exceed 4GPa under compression and an unmatched damage tolerance [B. Gludovatz et al. Science 345, 1153(2014)].

This project offers vast opportunities to explore, discover and develop a new class of materials for high temperature structural applications (aerospace and military industries, ...). It especially allows revisit the notion of what an alloy is, the principle known to metallurgists being to incorporate some minor quantities of addition elements in a matrix. However, in the case of high-entropy alloys, all the elements are present in equivalent proportions. Thus, the main objective of this study is the development (both theoretical and experimental) of refractory high-entropy alloys based on transition metals of columns IV, V and VI of the periodic table (Ti, V, Cr, Zr, Nb, Mo, Hf, Ta, W).

During this thesis, formulation and development of refractory high-entropy alloys, with advanced properties, including a very good mechanical behavior and sufficient ductility at room temperature to be shaped, will be implemented and optimized. The mechanical behavior and microstructural evolutions under large deformation solicitations (rolling, extrusion, high pressure torsion and impacts) will be studied. The microstructures thus induced and their subsequent influence on the deformation and damage mechanisms will be analyzed using a set of skills and of characterization techniques which have been for decades recognized as areas of expertise of the LSPM and of their partners involved in this project: chemical metallurgy with the formulation and development of alloys by conventional or non-conventional routes such as the SHS process, microstructural characterizations of the resulting microstructures (TEM, SEM, EBSD, XRD) and the understanding of the relationship between microstructure and mechanical properties.

This project, which will take place at LSPM, will be conducted in close collaboration with the *Institut de Chimie et des matériaux de Paris-Est* (ICMPE)

and *Nexter Munitions* (Bourges).

Profile: Physical Metallurgy, Materials Processing and design, Mechanics of Materials

Funding source: French Ministry of Higher Education and Research (open to foreign students)

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