PhD thesis
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Synthesis and characterisation of high entropy MAX phases by Self-propagating High temperature Synthesis

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Team in PPRIME	PPNa		
Academic partner	Yes	Laboratoire des Sciences des Procédés et des Matériaux, Université Sorbonne Paris Nord	
Thesis offer	Yes		
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Keywords	High Entropy MAX Phase	nanopowders	Self-propagating High temperature Synthesis
	Multi scale characterisation		

Subject Description :

MAX phases are nanolamellar compounds consisting of alternating metallic A-element layers and ceramic layers (M_6X octahedra); M is a transition metal, A is an element from groups 13 to 16 of the periodic table, and X is carbon or nitrogen. These materials exhibit good electrical conductivity, high impact resistance, and excellent oxidation resistance at high temperatures. In our laboratory, we have already synthesized numerous MAX phases, including Cr_2AlC, Ti_2AlC, Ti_3AlC_2, Ti_3SiC_2, etc. Very recently, the possibility of synthesizing high-entropy MAX phases has emerged in the literature, based on the concept that the contribution of configurational entropy to the free energy exceeds that of enthalpy, thereby stabilizing the material and optimizing its properties.

The high-temperature sintering techniques commonly used for the synthesis of MAX phases lead to high production costs, which are even more pronounced in the case of their 2D derivatives, calling for the development of less energy-intensive and less time-consuming synthesis methods. Within the framework of this PhD thesis, we propose to synthesize these materials using self-propagating combustion, which enables rapid, large-scale, and low-cost synthesis. Unlike conventional reactive sintering techniques, in which atomic diffusion must be sustained by a continuous input of thermal energy throughout the formation of the products, self-propagating reactions exploit the exothermicity of the product formation reaction to sustain themselves and synthesize the desired material within a few seconds. Powders synthesized by this method are typically nanometric in size, as demonstrated by high-entropy MAX phase synthesis trials carried out at the Laboratory of Process and Materials Sciences. The complexity of the synthesized phases requires multi-scale microstructural characterization, which we propose to perform during this PhD thesis.

The PhD work will be conducted along four distinct axes:

1. Synthesis, by self-propagating reactions, of high-entropy MAX phase nanopowders (and possibly their 2D derivatives).
2. Multi-scale characterization of the resulting powders (electron microscopy, energy-dispersive X-ray spectroscopy, and possibly electron energy loss spectroscopy).
3. Densification of the synthesized nanopowders by flash sintering.
4. Investigation of the physicochemical and physical properties of the resulting bulk materials (electronic transport properties (PPMS), oxidation resistance, and mechanical properties (microhardness and/or nanoindentation)).

Laboratory of the thesis:

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Profile of the candidate:

• Engineering school or Master 2 in Material Sciences
• Skills in material characterisation
• knowledge in powder metallurgy would be appreciated
• Good english and skills in communication
• facilities to write in French (appreciated) and English (mandatory)

Contacts:

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Candidature:

Thanks to join to your motivation letter:
• your CV

- your results in Master 1 et 2 or second and third year of engineering school
- a reference letter from your internship advisor