Expanding the Ashby Chart for Nanoengineered Complex Concentrated Alloy Thin Films: Overcoming the Strength-Plasticity-Thermal Stability Trade-Off

Matteo Ghidelli[1*]

[1]Laboratoire des Sciences des Procédés et des Matériaux (LSPM-CNRS), Villetaneuse, France.

*matteo.ghidelli@lspm.cnrs.fr

Conférence invitée

The design of high-performance structural materials is always pursuing the combination of mutually exclusive properties such as mechanical strength, plasticity and thermal stability. Complex concentrated alloys (CCAs) have recently attracted attention due to their superior mechanical/thermal properties, emerging from their multicomponent nature. However, such atomic complexity often prevents a nanoengineering approach with limited control over composition and microstructure, especially in bulk form.

Here, I will show how to exploit thin film (TF) synthesis to produce model CCA-TFs with precise control over composition and microstructure (crystalline phase, grain size, nanointerfaces), leading to large and tailored mechanical properties. Moreover, this approach encompassed both commonly employed synthesis method (i.e. sputtering) as well as pulsed laser deposition (PLD), leading to the development of novel microstructure with unique nanoscale features [1].

Firstly, I present a new strategy to synthetize ultrastrong and deformable crystal-glass CCA-based nanolaminates by sputtering, alternating Cr-Co-Ni (crystalline) and Ti-Zr-Nb-Hf-Cr-Co-Ni (amorphous) layers [2]. This alloy has an ultrahigh compressive yield strength of 3.6 GPa and large homogeneous deformation of ~15% strain at ambient temperature, surpassing those of conventional metallic glasses and nanolaminate alloys. Furthermore, it exhibits ~200 K higher crystallization temperature (T_X> 973 K) compared to that of the original TiZrNbHf-based amorphous phase [2].

Then, I will focus on totally new nanoengineering approach, reinventing the original CoCrCuFeNi CCA Cantor alloys by exploiting the potential of PLD, leading to unprecedented microstructural control [3]. I will show how to synthetize ultrafine grain structures with controllable size (down to 12 nm) which can be further tailored by post-thermal annealing treatments. This results in high hardness (11 GPa) and yield strength (2.0 GPa) due to Hall-Petch strengthening, outperforming similar CCA-TFs, while maintaining high plasticity (no fracture at 30% strain) [3]. Moreover, these ultrafine CCA-TFs show remarkable thermal stability, with grain growth initiating only at 49% of the melting temperature, while maintaining high hardness (9.1 GPa) after annealing for 1h at 460°C [3].

Overall, I will show how a comprehensive nanoengineering strategy can lead to an expansion of Ashby chart regions, while tailoring the mechanical properties of CCA thin films, offering new opportunities to overcome the strength-plasticity-thermal stability trade-off with clear impact for applications.

References

[1] F. Bignoli *et al.*, Acta Materialia, 300, 121456, (2025).
[2] G. Wu *et al*. Materials Today, 51, 6-14 (2021).
[3] D. Vacirca *et al.*, Under review to Materials Today, (2025).