

Unveiling Microstructure-Property Relationships for the Design of Sustainable HEA and Cermet Coatings through High-Resolution Nanomechanical 3D High Speed Mapping

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Developing next-generation high-performance coatings requires quantitative tools capable of resolving how local heterogeneities and microstructural gradients influence mechanical behaviour. In this work, we present an advanced nanoindentation-mapping methodology for producing high-resolution 3D mechanical property maps, enabling spatially resolved assessment of hardness and modulus across highly heterogeneous thermally sprayed surfaces. This approach reconstructs continuous mesoscale mechanical landscapes that capture the effects of splat boundaries, porosity, amorphous regions, and interfacial transitions, features that conventional indentation grids cannot resolve.

As a representative case study, we apply this methodology to High Entropy Alloy (HEA) and cermet coatings developed within the EU project CoBRAIN¹, which aims to create sustainable and high-performance alternatives to cobalt-containing materials for advanced manufacturing. The coatings, produced using thermal spraying techniques, exhibit pronounced microstructural and mechanical heterogeneity due to rapid solidification and the intrinsic complexity of multi-principal element systems. The resulting 3D mechanical maps reveal distinct mechanical phases, including FCC, BCC, oxides and TiC-rich regions, with hardness values and spatial distributions consistent with phase-specific statistical clustering obtained through GMM deconvolution.

Overall, the use of high-resolution nanomechanical 3D mapping provides a powerful framework for correlating microstructure and performance in thermally sprayed HEA and cermet coatings, supporting the design and optimization of next-generation CoBRAIN materials.