
***TAMÁS CSANÁDI***

**Institute of Materials Research SAS**


**Project number**
**IM-2022-67**

**Project duration**
**1.9.2023-31.8.2028**

*"With the support of the Impulz project, I am aiming to understand the structure-mechanical behaviour relationship of high-entropy ceramics and to establish predictive theoretical models for finding high-entropy systems with superior strength or plasticity (or both), going beyond the current state of the art."*

## BIOGRAPHY

Dr. Csanádi has been active at the Institute of Materials Research – Slovak Academy of Sciences (IMR-SAS) since 2013 where he started his second PhD studies and finished with a PhD degree in 2017. During these years, the focus of his research turned to the investigation of room-temperature deformation anisotropy of advanced ceramic grains (WC-Co, $\beta$-$Si_3N_4$, $ZrB_2$). The influence of crystal orientation on their mechanical properties was investigated using cutting-edge nanomechanical testing techniques, including nanoindentation, micropillar compression and nanoscratch testing. Starting in 2017, Dr. Csanádi, as a post-doc researcher at IMR-SAS, is working on ultra-high temperature ceramics (UHTCs), like $ZrB_2$, TaC and HfC, and is involved in the development of high-entropy UHTCs using micro/nanomechanical characterization techniques. The importance and scientific content of the above-mentioned results in the development of novel materials possessing exceptional mechanical properties are well described in his 22 first-author publications in several prestigious journals. To date, Dr. Csanádi has published 59 peer-reviewed scientific articles with more than 1900 citations in total and has an h-index of 24 (Scopus). Dr. Csanádi's research experience and knowledge gained during 8 years of his university and doctoral studies at Eötvös Loránd University (ELTE) in Hungary, which he adopted the field of ceramics, played/s an important role in his successful research career at IMR-SAS and will also play in the future.

# Atomic-scale controlled strengthening and plasticity of high-entropy ceramics

During the last decades, a growing need has arisen for structural materials that can be used as parts and tools for different combinations of load at temperatures exceeding 2000ºC in oxidizing atmospheres, such as hypersonic vehicles and spacecraft. To date, ultra-high temperature ceramics (UHTCs), based on the refractory carbides, nitrides and diborides of the group IV and V transition metals (e.g. TaC, HfN, $ZrB_2$), are the only group of materials that can withstand extreme environments. These materials have potential use as cutting tools, refractory linings, burners, turbocharger rotors and also in energy-related applications as structural materials in future fusional power plants. Although UHTCs have a number of excellent properties, they are: i) a limited group of materials; ii) macroscopically brittle; and iii) under increasing pressure to perform in more extreme operating conditions due to the demands of developing technologies. A promising way to broaden the application and improve the performance of UHTCs is the recent development of bulk high-entropy ceramics (HECs), which consist of no less than four different types of cations or anions stabilized by their configurational entropy, opening up a vast compositional space of new ceramics.
High-entropy carbides were first synthesized by a group of researchers in the UK, with whom Dr. Csanádi has a long-term collaboration, and their micromechanical properties were investigated by the fellow at the Institute of Materials Research - SAS in 2018. Since then, their collaboration has revealed that the hardness and yield strength of high-entropy carbides can go beyond any rules of mixtures for the corresponding carbides and their strengthening is attributed to their enhanced Peierls stresses caused by atomic randomness at the dislocation core. Currently, the synthesis of HECs is rapidly growing but the understanding of their structure-mechanical behaviour relationship is still missing and, therefore, the prediction of their mechanical properties is a great challenge due to their large compositional space. Since HECs are macroscopically brittle at room temperature similar to UHTCs, to improve their inherent mechanical properties, it is important to understand the factors that control their deformability at the level of grains that can only be studied practically using state-of-the-art micro/nanomechanical testing, such as nanoindentation and micropillar compression. This is the field of expertise of Dr. Csanádi who has achieved significant results in the understanding of deformation anisotropy and plasticity of refractory ceramics (WC, $\beta$-$Si_3N_4$), UHTCs ($ZrB_2$) and HECs.
Thus, MOSAIC takes on the challenge to understand the structure-mechanical behaviour relationship of HECs, via a systematic experimental study on a representative 'model system', and to establish predictive theoretical models for finding high-entropy systems with superior strength or plasticity (or both), going beyond the current state of the art. Dr. Csanádi proposes a nanomechanical testing-based approach to analyse the effect of compositional-related properties, such as valence electron concentration (VEC) and lattice distortion, on the yield stress and slip activation of HEC grains, something that is currently missing. Based on the applicant's experience on rock salt carbides, the key idea to improving plasticity/deformability is to promote both the glide on the {111} planes and cross-slip via the increase of VEC, while the key idea to retaining high-strength or improving it is to impede the dislocation movement through the increase of lattice distortion within the frame of synthesizability. This is planned to be achieved by a multidisciplinary approach realized on an optimized set of 5-metal high-entropy carbides, nitrides and carbonitrides, including material selection and synthesis, nanomechanical testing, characterization, deformation analysis and modelling.


impulz

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## PUBLICATIONS


1. T. Csanádi, E. Castle, M.J. Reece, J. Dusza, Strength enhancement and slip behaviour of high-entropy carbide grains during micro-compression, Scientific Reports 9 (2019) 10200. https://doi.org/10.1038/s41598-019-46614-w
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4. T. Csanádi, M. Bl'Anda, N.Q. Chinh, P. Hvizdoš, J. Dusza, Orientation-dependent hardness and nanoindentation-induced deformation mechanisms of WC crystals, Acta Materialia 83 (2015) 397-407. https://doi.org/10.1016/j.actamat.2014.09.048
5. T. Csanádi, N.Q. Chinh, J. Gubicza, T.G. Langdon, Plastic behavior of fcc metals over a wide range of strain: Macroscopic and microscopic descriptions and their relationship, Acta Materialia 59 (2011) 2385-2391. https://doi.org/10.1016/j.actamat.2010.12.034


https://orcid.org/0000-0002-4703-5775