STRENGTH AND HARNDESS ENHANCEMENT AND SLIP BEHAVIOUR OF HIGH-ENTROPY CARBIDE GRAINS DURING MICRO-COMPRESSION AND NANOINDENTATION

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Bulk polycrystalline high-entropy carbides are a newly developed group of materials that increase the limited compositional space of ultra-high temperature ceramics, which can withstand extreme environments exceeding 2000°C in oxidizing atmospheres. Since the deformability of grains plays an important role in macromechanical performance, we studied the strength and slip behaviour of grains of a spark-plasma sintered (Hf-Ta-Zr-Nb)C high-entropy carbide in a specific orientation during micropillar compression. Additionally, the hardness of grains of different orientations was investigated by nanoindentation. For comparison, identical measurements were carried out on the monocarbides HfC and TaC. Four micropillars were fabricated by focused ion beam (FIB) in visibly pore free regions of large (Hf-Ta-Zr-Nb)C, HfC and TaC grains of a specific orientation (Φ~14° and φ_2~45°) selected by electron backscatter diffraction (EBSD). This resulted in equal Schmid factors for both the $\{110\}\langle 1\bar{1}0\rangle$ and $\{111\}\langle 1\bar{1}0\rangle$ slip systems, which were reported to operate in HfC and TaC. It was revealed that (Hf-Ta-Zr-Nb)C had a significantly enhanced yield and failure strength compared to the corresponding base monocarbides, while maintaining a similar ductility to the least brittle monocarbide (TaC) during the operation of $\{110\}\langle 1\bar{1}0\rangle$ slip systems (Fig. 1). Nanoindentation investigations revealed a significant enhancement in hardness (~30%) of the high entropy (Hf-Ta-Zr-Nb)C material compared to that calculated according to the rule of mixtures from the base monocarbides (HfC, TaC, ZrC, NbC) and in comparison to the hardest monocarbide (HfC). Additionally, it was concluded that the much larger strength enhancement of micropillars compared to the average nanohardness of randomly oriented grains is attributed to the different slip systems. For (Hf-Ta-Zr-Nb)C, the operation of $\{110\}\langle 1\bar{1}0\rangle$ was identified in micropillar experiments, but the dominant slip system in nanoindentation is assumed to be the $\{111\}\langle 1\bar{1}0\rangle$, possibly via the activation of partial dislocations, which is attributed to the different Schmid factors due to the different stress fields between nanoindentation and micropillar compression.

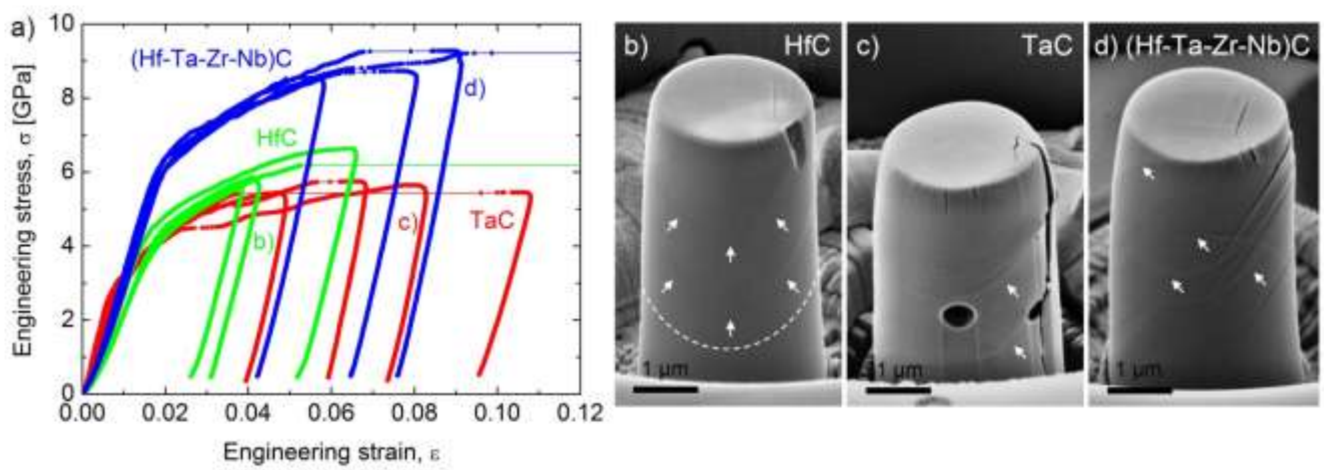

Figure 1 – a) Characteristic stress-strain curves obtained during micropillar compression of individual grains of HfC, TaC and (Hf-Ta-Zr-Nb)C, showing an enhanced yield and failure strength for the high-entropy ultra-high temperature carbide. Micropillars of similar orientations (Φ~14°) exhibit limited plasticity for grains of b) HfC but more ductile behaviour for c) TaC and d) (Hf-Ta-Zr-Nb)C high-entropy carbide. Slip traces on micropillar surfaces are marked by arrows.