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Densifying TaC ceramics with various additives and the relevant mechanisms

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Tantalum carbide (TaC) has the highest melting point, at up to 3997°C, among the carbides of the transient metals. Recently it has attracted extensive research interest as a member of the Ultra High-Temperature Ceramic (UHTC) family. However, pure TaC ceramics are extremely hard to densify. The entrapment of residual pores has hindered further densification. Herein we report our research results on densifying TaC ceramics by adding various additives, including (i) ceramic particles (SiC, Si_3N_4 and SiO_2), (ii) B4C as a reductive agent, (iii) metallic sintering aids (Al, Cu, Ag and Au), (iv) Si as a transient liquid sintering aid, and (v) ZrC. The relevant densification mechanisms were discussed. It was observed that full densities could be reached for most of the compositions after spark plasma sintering at 1600-1900°C under a mechanical pressure of 20-30 MPa. Although it was common that the secondary particles would increase densification of UHTCs by physically pinning the grain boundaries, a small among of glassy phase in the multi-grain conjunctions suggested liquid phase sintering in case of addition of SiC and Si_3N_4 to TaC. Elongation growth of the SiC and Si_3N_4 grains in the microstructures indicated dissolve-reprecipitation, also in consistency with existence of some liquids. The metallic sintering aids (Al, Cu, Ag and Au) could inhibit cross-boundary diffusion to avoid entrapment of residual pores and refine the TaC grains. Combining ZrC and trace metallic agents resulted in dense (Ta,Zr)C ceramics with fine microstructures and good mechanical properties. When Si was used as the sintering aid, transient liquid sintering was realized. Oxygen introduced by adding the SiO_2 substance did not hinder densification of TaC.

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