Emissivity and Melting Temperature of Dual-Phase High-Entropy Boride-Carbide Ultra-High Temperature Ceramics

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High entropy ceramics are a promising new category of UHTC receiving attention for their high strength and hardness, and high temperature stability achieved through high configurational entropy. Although the properties of these materials have been studied extensively at room temperature, measurements at the ultra-high temperatures at which these materials are intended to operate is challenging and has been rather limited in previous works. Using laser heating and radiation pyrometry, we conduct contactless measurements of melting temperature on a series of high-entropy carbides (Ti,Zr,Nb,Hf,Ta)C, high-entropy borides $(Ti,Zr,Nb,Hf,Ta)B_2$, and two-phase composites with varying HEB-HEC compositions. In these measurements, we laser-heat the samples through their melting point, then upon cooling from their molten state after shuttering the laser, we measure the radiance temperature at which the molten state solidified. To determine the true temperature of resolidification, we measure emissivity during this thermal arrest via spectrally resolved pyrometry within the visible wavelength range. Our results demonstrate a compositionally dependent melting temperature of these dual-phase high-entropy UHTC that varies with phase composition, which we show is related to the microstructure of the composite. We further characterize the melting dynamics of a pure HEC phase after heating with energy dispersive spectroscopy (EDS) and perform electron energy loss spectroscopy (EELS) on TEM samples taken from the melt region, to study the effects of high temperature and extreme thermal gradients on the solid solution. We compare the compositional gradients induced by fast-pulsed heating versus slow melting to study the effect of thermal shock and limited diffusion, as well as topological effects such as dendrite formation.