Novel Contactless Measurement Technique to Determine the Thermal Conductivity and Spectral Emissivity of UHTCs at Ultra-High Temperatures (above 2000 °C)

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New ultra-high temperature ceramics (UHTCs) are being developed as candidate hot structures for use as thermal protection systems with space and hypersonic vehicle applications. UHTCs experience extreme heat fluxes during hypersonic flight, resulting in peak surface temperatures well above 2500 °C. New hypersonic vehicles aim to operate at lower altitudes with smaller leading-edge radii, resulting in even greater heating and thus higher surface temperatures. Currently there is limited understanding of the thermal and radiative properties at relevant temperatures (>2000 °C) due to the difficulties conducting thermophysical properties measurements at these extreme temperatures. In this work we present a novel contactless measurement technique based on modulated laser heating, thermal imaging and hyperspectral radiative pyrometry to measure the thermal conductivity and spectral emissivity of UHTC materials from 2000 °C up to and through their melting points. This technique utilizes laser heating and hyperspectral radiative pyrometry to measure the temperature response at the sample surface subject to small perturbations in laser flux. By utilizing Stephan Boltzmann's Law to account for radiative losses, we isolate the contribution of conduction to the induced temperature differential to determine thermal conductivity. We have previously validated this technique on standard metals tungsten and molybdenum by measuring their thermal and radiative properties from 2000 °C through their melting points. We further evaluate our technique by measuring the thermal conductivities of TaC, HfC, ZrC and TiC from room temperature to 2000 °C, and compare our values with literature. Lastly, we measure the thermal conductivity and spectral emissivity of these materials as well as a novel high-entropy carbide (HEC) above 2000 °C for the first time. Thermal conductivity and spectral emissivity measurements at relevant temperatures are crucial for evaluating and influencing the design of the next generation of extreme temperature thermal protection systems.