Ultra-high temperature ceramics (UHTCs), such as ZrB2-based ceramic composites, have been identified as next generation candidate materials for leading edges and nose cones in hypersonic air breathing vehicles. Mechanical performance of ceramic composites play an important role in the ultra-high temperature applications, therefore SiC is added to ZrB2 as a strengthening phase to enhance its mechanical performance. The high melting temperatures of both ZrB2 and SiC, as well as the ability of SiC to form SiO2 refractory oxide layers upon oxidation make ZrB2-SiC ceramics very suitable for aerospace applications.

Thermal residual stresses appearing during processing are unavoidable in sintered ZrB2-SiC ceramic composites. Residual microstresses appear at the microstructural level (intergranular microstresses) or at the crystal structure level (intragranular microstresses). These microstresses are of enormous importance for the failure mechanisms in ZrB2-SiC ceramics, such as ratio of the trans- and intergranular fracture; crack branching or bridging, microcracking, subcritical crack growth and others, as they govern crack propagation-induced energy dissipation and affect the toughness and strength of the ceramic material. Therefore, understanding the evolution of residual stress state in processed ZrB2-SiC ceramic composites and accurate measurements of these stresses are of high priority.

In the present research the ZrB2-17vol%SiC, ZrB2-32vol%SiC, and ZrB2-45vol%SiC ultra-high temperature particulate ceramic composites were sintered using both Hot Pressing (HP) and Spark Plasma Sintering (SPS) techniques. The mechanical performance of the ZrB2-SiC composites was investigated using 3- and 4-point bending techniques for measurements of instantaneous fracture strength and fracture toughness. Resonant Ultrasound Spectroscopy was used for measurement of Young’s, shear, and bulk moduli as well as Poisson's ratio of the composites. The distribution of thermal residual stresses and the effect of the applied external load on their re-distribution was studied using micro-Raman spectroscopy. Piezospectroscopic coefficients were determined for all compositions of ZrB2-SiC ceramic under study and their experimentally obtained values were compared with the piezospectroscopic coefficients both published in the literature and calculated using theoretical approach. Finally, the novel ZrB2-IrB2-SiC ceramic composites were also produced using Spark Plasma Sintering (SPS), where IrB2 powder was synthesized using mechanochemical route. It is expected that the IrB2 additive phase might contribute to the improved overall oxidation resistance of ZrB2 based ultra-high temperature ceramic composites.