Chapter 8

Conclusion

In conclusion, this thesis focused on synthesizing and characterizing ZrB_2-based composites for ultra-high-temperature applications. The study aimed to explore the potential of ZrB_2 as a material for extreme environments and to enhance its properties through composite formation. By in situ formation of additives such as ZrC and SiC, the limitations of ZrB_2 ceramics, such as low self-diffusion coefficient, low fracture toughness, and surface oxidation, can be mitigated. The optimization of processing routes, composition, and microstructure further improves the overall performance of ZrB_2-based composites. Ongoing research and development efforts aim to advance the field of ultra-high temperature structural ceramics and overcome existing limitations.

The ZrB_2-based composites were synthesized and sintered through the reduction technique, employing pressureless and hot-pressing processes. These methods allowed for the control of the composite's microstructure and the incorporation of reinforcing phases. The detailed investigation involved varying the starting precursors, encompassing ZrO_2, B_4C, Si, and different carbon sources, to monitor the ultimate composition of the composite. The molar ratio of ZrO_2:B_4C: Si: C was systematically adjusted, optimizing the in-situ formation of SiC and ZrC content in the final ZrB_2-based composite. Characterizing the synthesized ZrB_2-based binary and ternary composites revealed significant improvements in their thermal stability, mechanical strength, and oxidation resistance compared to pure ZrB_2. The SiC and ZrC additives provide better dimensional and thermal stability during ablation at 2600°C due to the formation of SiO_2 and ZrO_2/SiO_2 protective oxide layer on the surface of oxidized composites.

Furthermore, detailed analyses, including X-ray diffraction, X-ray photoelectron spectroscopy (XPS) analysis, scanning electron microscopy, and thermal analysis, provided valuable insights into the microstructure and properties of the composites. The XPS analysis verified the synthesis of binary and ternary composites and provided detailed insights into the resulting materials' chemical composition and surface properties. These findings supported understanding the structure-property relationships, facilitating further optimization of the composite's performance.

The utilization of low-cost starting materials has made significant progress in the synthesis of ZrB_2-based composites. Mixing and optimizing composition in the proper ratio leads to forming an impurity-free ZrB_2-based composite. The variation of molar ratio and mole content provides these composites' long-term stability and reliability under prolonged exposure to ultra-high temperatures, which would be crucial for practical applications.

Overall, the synthesis and characterization of ZrB_2-based composites presented in this thesis contribute to advancing materials science and engineering for ultra-high-temperature applications. The findings provide a solid foundation for further research and development in this field, offering potential solutions to the challenges faced in extreme environment technologies.