253. ULTRA HIGH TEMPERATURE COMPOSITES FOR THERMAL PROTECTION SYSTEMS

PROJECT AT-A-GLANCE

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- **AST RESEARCH AREA:** 2.2 Vehicle Safety - Technologies
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- **EXECUTION ENTITY:** UCF
- **PERIOD OF PERFORMANCE:**
- **STATUS:** Ongoing

PROJECT DESCRIPTION

PURPOSE: One of the critical issues of high-speed flight vehicles is the aerodynamic thermal loading, encountered at the sharp leading edges. From aerodynamic considerations, hypersonic vehicles require sharp leading edges and recent estimates suggested that such edges should have a radius of curvature on the order of 3mm. As a result of such sharp geometry, temperatures in excess of 2600oC are generated, at the tip of a leading edge, and the resulting stagnation temperature exceeds the realistic upper use temperature of most materials. It was observed that even the most advanced materials such as Ti, Inconel X, carbon-carbon, silicon carbide-based composites cannot withstand the excessive heat generated, especially during reentry, resulting in blunting of the sharp leading edges. Thus, sharp leading edges and nose cones require thermal protection system (TPS) to prevent spacecraft from high aerodynamic heating loads, during reentry into atmosphere. The schematic presentation of the local geometry and flow conditions near leading edge is shown in Fig.1. The sharp leading edges experience extreme aerodynamic heating loads resulting in temperature gradient as high as 1000oC within 2mm beneath the surface. Only a few materials can withstand such high heating loads. It has been identified that the ultra high temperature ceramics (UHTCs), such as refractory metal diborides (ZrB_2 and HfB_2) based ceramics, with high melting temperatures and large thermal conductivities are ideally suited for the protection of sharp edges and yet capable of maintaining their sleek shapes without significant deformation or melting.

OBJECTIVES: The objective of this proposal is to develop multifunctional ultra high temperature ceramic composites with sensing capabilities for applications in hypersonic space vehicle, where aggressive environments including high temperatures and corrosive species prohibits the usages of the currently available technologies.

GOALS: The proposed work will provide a rigorous scientific methodology for development of multifunctional, nanostructured, light-weight, thermal protection systems (TPS) for high-speed air-breathing vehicles which have encountered many daunting challenges in various areas spanning thermal management, hypersonic aerodynamics, aerothermodynamics and aero-propulsion integration.

STATEMENT OF WORK

Ultra high temperature ceramics (UHTCs) are a class of ceramics that are physically and chemically stable at temperatures above 2400oC and have melting temperature above 3200oC. Potential applications of these materials include components for leading edges and nose cones of hypersonic missiles and vehicles, kinetic energy interceptors, advanced ceramic engine components, re-entry vehicles, and as TPS for rocket thrust nozzles, etc. The research team will develop composites of UHTC top layer (e.g., ZrB2-SiC) and PZT piezoelectric/ZrO2 chemical sensing/Polymer Derived Ceramic (PDC) bottom layer which would allow to perform temperature, oxygen content, and stress sensing. While the top layer is highly oxidation-resistant at elevated temperatures, the bottom layer can sense mechanical and thermal stresses, as well as provide an input on the oxidation status of the upper ZrB2 UHTC layer. Thus UHTC composites with multifunctional structures will be developed. The team proposes to utilize a rapid processing scheme called spark plasma sintering (SPS) method that can sinter powders within 5 min at elevated temperatures and simultaneously provide a gradient in the temperature profile so that ceramics and sensor materials (with piezoelectric properties) can be sintered simultaneously to form multifunctional materials as desired. Hot isostatic pressing along with magnetron sputtering will be also used for multilayered materials' manufacturing. The proposal focuses on development of many such multifunctional systems with different combination of materials, and will investigate fundamental issues of processibility, microstructure development, interfacial characteristics, and mechanical performance.