Materials for Hypersonics: Expected Course Outline

This course will include a brief history of hypersonic flight and design, along with a description of the aerothermal environment, to provide motivation for the use of ceramic materials as thermal protection systems (TPS) and window materials. The approach is to develop an understanding of materials structure, forming (including an introduction to additive manufacturing of ceramics) and sintering, and properties (mechanical and thermal) of ceramics, and then apply that knowledge for hypersonic applications. TPS such as ultra-high temperature ceramics (UHTCs including ZrB_2), ceramic matrix composites (including C_f/SiC, SiC_f/SiC, UHTCMCs), and Carbon/Carbon, along with ablatives and RF and IR window materials will be covered.

The course is designed for technical people who would like to learn more about the hypersonic materials problem. It is a survey course in essence, covering a broad content of material. Attendees are given access to the 360-page course notes (PowerPoint format).

Class Dates	Topics / Activities During Class
Monday, 06/23/2025	**Module 1 History of Hypersonic Flight:** Brief history of hypersonic flight will be discussed, considering the important programs of record. These aircraft will be presented in a historically sequential order so that students can understand how the technology has developed over the last ~70 yrs. (0.75 hrs) **Module 2 Hypersonic Aerothermodynamics:** This part of the course will consider the environmental conditions on the leading edges and other structure of the aircraft, focusing on the heat flow into and out of critical components. Establishing the local temperature, composition of the gaseous environment, and pressure from a thermodynamics viewpoint will help the students understand the materials requirements and be strong motivation to focus on ceramics and other high temperature materials as solutions. (2.25 hrs)
Tuesday, 06/24/2025	**Module 3 Colloidal Processing, Shaping Methods, and Sintering of UHTCs**: One class of these materials, identified as Ultrahigh Temperature Ceramics or UHTCs, will be covered extensively in this class. These materials include ZrB_2, HfB_2, and HfC. In this module we will present the basics of colloidal processing as it regards forming stable solutions of UHTC submicron powders in aqueous suspensions. We will also present common shaping methods including those via ceramic additive manufacturing. Sintering strategies to densify UHTCs will also be presented. (2.5 hrs)

	Module 4 Introduction to Mechanical Properties of Ceramics: In this section we will introduce flexure testing, Weibull statistics, elastic modulus, and fracture toughness, all with applications of UHTCs and other ceramics. (0.5 hrs)
Wednesday, 06/25/2025	**Module 4 Introduction to Mechanical Properties of Ceramics Cont:** In this section we will introduce flexure testing, Weibull statistics, elastic modulus, and fracture toughness, all with applications of UHTCs and other ceramics. (0.5 hr) **Module 5 Thermal properties of ceramics:** Thermal properties of ceramics are important as they determine heat conduction into the hot regions of the aircraft. Understanding thermal conductivity and how it is influenced by alloying/impurities and microstructural defects (such as porosity) is key. Starting with the fundamental origins of specific heat will be important. (1 hr) **Module 6 Applications of Thermal and Mechanical Properties:** Consideration of the relationship between thermal and mechanical properties will be presented. Topics including thermal shock of monolithic ceramics and space shuttle tiles will be discussed. Ablative coatings will be presented. (1 hr) **Module 7 Materials for RF and IR performance**: Development of the key materials properties for RF and IR windows will be discussed. The use of silicon nitride as a RF material will be highlighted. (0.5 hr)
Thursday, 06/26/2025	**Module 7 Materials for RF and IR performance Cont**: Development of the key materials properties for RF and IR windows will be discussed. The use of silicon nitride as a RF material will be highlighted. (0.5 hr) **Module 8 Composites:** Composites including carbon/carbon and ceramic matrix composites and their manufacture: This part of the course will focus on the properties, processing, and mechanical properties of composites, focusing on carbon/carbon and ceramic matrix composites. Of interest will be to discuss the densification techniques use for the matrix materials, and the influence on properties. SiC/SiC composites will also be discussed, focusing on crack deflection and high temperature strength. (2 hrs) **Module 9 Materials for Radiative Cooling:** Development of high emissivity coatings and the radiation theory behind this approach for cooling hot structure will be discussed. (0.5 hr)