Effects of High Temperature Water Vapor on Materials Durability

Elizabeth Opila
NASA Glenn Research Center

High temperature water vapor is present in many combustion, propulsion, and power generation environments. The durability of structural and functional materials in high temperature water vapor for these applications is therefore a key concern. In this presentation, experimental results demonstrating the effects of high temperature water vapor on silica- and chromia-forming materials will be discussed. In addition, mechanistic models that enable prediction of material life-times will be presented.

Silicon carbide and silicon nitride are proposed for applications such as turbine engine combustor liners for power generation and propulsion as well as rocket engine nozzles. In these high temperature environments, SiC and Si_3N_4 oxidize to form silica. The interaction of high temperature water vapor with silica is therefore of interest. Three effects of water vapor on silicon-based systems have been observed. First, water vapor increases transport of impurities to the silica surface. Silica growth rates are very sensitive to impurities; thus, oxidation rates of silicon-based materials are increased due to water vapor enhanced impurity effects. Second, oxidation rates of SiC and Si_3N_4 are also "intrinsically" increased in water vapor since the solubility of water in the silica scale is higher than that of oxygen. Finally, water vapor reacts with silica to form volatile hydroxide species which also affect the oxidation kinetics of SiC and Si_3N_4. Thermodynamic and kinetic models for predicting oxidation and volatilization reactions will be presented.

Chromia-water vapor interactions are also important in energy and power generation applications. Chromia-forming alloys are proposed as low-cost interconnect materials in fuel cells and for heat exchangers/recuperators for power generation applications. Until recently the volatility of chromia in water vapor was not well understood. Transpiration experiments that confirm the identity of the primary volatile chromia species and provide accurate thermodynamic data for formation of this volatile species will be described. These data enable prediction of chromia-forming alloy lifetimes in high-temperature water vapor-containing environments.