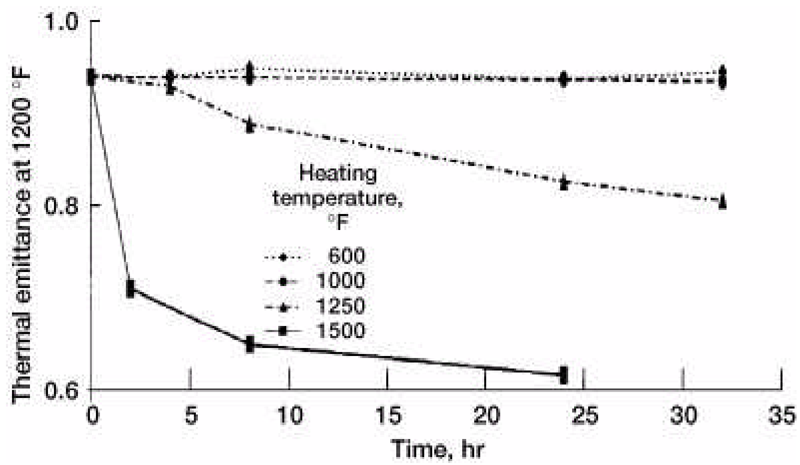
Effects Investigated of Ambient High-Temperature Exposure on Alumina-Titania High-Emittance Surfaces for Solar Dynamic Systems

Solar-dynamic space power systems require durable, high-emittance surfaces on a number of critical components, such as heat receiver interior surfaces and parasitic load radiator (PLR) elements. An alumina-titania coating, which has been evaluated for solar-dynamic heat receiver canister applications, has been chosen for a PLR application (an electrical sink for excess power from the turboalternator/compressor) because of its demonstrated high emittance and high-temperature durability in vacuum. Under high vacuum conditions ($\pm 10^{-6}$ torr), the alumina-titania coating was found to be durable at temperatures of 1520 °F (827 °C) for ~2700 hours with no degradation in optical properties. This coating has been successfully applied to the 2-kW solar-dynamic ground test demonstrator at the NASA Lewis Research Center, to the 500 thermal-energy-storage containment canisters inside the heat receiver and to the PLR radiator. The solar-dynamic demonstrator has successfully operated for over 800 hours in Lewis' large thermal/vacuum space environment facility, demonstrating the feasibility of solar-dynamic power generation for space applications.

Although the alumina-titania coating has operated successfully in the solar-dynamic ground test demonstrator system, solar-dynamic flight PLR hardware would require ambient pressure operation to verify proper system electrical function and to check out alternator control software. If operation of the PLR in air decreases the emittance, it will operate at a higher temperature than desired while on orbit. This could shorten the PLR's life, and possibly damage the elements. Therefore, a program was conducted at Lewis to test the high-temperature durability of the alumina-titania coating in air. Sixteen alumina-titania-coated Incoloy samples were prepared, and fifteen were exposed to high temperatures (316 °C (600 °F) to 816 °C (1500 °F)) for various times (2 to 32 hours). Samples were characterized prior to and after heat treatment for reflectance, solar absorptance, room temperature emittance, and emittance at 1200 °F (649 °C). Samples also were examined for physical defects and surface chemistry using optical microscopy, scanning electron microscopy operated with an energy dispersive spectroscopy (EDS) system, and x-ray photoelectron spectroscopy (XPS).



Thermal emittance (at 1200 °F) versus time of alumina-titania-coated samples that were heated in air at various temperatures.

Visual examination of the heat-treated samples showed a whitening of samples exposed to temperatures of 1000 °F (538 °C) and above. Correspondingly, the optical properties of these samples were degraded. Decreases in thermal emittance at 1200 °F are shown in the graph. A sample exposed to 1500 °F (816 °C) for 24 hours appeared white, and the thermal emittance at 1200 °F had decreased from the non-heat-treated value of 0.94 to 0.62. The coating on this sample was embrittled and spalling off the substrate in several locations. On the basis of this research, we do not recommend that components with alumina-titania coatings be operated at temperatures above 600 °F (316 °C) in air because optical degradation will occur, and structure degradation of the coating may occur also. These results also indicate that components with the alumina-titania coating are likely to experience optical property degradation with atomic oxygen exposure in space. Therefore, the atomic oxygen durability of this coating needs to be assessed prior to use on surfaces directly exposed to atomic oxygen in the low-Earth-orbit space environment.

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Programs/Projects: SDFD, SD GTD, future solar dynamic power systems and systems utilizing heat received technology