Ceramic Coatings for the Solar Probe Plus Mission

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This study aims to develop the coatings needed to protect the Solar Probe Plus Thermal Protection System (TPS) from the harsh environment it will encounter during its mission close to the Sun. The TPS will encounter solar fluxes 50 times larger than those seen by any previous spacecraft (Fig. 1). Controlling the optical performance of the coating at these very high temperatures is critical. Candidate coating technologies have been developed on the basis of those used in the reentry and nuclear systems. Measurement techniques were developed to assess both the optical properties and adhesion of these coatings (Fig. 2). The key part of this effort has been directed at the question *what makes a white coating white?*

The first part of the study addresses how a coating's microstructure affects its optical properties and how coatings can be designed to maintain the right microstructure over temperature. Work on this effort has been led by Dr. Dennis Nagle of the Advanced Technology Laboratory of the Whiting School of Engineering. The design effort focused on coating types, the use of a barrier coating to control chemical interactions of the coating and substrate, and the use of grain growth inhibitors to lock in the desired microstructure over a wide temperature range. Mr. Mark Buchta and Dr. Dajie Zhang of the Advanced Technology Laboratory and Ms. Elizabeth Congdon, Dr. Ryan Deacon, and Mr. Donald King of APL supported this work.

A second part of the work is focused on the measurement of the optical properties of these coatings and how those properties vary with temperature. Dr. James Spicer, of the Whiting School, has led this part of the study. He developed the theory of how grain structure and index of refraction affect the reflectance of the coating and how those properties can be varied to optimize the coating. As part of this effort, a test facility was developed that allows high-temperature, directional reflectance measurements to be made of coatings. Mr. Stephen Ryan, a graduate student at JHU, and Mr. Greg

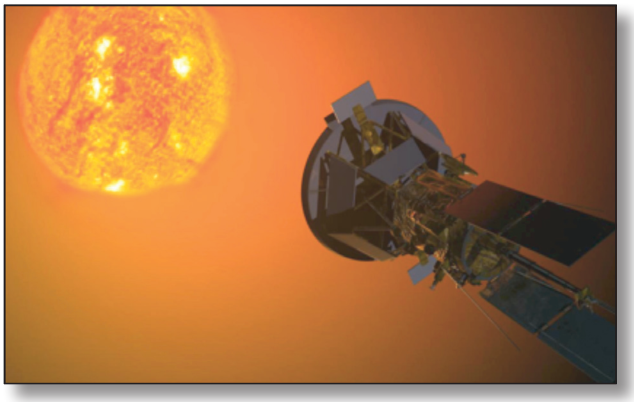

Figure 1. The harsh environment of the Solar Probe Plus spacecraft, with solar fluxes 50 times larger than any previous spacecraft has experienced. Newly developed ceramic coatings for the Thermal Protection System will help protect the spacecraft in this harsh environment.

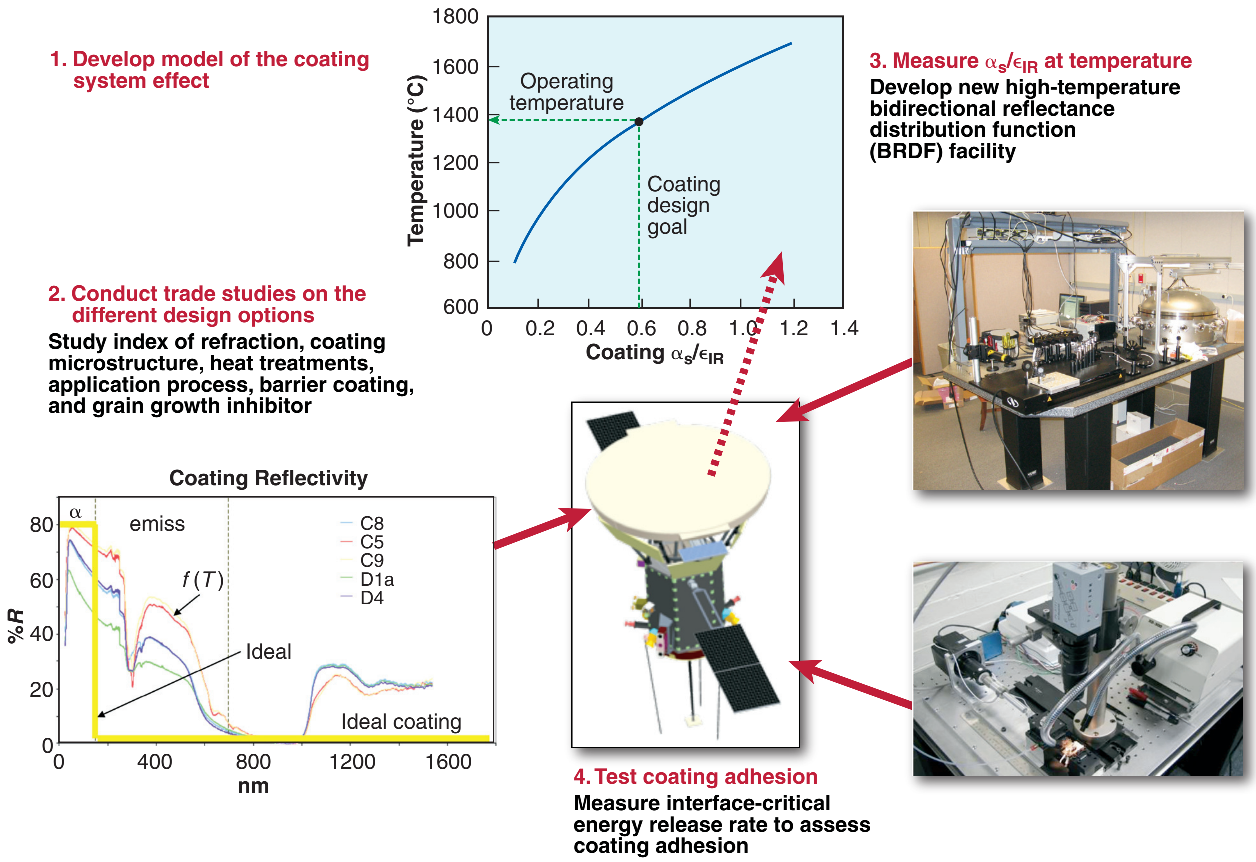

Figure 2. Development of candidate coating technologies, along with the measurement techniques used to assess both their optical properties and their adhesion.

Schlichter, an undergraduate student, have been supporting this effort. The original experimental concept was developed at APL by Mr. David Drewry, Mr. Dan Hahn, and Mr. Tom Wolf.

The third part of the study is directed at the adhesion of the coating. Dr. Kevin Hemker, of the Whiting School, has led this part of the work. This effort is being supported by Dr. Justin Jones, a postdoctoral fellow at JHU. He has focused on the development of a test method to measure the mechanical integrity of bimaterial interfaces, measuring interface critical strain energy release rates as a measure of the strength of those interfaces, and how the coating adhesion models can be integrated with APL's structural predictions to verify the adhesion of the planned coating in the mission environment.

The study has led to the development of a coating that will survive the harsh environments expected from the Solar Probe Plus mission. It has also improved understanding of the parameters that drive the optical properties of such coatings. Design elements include the use of a barrier coating to prevent chemical interactions between the different materials at high temperatures and the use of grain growth inhibitors to control the change in both the grain and splat size in the material at temperature. Finally, the presence of porosity was found to have an important effect on the coating's optical properties in the near-IR band.

For further information on the work reported here, see the reference below or contact douglas.mehoke@jhuapl.edu.

[1]The Johns Hopkins University Applied Physics Laboratory, *Solar Probe+ Mission Engineering Study Report*, National Aeronautics and Space Administration and The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, http://solarprobe.gsfc.nasa.gov/SolarProbe+ME.pdf (10 Mar 2008).