Cryogenic Selective Surfaces—How Cold Can We Go?

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The Concept

Hibbard (1961) showed that 40 K could be achieved with ideal materials. But real world materials are not ideal. The key question is, can we reach cryogenic temperatures with a realizable selective surface?

Modeling

We developed models—identical to published paint theory models—and coupled these to Mie scattering models, to predict the performance of our new coating. The plots below show the solar absorbed spectrum, the emitted power spectrum, and the emissivity for a 5 mm thick layer of BaF2. Surfaces designed to reflect one wavelength band and absorb the other are called Selective Surfaces.

Selective Surfaces are already used in space applications, but not at cryogenic temperatures.

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ThePayload Bay doors of the Space Shuttle Orbiter were coated with a selective surface to allow heat rejection in the presence of the sun. The Hubble Space Telescope also uses a selective surface to reduce solar heating.

The area under the curves is equal, but the sun’s irradiance is at a much shorter wavelength than the irradiance produced by the sphere.

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Experiments and Plans

Goals:
- Test “Solar White” sufficiently so its performance can be verified.
- Construct rigid versions of the coating (not based on powders).
- We started testing powders in a cryo-cooler with an infrared emitter. We plan on moving to a deuterium lamp to measure ultraviolet absorption.
- We tried sintering it to form a rigid coating, but the first attempt caused melting of the particles, as shown above.
- Solar White should allow cryogenic storage, superconductor operation, and the development of better thermal shields for deep space operation.
- We have obtained co-funding from KSC and from the Launch Service Program.
- We are in discussions with the Florida Institute of Technology, the International Space Station Program, the Payload Bay doors of the Space Shuttle Orbiter were coated with a selective surface to allow heat rejection in the presence of the sun. The Hubble Space Telescope also uses a selective surface to reduce solar heating.
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Solar White does not effectively reflect long wave infrared radiation, so radiation shields are needed to block that radiation from the warm portions of the vehicle and from nearby planets, such as the Earth.

Here is a possible configuration where a LOX tank is located between a warm fuel tank and warm engine/nozzle.

We modeled our sphere with 5 mm coatings on silver using seven broadband spectroscopy materials. Predicted temperatures, compared to those achievable by a Hibbard selective surface are shown to the left.

A coated 1 m radius sphere only absorbs about 3.5 Watts out of the 4300 Watts of solar power hitting it, enabling it to reach a predicted temperature of about 53 K!!

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We calculate the temperature along a 2 mm strut coated in Solar White in full sunlight and find that titanium struts chill sufficiently so that no heat is conducted to the LOX tank from warm vehicle items.