Impact of Thermochromic Coatings on Thermal Management for Human Spacecraft Applications

[*]Joseph Peoples, [**]Sydney Taylor, [**]Christopher Massina, and [*]Xiulin Ruan

[*]Purdue University
585 Purdue Mall
West Lafayette, IN 47907
(937) 207-6385
peoplesj@purdue.edu and
ruan@purdue.edu

[**]Lyndon B. Johnson Space Center
2101 E NASA Pkwy
Houston, TX 77058
(281) 244-0898
sydney.j.taylor@nasa.gov and
christopher.j.massina@nasa.gov

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Thermochromic variable emittance coatings (VECs) allow for passive, dynamic thermal management of space vehicles due to their temperature dependent optical properties. Ideally, a thermochromic material should exhibit low mid-IR emissivity for lower temperatures and switch to high mid-IR emissivity for higher temperatures; one promising material that demonstrates these characteristics is Lanthanum Strontium Manganite (LSM). The transition temperatures of LSM are dependent on the Lanthanum-to-Strontium ratio *x*, $La_{1-x}Sr_xMnO_3$. $La_{0.8}Sr_{0.2}MnO_3$, which has an emittance of 0.5 for < 270 K, then a linear increase in emittance to 0.8 over an increase of 70 K where it will saturate at ~340K, is commonly utilized but this is tunable by changing the Sr concentration. The tunability of the transition temperature range of LSM motivates a need to understand the optimal thermal transition range for human spacecraft. Additionally, LSM has high solar absorptance and to combat this issue the VEC will be micropatterned on top of a highly solar reflective layer of Barium Sulfate ($BaSO_4$). Consequently, this work will elucidate the tradeoffs between solar absorptance and variable emittance for this technology since the micropattern adversely couples the solar absorptance to the mid-IR emittance.

This work develops a computational model using Thermal Desktop to study the utility of VECs on human spacecraft, such as Orion, subjected to mission phases such as lunar transit and Gateway docking. The model considers both external heat loads, from solar irradiation and planetary IR, as well as vehicle heat loads, from avionics and crew, as an input into the body mounted thermochromic radiators. There are several designs targets for VECs, i.e. achieving the largest change in emittance, finding the optimal temperature range for the transition, and achieving the highest emittance in the high temperature phase. This work prioritizes these design targets for LSM to achieve the optimal heat rejection for a human spacecraft. The VECs are compared with static emittance coatings and the efficiency gains are quantified. Thermochromic VECs will ultimately lead to simplifications of active cooling systems which synergistically correlates to mass reduction and less energy consumption for space vehicles.

No ITAR material is included