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Investigation of the emittance properties of multilayer insulation used in cryogenic applications

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Multilayer insulation (MLI) is a critical material used to control radiative heat transfer in cryogenic systems. MLI consists of alternate layers of reflective aluminized mylar, separated by low thermal conductivity spacers. The thermal emissivity of the MLI layer plays a critical role in minimizing the radiative heat transfer through its layers. The formation of native oxide is inevitable in any aluminized coating. Any long-term atmospheric exposure of aluminized surfaces can affect the nature of native oxide formation. This native oxide layer can affect the emittance of the reflective layer depending on its nature and thickness. The exact microstructure and elemental composition of the native aluminium oxide is highly uncertain, and it is commonly identified as an amorphous combination of different oxides and hydroxides. It is essential to characterize the material and measure the emittance of the reflective surface of MLI before its application in cryogenic systems. This work aims to characterize the reflective surface of MLI structurally and functionally. This paper reports on the functional and structural characterization of aluminized mylar used in multilayer insulation. In this work, the emissivity of the reflective layer of multilayer insulation was measured experimentally, and the relation between emissivity and surface resistivity was demonstrated successfully. Grazing incidence x-ray diffraction result gives the diffraction peaks corresponding to polyethylene terephthalate (PET), which is the substrate (at $2\theta = 26^{\circ}$), and aluminium, which is the conductive coating material (at $2\theta = 38.47^{\circ}$ and 44.74°). Scanning electron microscopy (SEM) analysis shows that the surface is uniform, while elemental analysis through energy dispersive spectroscopy (EDS) indicates the presence of only Al, O, and C. Atomic force microscopy (AFM) shows that the MLI surface is smooth with a surface roughness (Ra) of ˜ 4.7 nm. The total hemispherical emissivity is measured as per ASTM C 1371 standard using a portable emissometer at room temperature and found to be 0.03 ± 0.01 and is compared with the estimated value from measuring the sheet resistivity of MLI using the Hagen-Rubens relation. While native oxide formation in aluminium is inevitable, the measured results show that the reflective layer of MLI maintains its low emissivity due to the minimal thickness of alumina.
Keywords: Multilayer insulation; Emissivity; Sheet resistance; Aluminum coating; Oxide thickness

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