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Performance Measurement And Analysis of Multi-layer Insulation Material (MLI) From 20 K-300 K

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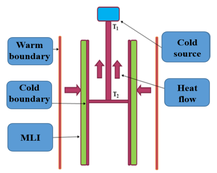
Abstract

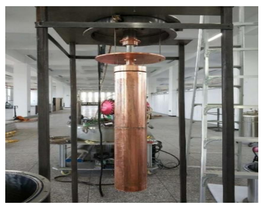
This paper introduces a cryogen-free high vacuum multi-layer insulation material(MLI) measurement system based on a G-M cryocooler, which uses the steady-state axial heat flux method for heat measurement. The system enables cold boundary temperatures from 20 K to 120 K, and the thermal insulation performance of a commonly used MLI produced by double aluminized-Mylar and fiberglass paper is tested by this system. A modified numerical analysis method for the heat transfer coefficients of the MLI is introduced, which sets temperature as a variable. The heat transfer of the MLI is analyzed according to the test and the calculation result, and thereby some MLI performance optimization method is proposed.

MLI measurement system and test specimen

(a)



(b)

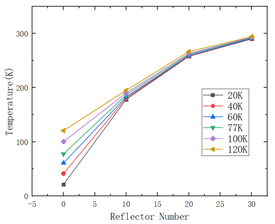


(c)

- This system uses the steady-state axial heat flow method.
- The cooling power of the cryocooler is transferred to the cold boundary through a metal rod that has been calibrated before use.
- The heat flow through the rod is equal to the heat flow through MLI.

The internal heat transfer in MLI

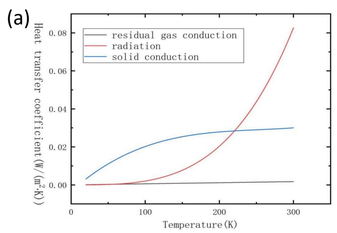
Cold boundary temperature (K)	Temperature difference on the rod (K)	Heat flux through the MLI (W/m^2)	Vacuum degree of the system (Pa)
21.1	0.921	1.41	6.4×10^{-5}
41.5	1.295	1.35	6.7×10^{-5}
62.8	2.324	1.28	7.2×10^{-5}
80.2	2.842	1.16	9.5×10^{-5}
103.5	2.937	1.03	1.5×10^{-4}
123.2	2.584	0.86	2.6×10^{-4}



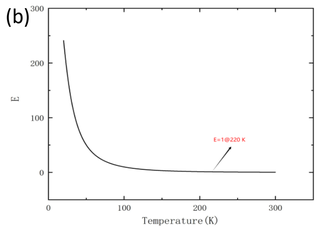
- With the increase of the cold boundary temperature, the increment of heat flux decreases with the decrease of cold boundary temperature.
- The temperature gradient at the low temperature position is larger than that at the high temperature position.

The MLI performance improvement methods by three independent ways of the heat flux

(a)



(b)



- With the increase in temperature, the heat transfer coefficient of the three types of heat transfer ways all increase.
- The solid heat transfer coefficient is the largest in the low temperature position.
- When the temperature is above about 200 K, with the increase of the temperature, the radiation heat transfer coefficient increases sharply, reaching almost two orders of magnitude larger than the solid heat conduction at ambient temperature.

Conclusions

- We study performance of the double aluminized-Mylar and fiberglass paper material by a cryogen-free high vacuum measurement system based on a G-M cryocooler which enables temperatures from 20 K to 120 K.
- We put forward a modified MLI model with temperature as a variable and discusses the comparison of three kinds of heat transfer ways in adjacent reflectors from 20 K-300 K.
- Based on the calculation results, we propose the improvement methods for MLI in different temperature range.