Measurement and Estimation of Thermal Conductivity of Polyimide Foam in the Temperature Range from 160 K to 370 K in a Vacuum

Ryuichi Takagi [C, S]
Keio University, School of Integrated Design Engineering, Yokohama, Kanagawa, Japan
takagi@naga.sd.keio.ac.jp

Sumitaka Tachikawa
Japan Aerospace Exploration Agency, Sagamihara, Kanagawa, Japan

Takahiro Ohmura
NICHIAS Corporation, Hamamatsu, Shizuoka, Japan

Yuji Nagasaka
Keio University, Department of System Design Engineering, Yokohama, Kanagawa, Japan

Multilayer insulation (MLI) has been used for spacecraft, and known for high performance thermal insulation for space use. But the effects of seam and Velcro as a heat path are not negligible, and make the performance of MLI degraded. High thermal insulation performance is required to accomplish deep space missions or lunar exploratory missions, because saving heater power is the key factor for those missions. Additionally, upper temperature limit of thin non-conductive spacer used in MLI is about 393 K, and this might not be enough to achieve inner space mission. To satisfy these requirements, we focus on polyimide foam (PF) and propose new multilayer insulation, which could be an alternative to conventional MLI. By evaluation of thermal conductivity of polyimide foam in a vacuum condition, the optimum configuration (layers, density, etc.) of new multilayer insulation, which is lighter and have higher performance than conventional MLI, can be determined. To measure thermal conductivity in the temperature range from 160 K to 370 K, Periodic Heating Method is applied. But especially for low density porous material in a vacuum, it might be difficult to detect the phase difference in Periodic Heating Method, because thermal radiation is dominant. Therefore, Steady State Method is also applied to measure thermal conductivity of the lowest density PF (4~6 kg/m^3). For estimating, Lattice Boltzmann Method (LBM) has been applied. In the process, X-ray CT and dodecahedron model is composed to reflect the complicated inner structure of PF. As a results, measured and estimated thermal conductivity are extremely low (10^{-3} W/(mK) order) from 160 K to 370 K. They change with density, and local minimum value, are ascertained from both measurement and estimation. Based on these results, optimum density of PF is determined, and polyimide foam multilayer insulation (PF-MLI) is proposed as the new insulation system.