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Author: Dr. Matthew Dalton
Sonaca Space GmbH, Germany

Dr. Sandrine Berthon-Fabry
ARMINES, France
Dr. Claudia Hildenbrand
ARMINES, France
Dr. Barbara Milow
DLR (German Aerospace Center), Germany
Prof. Lorenz Ratke
Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany
Prof. Luisa Durães
University of Coimbra, Portugal
Ms. Marta Ochoa
Active Aerogels, Portugal
Ms. Ana Maia
University of Coimbra, Portugal
Mr. Riccardo Nadalini
Sonaca Space GmbH, Germany
Ms. Jessica Laskowski
DLR (German Aerospace Center), Germany

THE 3 OMEGA TRANSIENT LINE METHOD FOR THERMAL CHARACTERIZATION OF SUPERINSULATOR MATERIALS DEVELOPED FOR SPACECRAFT THERMAL CONTROL

Abstract

The 3 Omega Method is a form of the transient line method for thermal characterization that has been in limited use since 1912. Through sinusoidal heating of a thin copper wire located on the specimen and varying the input frequency, a third harmonic voltage arises, the frequency dependance of which carries information about the thermal conductivity and diffusivity of the sample being tested. Thus the heating wire serves also as the sensing element in this method. Major advantages of this approach include very small temperature oscillations, on the order of a few degrees or less, significantly reducing errors arising from thermal radiation and gaseous convection that plague more traditional methods which typically require very large temperature gradients for low conducting materials. Additionally, in this method, thermal conductivity and diffusivity are extracted from the measurement simultaneously based on first principles, eliminating the need for complex and unreliable thermal modeling and calibration of the measurement system. The implementation of this method has been significantly facilitated and its sensitivity and dynamic range improved by the advancement of modern technology, especially the development of lock-in amplifiers and subsequently digital signal processing. Traditionally, this method requires fabrication of micro heating elements through vapor deposition of copper on the specimen to be tested. This method has been implemented at Active Space Technologies GmbH for testing aerogels developed in the context of the AerSUS - Aerogel European Supplying Unit for Space Applications - project FP7 (contract no: 284494), an initiative funded by the Seventh Framework Programme of the European

Union. To the best of our knowledge, this is the first time that it has been implemented using macroscopic (60 micro-meter diameter) mass produced copper wire, significantly reducing sample preparation cost and time. Furthermore, this work represents the first use, to our knowledge, of digital signal processing techniques, namely discrete Fourier powers, to extract the third harmonic signal, eliminating the need for large time constant analog circuitry, and making feasible the extremely low frequencies (down to 0.001 Hz) which are required for thermal characterization of superinsulators. We present the implementation of this method, a comparison of results for known materials from the literature and thermal characterizations of superinsulators for space applications. Additionally, simulations and analysis are presented to showcase the use of such super-insulating materials developed by the AerSUS consortium in a realistic Mars lander scenario.