Dynamic Electrothermal Model of a Sputtered Thermopile Thermal Radiation Detector for Earth Radiation Budget Applications

by

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(ABSTRACT)

The Clouds and the Earth's Radiant Energy System (CERES) is a program sponsored by the National Aeronautics and Space Administration (NASA) aimed at evaluating the global energy balance. Current scanning radiometers used for CERES consist of thin-film thermistor bolometers viewing the Earth through a Cassegrain telescope.

The Thermal Radiation Group, a laboratory in the Department of Mechanical Engineering at Virginia Polytechnic Institute and State University, is currently studying a new sensor concept to replace the current bolometer: a thermopile thermal radiation detector. This next-generation detector would consist of a thermal sensor array made of thermocouple junction pairs, or thermopiles. The objective of the current research is to perform a thermal analysis of the thermopile. Numerical thermal models are particularly suited to solve problems for which temperature is the dominant mechanism of the operation of the device (through the thermoelectric effect), as well as for complex geometries composed of numerous different materials. Feasibility and design specifications are studied by developing a dynamic electrothermal model of the thermopile using the finite element method. A commercial finite element-modeling package, ALGOR, is used.

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Table of Contents

1. Introduction 1

1.1 The Earth Radiation Budget 2

1.2 A Brief History of the Earth Radiation Measurements 5

1.3 Signal Processing 9

1.4 Description of the Sputtered Thermopile Thermal Radiation Detector 11

1.5 Goals and Motivations 15

2. The Thermopile 16

2.1 Background and Theory 17

2.1.1 The thermoelectric effects 17

2.1.2 Thermodynamics of thermoelectricity 21

2.1.3 Literature on thermoelectric effects 25

2.2 The Thermopile 26

2.2.1 Description of the device 26

2.2.2 Motivation for the choice of a thermoelectric device 29

2.2.3 The thermopile thermal model 30

2.2.4 The thermoelectric radiation detector specifications and design 34

2.2.5 Parameters available to improve the sensitivity of the device 36

3. Finite Element Model 38
3.1 Finite Element Formulation 38
3.2 Finite Element Software 41
3.2.1 ALGOR operation modes 41
3.2.2 Capabilities of and comments on the software 44
3.3 The Thermal Models 45
3.3.1 General assumptions and approximations 46
3.3.2 One-dimensional model 47
3.3.3 Two-dimensional model 53
3.3.4 Validation of the models 56

4. Results and Discussion 60
4.1 One-Dimensional and Two-Dimensional Model Results 61
4.1.1 Temperature distribution 61
4.1.2 Sensitivity 63
4.1.3 The time response 71
4.1.4 Conclusion 83
4.2 Parametric Study 84
4.2.1 Heat-source (active junction) size effect 84
4.2.2 Ramp slope effect 88
4.2.3 Heat flux boundary condition 93
4.3 Electrical Model of the Active Junction 95

5. Conclusions and Recommendations 99
5.1 Conclusions 99
5.2 Recommendations for further study 100

References 102
Vita 105

List of Tables

Table 1.1. Planned EOS instrument launches [Wielicki, 1995] 7

Table 1.2. Planned CERES Host Spacecraft [Barkstrom, 1990] 8

Table 2.1. Nominal material and thermal properties of the thermopile, the absorber layer and the heat sink. 36

Table3.1. Comparison of the finite element results obtained with ALGOR and PATRAN-ABAQUS 57

Table 4.1. Effect of junction definition on the predicted sensitivity 69

Table 4.2. Sensitivity of the detector based on the one-dimensional and two-dimensional models 70

Table 4.3. Influence of the device geometry on time constant and rms error 79

Table 4.4. Comparison between the one-dimensional and two-dimensional models 83

Table 4.5. Time constant and rms error associated with different active junction lengths 88

Table 4.6. Sensitivity, time constant and rms error for different ramp angles 93

List of Figures

Figure 1.1.	Illustration of the global energy balance at the top of the atmosphere and at the surface of the Earth [Bulletin of the American Meteorological Society (cover),1995]	3
Figure 1.2.	Data processing [Haeffelin, 1997]	10
Figure 1.4.	(a) Detail of a single pixel and (b) the thermopile linear array and connection leads [Mahan, 1997]	12
Figure 1.5.	The thermopile linear array and its cavity [Mahan, 1997]	13
Figure 2.1.	Electromagnetic spectrum	16
Figure 2.2.	Illustration of the Seebeck effect	18
Figure 2.3.	Illustration of the Peltier effect	19
Figure 2.4.	Thomson effect	20
Figure 2.5.	Example of a Thermopile	28
Figure 2.6.	Fabrication sequence for the thermopile linear array [Mahan, 1997]	31
Figure 2.7.	The energy balance on a system consisting of a thermal mass, C, and a thermal impedance of conductance, K	32
Figure 2.8.	Profile of the thermocouple design	35
Figure 3.1.	Two-dimensional region subdivided in finite elements	39
Figure 3.2.	The types of available boundary conditions in ALGOR	40
Figure 3.3.	Summary of stages used in ALGOR	43
Figure 3.4.	Example of a two-dimensional mesh created on ALGOR	44
Figure 3.5.	Boundary conditions applied to the pixel	47

Figure 3.6.	One-dimensional model of the active junction	48
Figure 3.7.	Schematic representation of the one-dimensional steady-state formulation	50
Figure 3.8.	Thermocouple three-dimensional geometry	54
Figure 3.9.	Two-dimensional model of the thermocouple boundary conditions	55
Figure 3.10.	Dimensions and materials of the two-dimensional model	55
Figure 3.11.	Temperature distribution obtained with ALGOR	59
Figure 3.12.	Temperature distribution obtained with PATRAN-ABAQUS	59
Figure 4.1.	The steady-state one-dimensional temperature distribution for the boundary conditions shown in Figure 3.6.	62
Figure 4.2.	The steady-state two-dimensional temperature distribution corresponding to the boundary conditions of Figure 3.9	62
Figure 4.3.	Comparison between different type of junctions: (a) the typical design and (b) the current design.	64
Figure 4.4.	Temperature profile along the active junction	65
Figure 4.5.	The law of intermediate temperatures applied to our model	67
Figure 4.6.	Definition of three different candidate junctions according to their locations	68
Figure 4.7.	One-dimensional model time step optimization	73
Figure 4.8.	Two-dimensional model time step optimization	74
Figure 4.9.	Junction nodes selected (active junction length of 60 μm)	75
Figure 4.10.	Time response of different junction nodes (active junction length of 60 μm)	76
Figure 4.11.	Junction nodes selected (active junction length of 93 μm)	77
Figure 4.12.	Time response of different junction nodes (active junction length of 93 μm)	78
Figure 4.13.	Comparison between the finite element time response function and the “best-fit” (Equation 4.2) curve from the first-order model	81

Figure 4.14. (a) Error (percent) between the finite element time response function and the "best-fit" curve (Equation 4.2), and (b) view with greater vertical resolution for $t \geq 0.7\times10^{-3}$s. 82
Figure 4.15. Influence of the size of the active junction on the thermal time response of the thermocouple 85
Figure 4.16. Sensitivity of the thermocouple as a function of the active junction length 86
Figure 4.17. Time constant of the thermocouple as a function of the active junction length 87
Figure 4.18. Comparison of three different designs considered in the parametric study 89
Figure 4.19. Effect of the ramp slope on the thermal time response of the thermocouple 90
Figure 4.20. Sensitivity as a function of the ramp angle α. (The "best fit" curve has been provided to guide the eye through the calculated results) 92
Figure 4.21. New model boundary conditions 94
Figure 4.22. The distributed junction represented as (a) sixty discreet cells (61 nodes) and (b) the associated electrical model. 96

Nomenclature

A	Cross-sectional area (m^2)
C	Heat capacity (J/K)
C_p	Specific heat (J/kg.K)
E_{AB}	Relative Seebeck Electromotive force (V)
I	Electrical current (A)
k	Thermal conductivity (W/m.K)
K	Thermal conductance (W/K)
L	Length (m)
m	Mass (kg)
n	Number of thermocouple pairs (-)
P	Radiative energy (W), heat energy (W), electrical power (W)
P_{AB}	Relative Peltier coefficient (V)
q´´	Heat flux (W/m^2)
q´´´	Heat source (W/m^3)
r	Aspect ratio (-)
R	Electrical resistance (Ω)
R_t	Thermal resistance (K/W)
S	Absolute Seebeck coefficient (V/K)
T	Temperature (K)
t	Time (s)

V	Electrical potential (V)
x,y	Cartesian coordinates (m)

Greek

α	Diffusivity (m^2/s)
ϕ,ψ	Function of variables
λ_n	Eigen values
ρ	Volumetric density (kg/m^3), resistivity (Ωm)
σ	Thomson coefficient (V/K)
τ	Time constant (s)
μ	micro