Smart functions for carbon nanotube bolometer

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Abstract—**Resistive bolometers are thermal type infrared detectors that can be used in radiometric instruments. This paper presents the first results of control and diagnostic functionalities implemented with the Capacitively Coupled Electrical Substitution (CCES) technique and involving bolometer with Vertically-Aligned Carbon Nanotube (VACNT) absorber. In particular self-identification result for resistive bolometer is presented. Experiments are performed at room temperature.**

Keywords—bolometer, electrical subsitution, carbon nanotube, smart functions

I. Introduction

Resistive bolometers are one type of infrared radiation detectors. They are part of the thermal type infrared detectors with Golay cells, thermoelectric detectors and pyroelectrics detectors. The second type of infrared radiation detectors is the photonic ones: photodetectors using semiconductors.

The resistive bolometers, sketched in Fig.1, are composed of three parts: (1) a supporting substrate covered by a layer that absorbs the incident optical power; (2) a thermal link between the detector and a heat sink; (3) a thermistor on the supporting substrate.

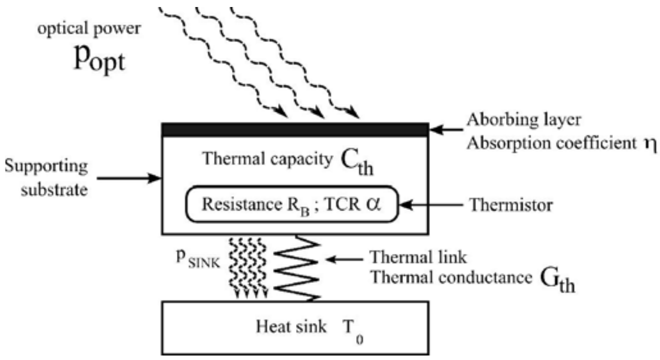

Fig. 1. Thermal sketch of a bolometer. The main parameters of the bolometer are: the thermal conductance (G_{th}) between the supporting substrate and the heat sink at temperature T_0, the thermal capacity (C_{th}) of the supporting substrate and the absorbing layer, the coefficient of temperature and the resistance of the thermistor (α and R_B respectively), the absorption coefficient of the radiation absorber (η). The incoming radiation power (P_{opt}) is absorbed by the absorbing layer. P_{SINK} is the power flowing from the active portion of the bolometer (supporting susbtrate and absorber) to the heat sink.

The detection principle of resistive bolometers is based on the temperature measurement of the thermistor coupled to the thermal mass. The absorber on the thermal mass converts the incident optical power into a temperature variation. Bolometers when used as detector into a radiometer are calibrated by the means of Electrical-substitution (ES). Electrical-substitution is used to link optical power measurements to the watt by comparing the temperature rise induced in an absorbing mass by incident optical radiation to that induced by electrical heating on the same mass [1]. The CCES technique [2] enables the Electrical Substitution directly onto the thermistor. Using this technique, the bolometer can be operated in closed-loop mode [3] and smart-functionalities can be implemented.

If we refer to the IEEE 1451.2 definition of smart sensors which are sensors "that provide functions beyond those necessary for generating a correct representation of a sensed or controlled quantity", every functionality beyond basic signal conditioning can be defined as a smart function. In that sense, analog-to-digital conversion and digital communication integrated in nowadays sensors available on the market represent a large part of smart functions. Other smart functions can be gathered in two categories: the control category and the diagnostic category. This work focuses on smart functions of those categories and their implementation for resistive bolometers. Both relying on heat feedback [4], they enable choosing in closed-loop mode, the measurement range, dynamic and operating point (control) and evaluating the operating conditions (diagnostic) [5]. Self-identification illustrated in the result section is an example of diagnostic functions.

Here for the first time, the CCES technique is applied to a highly absorbing (~0.999 absorption coefficient in VIS-FIR) and micro-machined silicon bolometer with Vertically Aligned Carbon Nanotubes absorber [6], combining the latest developments of two research teams. One goal is the development of a smart radiometer with self-calibration functionality.

II. Experimental Set-up

The experiments involve a planar Vertically Aligned Carbon NanoTubes (VACNT) bolometer described in details in [7-9] and pictured in the holder of the vacuum chamber of the experimental set-up in Fig.2. The absorbing layer of the device is made of Vertically Aligned multiwall carbon NanoTube Arrays (VANTAs). VANTAs have been demonstrated to be the blackest substance known [10, 11] with a highly efficient absorption, η~0.999, in the VIS-FIR [12].

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