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The optimization of low cost integrated pyroelectric sensor arrays

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Abstract

A matrix formalism for optical and thermal waves has been developed to provide an efficient tool for the device modelling and optimization of layered pyroelectric sensor structures. The performance of integrated pyroelectric sensors can be improved by a reduction of the heat flow from the pyroelectric element to the silicon chip. This can be achieved by means of thermal insulation layers or thin etching of the silicon substrate. Both possibilities are simulated and discussed. The influence of unpolar surface layers in pyroelectric polymer films is taken into account. Integrated 8×1 arrays with a thermal insulation layer between the pyroelectric film and the silicon chip have been fabricated as demonstrators. The specific detectivity of these sensors achieves 2×10^7 cm Hz$^{1/2}$/W.

1. Introduction

Research on low cost infrared sensors has been stimulated in the last years by a wide variety of applications. Examples are spectrometers for the gas analysis, the automatic supervision of fabrication processes, especially in the chemical industry, or thermal imaging for fire detection and automatic fire fighting. Several methods for the integration of pyroelectric materials with silicon chips containing amplifiers and multiplexers are reported in the literature [1–3]. The thermal properties of silicon cause a significant drawback of the sensor performance of integrated pyroelectric sensors with respect to a freely suspended pyroelectric layer, however. Caused by its high heat conductivity and high heat capacity, a thick silicon chip acts as an effective heat sink at the interface to the pyroelectric layer. Possible measures for a reduction of heat loss from the pyroelectric element to the silicon chip are thermal insulation layers or thin etching of the silicon chip.

2. Theory

An integrated pyroelectric sensor consists of an absorber structure for the incident radiation, a pyroelectric element, which generates the electric signal, and an electric circuit for amplification and signal conditioning. Absorption, heat propagation, generation of the pyroelectric signal and the coupling of the electric signal to an electric circuit are essential to the sensor performance.

An integrated pyroelectric sensor with good performance cannot be constructed by assembling it from functionally separated modules, each one optimized for a specific task. In a well-designed sensor system these tasks are mixed, e.g., the pyroelectric layer is also acting as an essential component of the absorber structure [4]. Therefore, the modelling of a pyroelectric sensor must cover its optical, thermal and electric properties.

In general, a pyroelectric sensor is built up as a layered system. Many of the sensor properties can be understood and described using rather simple physical models. Particularly useful is the physics of waves, describing reflection, transmission, absorption and interference of electromagnetic and of thermal waves within the pyroelectric sensor system [5].

2.1. Modelling of sensor properties with a matrix method

Matrix theories are well appropriate for the numerical treatment of wave propagation in a multilayer system. A matrix theory for electromagnetic waves was given by Harbecke [6]. In this formalism the Fresnel formulae for transmission and reflection at each layer boundary and Beer's law of absorption within each layer are represented by a matrix. The propagation of the electromagnetic wave is described by a matrix product.

For the calculation of the signal output from a pyroelectric sensor, a matrix formalism for both the optical and the thermal waves, generated by optical

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