Characterization of Materials for Integrated Pyroelectric Sensors*

BERND PLOSS and SIEGFRIED BAUER

Institut für angewandte Physik der Universität (TH) Karlsruhe, Kaiserstrasse 12, 7500 Karlsruhe (F.R.G.)

Abstract

The pyroelectric element in an integrated IR sensor is usually in good thermal contact with the silicon chip. To characterize materials for these applications, heat sink figures of merit are introduced and various materials are compared. Integrated arrays with the materials poly(vinylidene fluoride) (PVDF) and $LiTaO_3$ are realized. The measured specific detectivity of arrays with 40 μm thick PVDF is $D^* = 1.4 \times 10^7$ cm $\sqrt{\text{Hz}}$/W.

1. Introduction

In general it is a complex task to select a pyroelectric material for a special application in a sensor. The thermal coupling to the surroundings and the electrical circuit arrangement interact with the physical parameters of the material, and the element size and the modulation frequency of the absorbed power must be taken into account. To perform a classification of different materials, it is common to consider figures of merit for a first evaluation of a pyroelectric material.

In single-element sensors it is possible to realize a weak thermal coupling between the sensor element and the surroundings. In this case the interesting modulation frequencies $\omega = 2\pi f$ are often higher than the reciprocal thermal time constant τ and higher than the reciprocal electrical time constant τ_{el}: $f > 1/(2\pi\tau), f > 1/(2\pi\tau_{el})$.

For these frequencies, the voltage figure of merit, F_V, characterizes a material in applications where the load capacity is small compared to the element capacity, the current figure of merit, F_I, describes an application with a high load capacity and the signal-to-noise figure of merit, F_D, is valid if the dielectric noise of the pyroelectric element is the dominating source of sensor noise [1].

Several methods for the integration of pyroelectric materials with silicon chips containing amplifiers and multiplexers are known in the literature [1–4]. A common feature of these methods is that the pyroelectric sensor material is in thermal contact with the chip, which acts as a heat sink. If different pyroelectric materials are to be compared for such applications, none of the known figures of merit is adequate, because they assume a free-bearing sensor.

2. Pyroelectric Materials

If a pyroelectric material is in good thermal contact with the silicon chip, the reciprocal thermal time constant $1/\tau$ is shifted to higher frequencies, and often the interesting modulation frequencies f are within the range $1/(2\pi\tau_{el}) < f < 1/(2\pi\tau)$. For many realizations of integrated pyroelectric sensors it is a good approach to assume a heat sink at one side of the pyroelectric material, due to the good heat conductivity of silicon compared to most pyroelectric materials. Assuming a heat sink at one side of the pyroelectric material and solving the heat conduction equation [5], the voltage sensitivity in the flat region between $1/(2\pi\tau_{el})$ and $1/(2\pi\tau)$ is given by

$$R_V = \frac{\eta d}{2(C_A + C_P)} \frac{p}{\kappa} \qquad (1)$$

*Dedicated to Professor Dr K. H. Härdtl on the occasion of his 60th birthday.

0924-4247/91/$3.50