Interference Effects of Thermal Waves and their Application to Bolometers and Pyroelectric Detectors*

SIEGFRIED BAUER and BERND PLOSS
Institut für angewandte Physik der Universität (TH) Karlsruhe, Kaiserstrasse 12, 7500 Karlsruhe (F.R.G.)

Abstract

Thermal waves are generated via the absorption of intensity-modulated infrared radiation at the front surface of a 25 μm thick pyroelectric poly(vinylidene fluoride) (PVDF) film. The amplitude of the transient surface temperature of the film is measured with a thin-film bolometer and the average temperature of the film via the pyroelectric effect. Two cases are compared: a free-bearing film and a film which is coupled to a heat sink at the rear surface. Using the concept of the interference of thermal waves, it is shown that for a material with thickness d and thermal diffusivity D, the surface temperature of the film coupled to the heat sink exceeds that of the free-bearing film within the frequency range $\pi D/16d^2 < f < 9\pi D/16d^2$; for the average temperature the frequency range is $\pi D/4d^2 < f < 9\pi D/4d^2$, in full agreement with the experiment. The interference of thermal waves thus has an application in infrared sensors. In the given modulation frequency ranges, the sensitivity of the sensors on the heat sink exceeds the sensitivity of free-bearing sensors of the same construction.

1. Introduction

For the characterization of pyroelectric materials for use in infrared sensor applications, an experimental arrangement which enables the specific heat, the thermal conductivity, the dielectric constant and the pyroelectric coefficient to be measured simultaneously on the same sample is of interest. Recently, a combination of a thin-film bolometer with negligible thermal capacity on a pyroelectric detector was introduced. With a combination of several well-known experimental techniques, it is possible to characterize the pyroelectric material completely with only one sample and within one temperature scan [1].

This arrangement is especially useful for the study of the pyroelectric response of pyroelectric materials on substrates, as is common in infrared sensor designs [2]. In the following paper, two important cases are compared: the free-bearing mounted sensor and the sensor fitted to a heat sink with its rear surface. The unexpected signal amplitudes revealed are explained by the interference of thermal waves.

2. Experimental Arrangement and Results

2.1. Experimental Arrangement

A detailed description of the experimental arrangement is reported elsewhere [1]. The samples are 25 μm thick poly(vinylidene fluoride) (PVDF) films from Solvay. The films are metallized with structured electrodes, consisting of a 30 nm thick aluminum film covered with a 15 nm thick bismuth film. The thermal excitation of the film is performed via the absorption of intensity-modulated light within the sample electrode. A laser diode with 856 nm wavelength is used as the light source. The intensity of the light diode is varied as $j = j_0 + j_\sim \cos(\omega t)$ with $j_\sim \approx j_0$ and $\omega = 2\pi f$, where f denotes the modulation frequency. The temperature increase ΔT in the film is given by $\Delta T = \Delta T_0(x) + \Delta T_\sim(x, t)$, with $\Delta T_0(x)$ the stationary time-

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

0924-4247/91/$3.50