Appl. Phys. B 54, 544–551 (1992)

Applied Physics B Photophysics and Laser Chemistry

The Physics of Pyroelectric Infrared Devices

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Received in revised form 23 December 1991/Accepted 20 February 1992

Abstract. The absorption of radiation with pyroelectric detectors and the thermal properties of these devices are discussed using a simple physical picture – the physics of waves. Considered are the reflection, transmission and interference of electromagnetic and of thermal waves within the pyroelectric sensor arrangement. In particular, thin metal films, quarter wavelength structures, and anti-reflection coatings on metal films as absorber structures are discussed. The effect of the substrate on the pyroelectric response is treated and new figures of merit are introduced for the comparison of sensor materials which are mounted on a heat sink.

PACS: 07.62.+s, 85.50.Ly

A pyroelectric radiation detector consists of a pyroelectric element, covered by two metal electrodes and, in general, a radiation absorbing layer on top of the sensor and a substrate at the back of the sensor, as shown schematically in Fig. 1. The sensor element is heated by the absorption of intensity modulated light. This causes a temperature increase of the pyroelectric film, which is detected either as a voltage or as a current signal.

For a pyroelectric sensor element having an absorber structure and a substrate with thermal capacities negligible compared to that of the pyroelectric layer, the pyroelectric current is given by [1]:

$$I_\sim = \frac{\eta j_\sim A p}{c \varrho d} \tag{1}$$

with:

η : absorption
$j_\sim$: incident intensity of the modulated light
A : sensor area
p : pyroelectric constant
c : specific heat
ϱ : density
d : thickness of pyroelectric element

independent of the modulation frequency. However, in the case of an absorber structure and a substrate with thermal capacities comparable to that of the pyroelectric element, the calculations become more difficult, as now not only the pyroelectric element is heated by the incident radiation, but also the whole multilayer structure of Fig. 1. If the incident radiation is not absorbed solely by the absorber structure, it is necessary to take into account the optical properties of the complete multilayer of Fig. 1. As the thermal properties of each layer are also different, it seems to be a difficult task to calculate the temperature increase within the multilayer.

While the general features of pyroelectric detectors can be found in the review article of Whatmore [2], the idea of this theoretical paper is a simple discussion of the optical and thermal effects that enter into the response of the device. For this purpose a simple physical picture is used – well known in the field of photoacoustics [3] – the physics of electromagnetic and thermal waves and their reflection, transmission, and interference within the multilayer of Fig. 1.

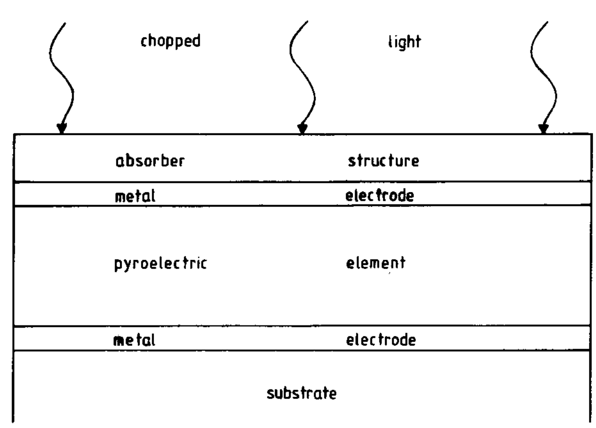

Fig. 1. Schematic view of a pyroelectric sensor element. The sensor consists of the pyroelectric element, covered by two electrodes, of an absorber structure, and a substrate