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Determination of thermal effusivity of solids by a photoacoustic scanning technique

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Abstract. A new method is proposed to determine the thermal effusivity of solid samples using a one dimensional photoacoustic scanning technique. The method employs a sample configuration in which the backing for a good light absorber layer is changed from a reference sample to the unknown sample by scanning the absorber surface with an incident modulated light beam. From the measured phase difference or amplitude ratio one can determine the thermal effusivity of the unknown sample, knowing the effusivity of the reference sample. The Rosencwaig–Gersho theory of photoacoustic effect has been extended to the present experimental situation and expressions have been derived for photoacousitc phase difference and amplitude ratio as the backing is changed. Values calculated using these expressions are found to agree well with measured values for different sample combinations except in amplitude ratio values when the thermal effusivities of the samples differ very widely. The reason for this disagreement is discussed.

Keywords. Photoacoustic effect; thermal effusivity; scanning technique.

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1. Introduction

The photoacoustic (PA) technique has emerged as a very powerful technique to study optical and thermal properties of solid samples [1]. It is now the best alternative analytical technique for samples in which conventional absorption spectroscopic techniques often fail. The technique has proved its power over a very wide variety of samples ranging from human blood to superlattices. A number of review articles have appeared in literature on this subject [1–3]. Since the amplitude and phase of the PA signal ultimately depend upon material parameters such as optical absorption coefficient, thermal conductivity, heat capacity and density, it has proved its ability to detect and measure thermodynamic changes such as phase transitions in solids [4]. In photoacoustic effect, since optically generated thermal waves propagate through the sample causing pressure variations in the surrounding gas medium, it finds application in thermal wave depth profiling, microscopy and nondestructive testing of materials [5–7].

A number of papers have appeared in literature on the determination of thermal parameters such as thermal diffusivity (α) and effusivity (e) of solid samples using PA technique. Measurement of thermal diffusivity and effusivity lead to the determination of thermal conductivity (k) and heat capacity (C). The PA technique belongs to the category