A simple approach to introduce photothermal techniques basic principles for thermal diffusivity measurement

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Abstract

We report an approach to introduce the students to the field of the photothermal techniques. For this, we describe an experiment about the measurement of the periodical oscillations of the temperature in a body heated with a periodic heat source. These thermal oscillations can be called thermal waves. We show how, by means of the measurement of the phase difference and attenuation of the thermal waves with the penetration distance in the body, we can determine their thermal diffusivity. This is a result in which some of the photothermal techniques are based for applications related with the thermal characterization of materials. In particular we use the technique of pyroelectric detection to show this purpose.

Keywords: Photothermal, thermal diffusivity, heat, temperature.

Resumen

Presentamos una forma de introducir a los estudiantes en la temática de las técnicas fototérmicas, para lo cual describimos un experimento sobre la medición de las oscilaciones periódicas de la temperatura de un cuerpo calentado con una fuente de calor periódica variante en el tiempo. Estas oscilaciones de temperatura pueden denominarse ondas térmicas. Mostramos como, a partir de la medición de la diferencia de fase y la atenuación de estas ondas térmicas con la distancia de penetración en el cuerpo, podemos determinar su difusividad térmica. Este es un resultado en el cual se basan algunas de las técnicas fototérmicas para aplicaciones relacionadas con la caracterización térmica de los materiales. En particular, utilizamos la técnica de detección piroeléctrica para mostrar este propósito.

Palabras clave: Fototermal, difusitividad termal, calor, temperatura.

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I. INTRODUCTION

The photothermal (PT) techniques [1] are a group of experimental methods based in a common principle of heating a sample with periodical (harmonic) or pulsed radiation (often visible light) and on measuring directly or indirectly the induced temperature changes. These are related with characteristic sample's properties that can be recovered by designing a proper experiment. Among these properties, we should mention the sample's absorption coefficient at the impinging radiation wavelength [2], the parameters involved in the incident radiation energy into heat conversion process (for example the quantum efficiency of this process) [3, 4], and thermal properties such as the thermal diffusivity, α [5], and the thermal effusivity, ε [6, 7]. One of the most important fields of applications of the PT techniques is the thermal characterization of materials. Among the mentioned parameters, the thermal diffusivity is the most widely studied using PT approaches, and several experimental configurations have been designed for its determination [8, 9, 10]. In the last years we have witnessed the widespread and routine use of the PT techniques for this purpose in many research laboratories worldwide. Thus, we think that it is necessary the familiarization of physics students and teachers in high-schools, colleges and universities with their basic principles and related phenomena, in the same way as they familiarize with other more traditional instruments, which they can use to look inside their surrounding world.

In this article we will show how an inexpensive and simple experiment can be useful to introduce the students, in a straightforward way, to the basic principles of the PT techniques for thermal diffusivity measurement in materials.