Temperature Dependence of Thermal Diffusivity Measured by Photothermal Radiometry

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Thermal diffusivity is generally measured by impulse or modulated flux methods; the temperature distribution inside the sample is measured by thermocouples. The nonintrusive photothermal techniques do not induce geometrical or thermal changes inside the sample; an indirect procedure gives the temperature variations on the sample surface. Photothermal radiometry, based on the measurement of the radiative flux emitted by the sample, is all the more accurate as the temperature is elevated. We have used this method to measure thermal diffusivities of thin and opaque solid samples at temperatures above 400 K. The temperature field is calculated by using a standard model accounting for the emitted radiative flux. The experimental apparatus is briefly described and experimental results for selected materials (nickel, stainless steel) and cast-iron samples are presented. The influence of the material structure on the thermal diffusivity is discussed.

KEY WORDS: cast iron; photothermal technique; radiometry; thermal diffusivity.

1. INTRODUCTION

The ability of photothermal technique to detect surface temperature variations in a noncontact manner has made this method of great interest for the measurement of thermal or mechanical properties of materials [1]. A great variety of photothermal techniques, which differ in the probing system, has been applied to thermal diffusivity measurements over the last few years: photoacoustic [1–5], photodeflection [5, 6], mirage effect [5, 7–12], and radiometry [13–16].

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Photothermal radiometry (PTR) uses the detection of thermal radiation emitted by a sample heated by optical means. Cowan [17] and Wheeler [18] had to perform measurements at high temperatures because of the limitation of the detection system they used, which consisted of phototubes. Low-temperature measurements are, nevertheless, possible today due to the development of infrared detectors.

This paper deals with a method for the determination of the thermal diffusivity of thin solid samples above 400 K by photothermal radiometry. The theoretical model is presented in Section 2. The experimental setup is briefly described in Section 3. Experimental results for selected materials (nickel, stainless steel) and some specific cast-iron samples are presented and discussed in Section 4.

2. THEORY

2.1. Presentation of the Model

The model used for the calculation of the temperature distribution is the piston model presented by Rosencwaig and Gersho [2, 19]. Nevertheless, for this application, the thermal radiation emitted by the sample has been taken into account. The bases of this model are the following.

(a) The sample (s) of thickness $l_s$ is front illuminated by electromagnetic radiation, modulated at frequency $f = \omega/2\pi$ (Fig. 1). The

![Fig. 1. Schematic diagram of the photothermal cell. g, gas; s, sample; b, back.](image-url)