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Absolute measurements of thermal effusivity using the electropyroelectric technique

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ABSTRACT

The so-called electropyroelectric technique uses amplitude modulated electrical current as excitation source of thermal waves in a pyroelectric sensor in contact with a liquid sample. Here it is showed that this technique allows absolute measurements of the thermal effusivity using the quotient of the signal amplitudes obtained from the inverse and the direct configurations. In this way the influence on the experimental results of the frequency dependent instrumental transfer function can be straightforwardly eliminated. Measurements performed in various test liquid samples are presented that demonstrate the good accuracy and usefulness of the method.

1. Introduction

In a recent published paper [1] the so-called electropyroelectric (EPE) technique for thermal effusivity measurements in liquids is described. The main idea behind this method is the use of amplitude modulated electrical current flowing through the metal contact at one side of the pyroelectric (PE) sensor as the source of oscillatory heat flux via Joule effect, instead of the modulated laser beam widely used in the well known photopyroelectric (PPE) method [2]. That last method has been recognized as a reliable tool for the measurement of the thermal properties of condensed matter samples and the EPE technique is inspired in its principles. Two EPE measurement configurations have been proposed, namely one with the heat source located at the metallic coating of the pyroelectric opposite to that in contact with the sample, the so-called inverse EPE (*i*-EPE) variant, and another in which it is situated in the electrical contact between the sensor and the sample, which was denoted as the direct EPE (*d*-EPE) configuration. Due to the use of electrical heating, the PE signal independence on the optical opaqueness or transparency of the sample and the sensor becomes an advantage of the method. It has been demonstrated [1] that both configurations are suitable for precise thermal effusivity determination with measurement uncertainties of about 3%. However, the need of a data normalization procedure using a test sample of well known thermal properties to account for the instrumental transfer function becomes a handicap of the technique, because this methodology involves the systematic placing and replacing of both the investigated and the test sample in order to obtain accurate results. As measurements of the EPE signal are performed as a function of the electrical current modulation frequency, *f*, this transfer function includes the frequency response of the experimental system's electronics, which is in general not well known. Thus, although other configurations for measurements without previous calibration could be considered (for example using a second PE sensor in front of the sample, as discussed by Pereira et al. [3] in the framework of the PPE technique), in this paper we propose a method for absolute determination of the thermal effusivity using the ratio of the signal amplitudes resulting from both, the front and the rear configurations, without the need of a reference sample. This methodology is not useful using the conventional PPE technique, because in the configuration equivalent to our direct, a laser beam which heats the PE surface in contact with the sample is weakened by the optical absorption of the sample. This fact introduces an unknown difference in the light energy absorbed by both surfaces. The proposed method will be tested by measurements performed in samples of well known thermal properties showing a good agreement.

This paper will be organized as follows: in the next section we will briefly remember the fundamental theoretical aspects behind

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