Development and Characterization of Optical Sensors Based on Evanescent Wave and Photoacoustic Detection

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Introduction

The photoacoustic (PA) effect in solids has recently been used to study the optical properties of bulk, surface and subsurface structure[1]. In conventional photoacoustic technique the sample is placed in an enclosed gas-filled cell and illuminated with a modulated light beam. The thermal waves produced by optical absorption generate a pressure variation in the gas, which is then detected by a sensitive microphone or piezoelectric transducer. The greatest potential for photoacoustic lies in the field of solid and absorbing film, because most of these materials are in the form that made them difficult to study by using conventional optical transmission technique[2]. In photoacoustic technique, the microphone detection system is mounted away from the sample, thus allows a non-invasive study to be carried out. In this study we have used both microphone and piezoelectric detection system[3].

Materials and Methods

The sample was illuminated at one side with a periodically chopped Argon-laser (Omichrome-500mWatt). The photoacoustic signals (amplitude and phase) as a function of the modulation frequency detected by a sensitive microphone and piezoelectric transducer were processed by Lock-in amplifier (SR530-Stanford Research System). All photoacoustic measurements were performed at room temperature with a frequency range of (10 – 200)Hz.

Results and Discussion

The experiments were made for pure metals; Au, Ag, Al, Zn, Cu, Sn, polymer; (ENR25, ENR50), Semiconductor (Si); gold alloys and superconducting materials[4,5,6]. Our results for pure metals and semiconductor are in a good agreement with the value obtained by other methods reported by previous researchers. Photoacoustic effect has also been used for characterizing the liquid samples. For the present work, this technique has been used for monitoring the evaporation rate of solvents and thermal diffusivity of palm oil, fuel and chitoson[7,]. A study of photobleaching of dye molecule in PMMA matrix has also been carried out using the developed photoacoustic technique. The details of the findings are listed in our publications.

Conclusions

The photoacoustic technique provides rapid and detailed analysis using small quantity of solid/liquid samples with a minimum of sample preparation. Thus the technique is faster, more cost-effective, and safer than many of it alternatives.

Benefits from the study

A very sensitive method has been developed for characterizing the optical and thermal properties of solid and liquid samples that cannot be measured by using conventional methods such as a optical transmission and reflection techniques. It has been proven to work equally well for transparent and opaque samples. The absorption coefficient and thermal diffusivity can be measured up to $10^{-6}cm^{-1}$ and 10^{-3} cm^2/s respectively. The method is nondestructive, simple in its construction and operation and offers a fast and easy measurement with high precision. The measurements in various categories of samples have been carried out using this technique.

Depending on specific system design, PA has numerous applications for commercialization such as environmental monitoring system, monitoring production process, determining chemical concentration, testing and evaluating of food additive. In this respect, the photoacoustic measurement scheme can be tailored into meeting specific needs of biophysical and biochemical researches, and also industrial processes. The work we have pioneered on characterizing metals, alloys, superconducting ceramic, palm oils, engine oils, doped PMMA, conducting polymer (polyaniline), has proved that the PA is a powerful tool for characterizing various materials. In addition, this technique has a very promising future in the development of optical gas sensor based on IR absorption in gas media, as well as microscopic study of gas mixtures.

In summary, the photoacoustic techniques developed in this project are:

Versatile technique capability- The photoacoustic technique can provide quick semi-quantitative results or more accurate quantitative results; faster and more efficient- elimination of sample preparation steps cuts time requred for individual analysis so that more samples can be analysed in a given time period; smaller sample size/quantity required- as compared to gram-size sample required by other techniques, the photoacoustic needs only a milligram-size sample to run a analysis, further reducing worker/researcher exposure to hazardous materials; more cost-effective, - the photoacoustic technique save money by reducing labor cost of time-consuming; and reduced waste- no secondary waste is created during sample preparation or analysis.

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