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Photoacoustic cell with black absorber as a detector for spectrophotometric studies

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Abstract. The PAS cell with carbon black absorber is used as a detector for spectrophotometry in an open room. This has immense potential of obtaining absorption speciation information from remote samples.

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Photoacoustic spectroscopy (PAS), essentially monitoring the thermal effects following nonradiative relaxation of an optically excited medium, is shown [1] to be a powerful tool to investigate the optical and thermal properties of the substances. It has many distinct features compared to normal absorption spectroscopy, such as depth profiling, ability to elucidate information from opaque samples etc. The most distinctive feature, however, is that the sample itself acts as the primary detector of the absorption process, to the extent that the sensitivity of detector does not depend on the excitation wavelength per se. In PAS, carbon black loaded in PAS cell, is normally used for monitoring the emission profile of the source. This information is used to normalize the PAS spectra. PAS has been found to have many applications in various areas of solid state physics [2]. Manfred Low [3, 4] has conducted extensive experiments for the adaptability of PAS to various applications in IR region. We have found yet another application of PAS technique to spectrophotometry of highly toxic samples. In this short communication it is shown that carbon black loaded PAS cell can be used as a very effective detector for obtaining absorption spectra. It is shown that one can get an absorption spectrum comparable to that of a commercial Beckmann spectrophotometer. The 'carbon black PAS' (CB-PAS) detection has the advantage of getting absorption spectra for samples kept in an open room. To the best of our knowledge this is the first report of this simple technique applied for obtaining 'conventional absorption spectra' and singularly useful for speciation of radiotoxic actinides in nuclear waste materials directly [5, 6] from not easily accessible regions (such as glove boxes with radiotoxic or any other toxic substances).

The measurements were carried out using PC coupled home built PAS unit described elsewhere [7, 8]. The block diagram is shown in figure 1. The PAS spectrum of carbon

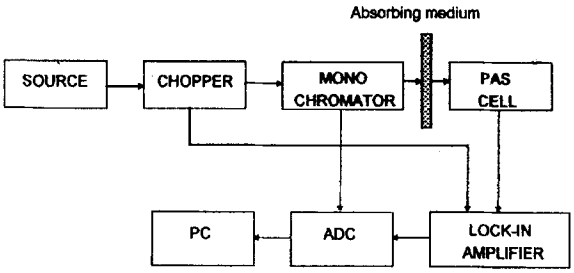

Figure 1. Block diagram of the PAS unit built in our laboratory. Absorbing medium is in the optical path and PAS cell is loaded with carbon black. This set up gives conventional absorption spectrum. If PAS cell is loaded with the sample with no absorbing medium in the optical path, PA spectrum of the sample can be obtained.

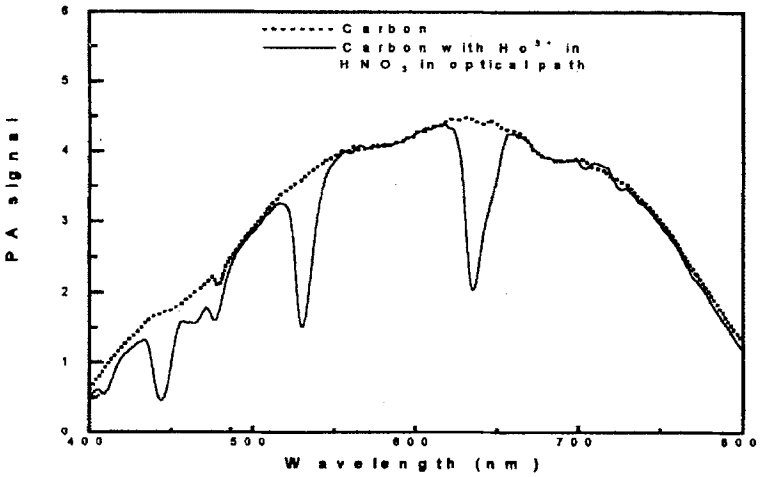

Figure 2. PA spectrum of carbon black with and without Ho^{3+} in HNO_3 in the optical path.

black with and without Ho^{3+} in HNO_3 in the optical path is shown in figure 2. Since carbon is a strong and uniform absorber of radiation throughout the spectral visible region viz. 400–750 nm, the optical absorption in any medium shows up as changes in the broad PA signal of carbon black. Since the PA signal from microphone was recovered using lock-in detection, the absorption spectral information can be obtained in an open room, the only condition being that the chopped optical beam should pass through the 'absorption cell' before entering the PA cell. The final analogue PA signal obtained from the lock-in-amplifier resembles the absorption spectrum of the sample but for the sign of the signal. The absorption spectrum of the sample in the standard form was obtained after further processing of the analogue signal with the personal computer with software developed in quick basic (QB) ver. 4.5 environment for data acquisition and converting the transmission spectrum to that of absorption. The corrected spectrum of Ho^{3+} solution obtained with CB-PAS detector and that of absorption spectrum of Ho^{3+} solution on Beckmann spectrophotometer

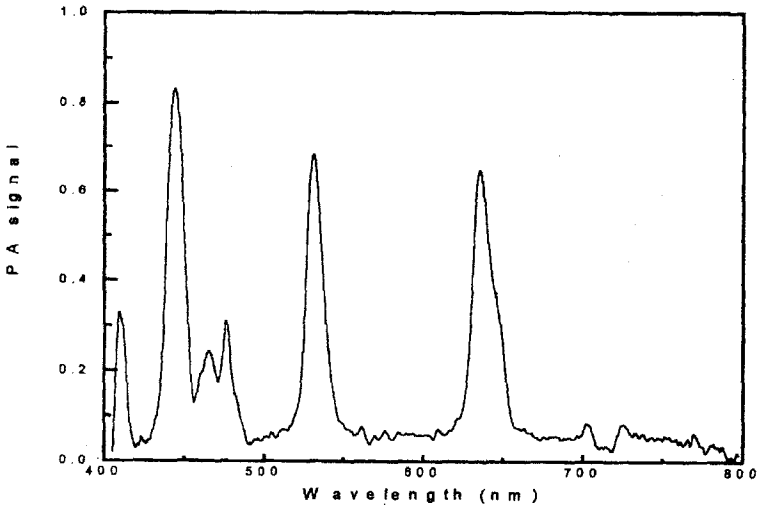

Figure 3a. Normalized and corrected spectrum for the optical absorption of the samples. The raw data is shown in figure 2.

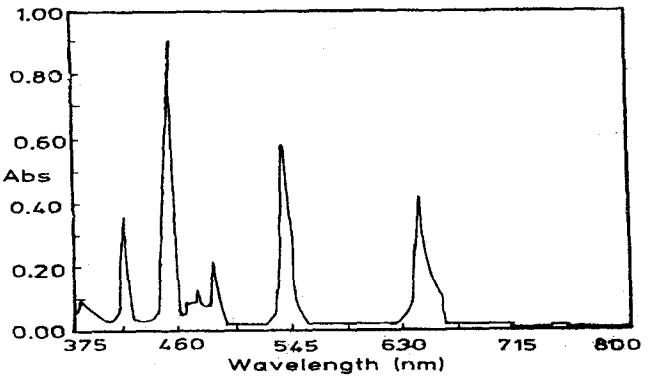

Figure 3b. Absorption spectrum obtained for the same sample (Ho^{3+} in HNO_3 using Beckmann spectrophotometer).

are shown in figures 3(a) and 3(b) respectively. The essential features of the spectra are identical. The relative intensities however, are found to be slightly different. A low dispersion 1/4 M monochromator was used in our PAS set up with slit width 1mm (2.5nm/mm). Furthermore, the source profile (see figure 2) has maximum at 650 nm and in the lower wavelength side the intensity falls off rapidly. Even slight error in the normalization can cause large variation in the relative intensities in that region. This would not be a serious problem if a "flat" and intense source is used in the experiments. Satisfactory agreement between these two spectra proves the potentiality of carbon black PAS (CB-PAS) technique as a detector for spectrophotometry. The main advantage of this technique is that it can be used to obtain the spectra of samples kept in an open and lighted room and also from the inaccessible remote regions using laser beam. The absorption spectra of radioactive substances can also be obtained using optical fibres. In such cases the optical fibres are in

radioactive field for very long times and their optical quality can get degraded due to radiation damage. It is not uncommon to send a laser beam (in visible region) from one room to the other without significant attenuation. Such experimental configuration can be used in the present set up. For CB-PA cell detector described in this paper, such problems will not be encountered. Furthermore, in CB-PAS the signal intensity is directly proportional to the intensity of the exciting light source but does not depend on the wavelength as in case in conventional light detectors. Therefore this technique has immense advantage to monitor the absorption spectra of highly radiotoxic materials.

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