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A photothermal 'mirage' imaging system

C.A. Hall and A.W. Williams

Department of Physics, University College Swansea, University of Wales, Swansea SA2 8PP, U.K.

Abstract We describe a scanning mirage microscope system that uses a diode probe laser. The sample is raster scanned using X-Y motorised microstepping stages under an Ar⁺ pump beam to give two dimensional scans and depth profiles. The results for a test sample are given and are compared to that obtained by scanning using a conventional large photoacoustic (PA) cell.

1. INTRODUCTION

Photothermal beam deflection microscopy or 'mirage' [1] has been effective in the field of non-destructive evaluation [2],[3], measurements of thermal diffusivities of solids [3],[4] and for photothermal spectroscopy [5]. Conventional 'mirage' systems usually probe at a single point or carry out line scans of a sample. In the present experiment, a 3D scan of the sample is possible.

2. EXPERIMENTAL APPARATUS AND METHOD

Fig.1 shows a block diagram of the experimental arrangement. A single mode, 488nm Ar⁺ laser (Spectra-Physics 2016) provides the pump beam, which is defocused, steered into a metallurgical microscope and focused down onto the sample surface. The photothermal detection system uses a diode laser probe beam (Uniphase 3501) whose output is gaussian and single mode at 670nm. A lens arrangement focuses the probe beam into the Refractive Index Gradient (RIG) in the air near to the heating pump beam using a microscope objective lens arrangement. The probe beams deflection on passing through the RIG is measured by a 2D position sensitive detector (Hamamatsu S2044) whose signal outputs are amplified and converted into a normal and transverse deflection signal. These signals together with the associated phases relative to the modulator, are recorded by two lock-in amplifiers and a computer interface.

The sample which is mounted on a micropositioning Z, ϕ , θ stage and an X-Y microstepping computer controlled stage, allows any reasonably flat sample to be moved in a raster scan with a minimum step size of 0.1 μ m. The pump beam is focused to a 50 μ m diameter spot on the sample while the probe beam diameter is 25 μ m at the RIG. A sodium lamp source provides illumination of the sample surface, which may be viewed or photographed through the microscope eyepiece. An edge filter (OG570) placed in the reflected light path, protects the observer from scattered laser light. The deflections of the probe beam allows sub-surface scanning over a selected area due to changes in the thermo-optical properties of the sample.

3. RESULTS

A prepared sample was used to test both the system sensitivity and its depth probing capability. Fig.2 shows a vertical cross-section through the sample which consisted of two plates, one copper, 2.75mm wide, one brass, 2.50mm wide both 300 μ m thick and 17mm long separated by a distance of 3.70mm set in epoxy resin at a small angle to the surface. The sample was scanned by using both the mirage and photoacoustic (PA) cell methods, at a fixed modulation frequency of 16Hz. The inclined plates allowed measurement of the depth resolution of the system. The PA scans served as a comparison for the same sample conditions. A 2D raster scan was performed by stepping 250 steps in the X direction and 67 steps in the Y direction. In the X and Y direction 1 step corresponded to 50 μ m.

2D and 3D plots of the signal and phase are shown for the transverse mirage deflection in figures (3,4) while figures (5,6) show the signal and phase for the PA cell. The signal decreases when crossing the copper and the brass plates, since the thermal reflection coefficients for epoxy/copper and epoxy/brass are -0.97 and -0.94 respectively. This leads to a minimum in the surface temperature above the plates and thus a minimum in the probe beam deflection. This is in direct comparison with the minimum signal from the PA cell.

The two plates are clearly visible, the signal and phase magnitude decreasing along the plates in the Y direction as the epoxy depth increases. It was also noted that the phase was more sensitive in both techniques and could detect the plates about 1.47 times deeper than the PA and transverse mirage signals. These results agree with those of Busse and Rosencwaig [6] who quoted a 1.5 times increase in depth sensitivity. The graphs show that even for relatively large samples where it is difficult to focus the probe beam close to the surface, the mirage method still gives similar sensitivities to the traditional PA method.

The results show that the mirage effect can be used for 2D scanning and is extremely sensitive to sub-surface features. A x40 microscope objective gave an optical resolution of 5 μ m that is considerably better than has been previously reported. By changing the frequency 3D scanning should also be possible. Further tests are being carried out on semiconductor circuits.

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Experimental and Data Acquisition System
MIRAGE SETUP