PHOTOACOUSTIC EVALUATION OF GREEN STATE ALUMINA SAMPLES

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INTRODUCTION

Material characterization and testing of construction ceramics without destruction of the sample is needed to ensure the quality of ceramic products. In the most demanding applications testing of every product would be needed, therefore we are seeking a method which would be both fast and reliable. We have tested a method to characterize the defects in green state alumina where the process is based on the generation of ultrasonic waves by a focused pulse laser. The generated nanosecond scale pulse is used to measure the transit time between the generation volume and the ultrasonic detector and the time is used to calculate the relative density change.

BACKGROUND

The characteristics of the generation of acoustic waves in solid surfaces by a pulsed light source are well known [1]. These short pulses have been used in various NDE applications involving coatings and the detection of cracks in bulk materials [2, 3, 4]. The generation efficiencies are fairly high, up to 30% when the laser pulse causes material ablation, therefore easy detection of the acoustic pulse is insured even through highly attenuating materials such as nonsintered ceramics. The very high slew rate of the pulses makes accurate timing measurements easy, and the transit time measurement accuracy is mainly limited by the measurement equipment's time resolution.

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In the thermoelastic regime, below a laser intensity of 1 MW/cm^2 the acoustic pulse consists of a longitudinal and a transversal step if viewed directly below the epicenter [5]. In these conditions the generation efficiency is about 10^{-4}%. The signal from the ultrasonic transducer now consists of two pulses, both looking very much like the transducer's step response. Since the waveform is well defined it can easily be used in timing measurements, and both the transversal and the longitudinal sound velocity can be calculated. Because the time resolution, sample dimensions, and sound velocity are known the corresponding speed measurement accuracy and overall density difference measurement accuracy can be calculated [6].

EXPERIMENTAL PROCEDURES

The measurement setup as shown in Fig. 1 consists of a computer controlled translation stage, a 100mJ, 30 ns FWHM NdYAG pulse laser, and a digitizing oscilloscope. The waveform is transferred to the computer and the transit time is calculated using a constant fraction algorithm. The measurement is repeated 10 times at every measurement position of the line scan. If the signal is too noisy or the algorithm fails, the measurement program is capable of discarding bad points by comparing the result to given limits. The time resolution achieved was better than 10 ns. The acoustic contact material used between the transducer and the sample was a plastic adhesive tape with the glue against the sample which ensured small enough transmission loss to make the measurement possible.

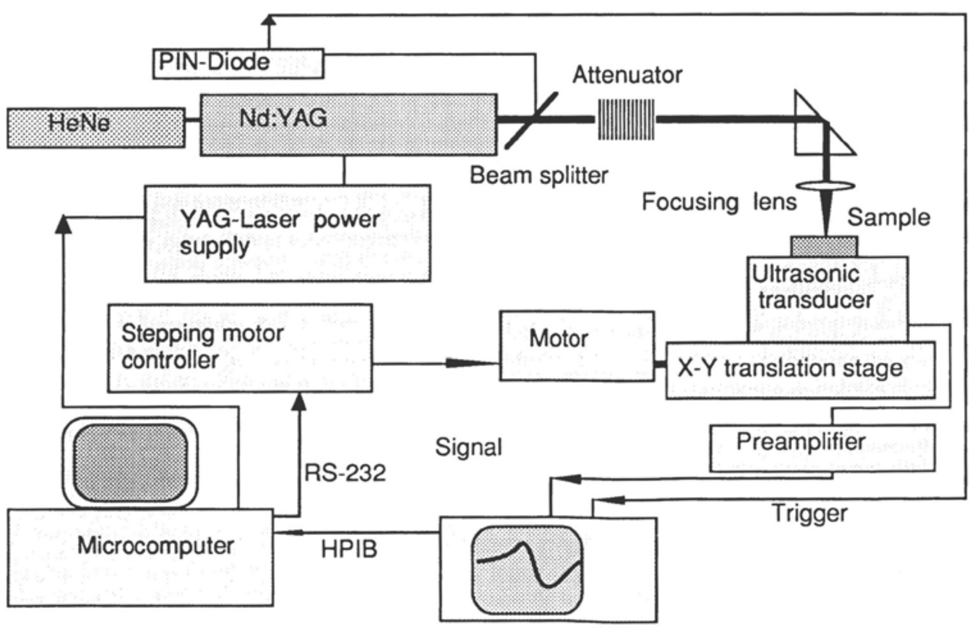


Fig. 1. Photoacoustic measurement setup.

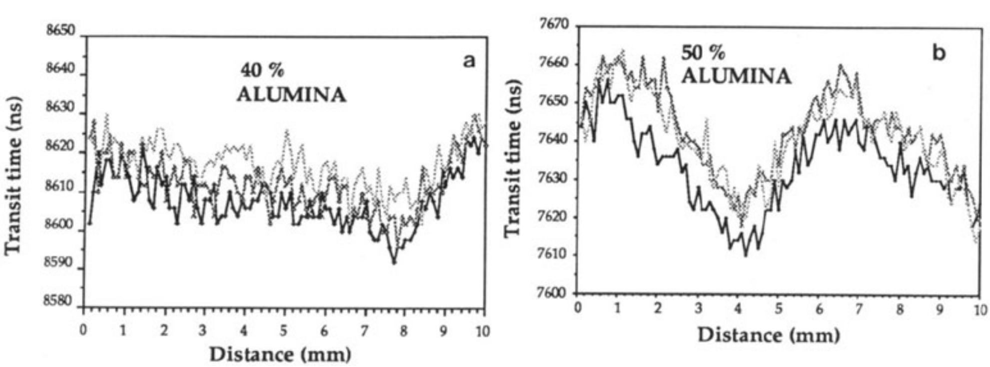
EXPERIMENTAL RESULTS AND DISCUSSION

A set of alumina/polyethylene samples containing various amounts of alumina were studied. The samples represent green state ceramics and our intention was to determine if the distribution of alumina was even throughout the sample. The samples were 10 mm thick and 50 mm long alumina/polyethylene rods with smooth, flat surfaces.

In Figures 2a and 2b we show two typical transit time line profiles with three repeated measurements. The sample surfaces were flat and parallel. In both figures the noise is due to the surface structure. The sample in Fig. 2a contained 40% alumina by volume. The curves in Fig. 2a have only slight variations if the noise is not considered. In Fig. 2b the sample was 50% alumina and far wider variations in the transit time profiles are seen. This is due to an overall peak to peak density variation of about (0.8±0.1) kg/m^3 along the path from the generation spot to the transducer surface.

Table 1. Sound velocities and corresponding acoustic measurement accuracies.

Alumina content %	Sound velocity (m/s)	Velocity difference accuracy (m/s)	Density kg/m^3	Density difference accuracy kg/m^3
20	1820	3	1520	0.1
30	1870	4	1720	0.2
40	1960	4	2090	0.2
50	2070	4	2410	0.2
60	2340	5	2660	0.2



Figs. 2a and 2b. Transit time profiles.

CONCLUSIONS

The main advantage of the photoacoustic method is that the sample does not have to be immersed into water or other liquids which would have an adverse effect on resolution due to the liquid penetrating into porous samples. The light can also be brought to the surface of a sample where an ultrasonic transducer would be too bulky or where the geometry of the sample is too complicated. Our results show that the time delay measurement gives useable data on material parameters but further development is needed. Our next step is to develop a more efficient measurement setup which is capable of measuring more parameters from the acquired acoustic waveform, including the rise time and spectra.

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