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Photoacoustic Spectroscopic Imaging System with Multi-wavelengths LD and LED Optical Source

多波長 LD / LED による光音響分光イメージングシステム

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1. Introduction

In photoacoustic (PA) imaging system, monochromatic light soureces have dominantly used until now. However, imaging of spectroscopic objects such as dry chemicals[1] or pollen[2], with a photoacoustic microscope (PAM), various information can be obtained including defth profiling including spectroscopic information. Correlation photoacoustic spectroscopy (PAS) is one of the powerful application of spectroscopic measurement using a PAM.[3] Furthermore, differential absorption and subtraction technique can remove noise. In this paper, basic experimental foundation to design a PA imaging system with multiple wavelengths was established by measuring correlations between PA signal amplitude versus optical reflectivity of the solid specimens, Furthermore, the design and fabrication of the multiple wavelengths (13 wavelengths in visible region) PAM system was reported.

2. Experimental Apparatus and Specimen

The basic experimental setup is shown in **Fig. 1**. In this experiment, individual LEDs and LDs were used, the wavelengths of which are in four wavelength in the visible spectrum; LD (406nm, 532nm, 660nm), LED (470nm, 525nm, 590nm, 625nm). Modulation was performed with a function generator (NF Circuit Block, DF1906), and a diode laser current controller (Thorlab, LDC210C). The LD or LED light was focused by a microscope objective.

As a solid state specimens, an aluminum plate covered with color paints were prepared, and the optical reflectivity of the specimens at the corresponding wavelengths was previously measured with a conventional spectrometer (Shimadzu, UV-2500) and an integration sphere.

Scanning of specimens was achieved by linear-motor slide stages.

The generated PA signal was detected by a high-sensitive condenser-microphone (Brewer-Kaejer 4166) and a lock-in amplifier (NF Circuit block, LI-5160B). Phase-sensitive detected a amplitude and phase signals were transferred to PC via GP-IB interface, and were constructed by amplitude and phase images.

After the integration of the PA images over the specimen surface, the integrated or averaged PA signals were compared with the amount of the optical absorption (A=1-R) data calculated from the optical reflectivity (R) of the specimens at the respective excitation wavelengths (660nm , 532nm, and 406nm for LD, and 625nm, 590nm, 525nm, and 470nm for LEDs).

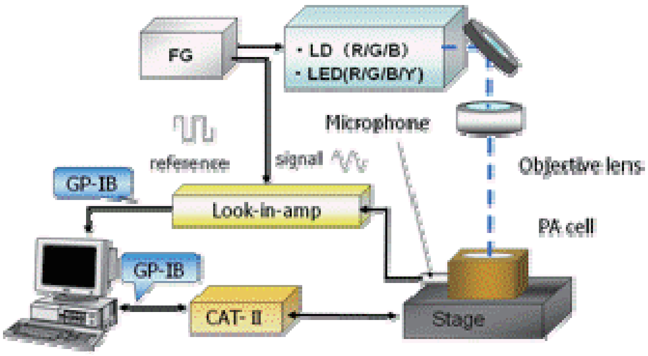

Fig. 1 Experimental setup

3. Experimental Results and Discussions

Specimen surface for each color paint was covered with enough thickness so that the generated PA signal is regarded to be proportional to the amount of the heat generated at each excitation.

PA amplitude images obtained for green and red color paints excited by a red LED (625nm) were shown in upper and lower images in **Fig. 2** (a) and (b), respectively. As predicted naturally, the complementary color and similar color paints generated strong and weak PA signals , respectively. For quantitative analysis, PA amplitude signal was integrated over the whole specimen surface, and compared with the reflectivity data.

In **Fig.3**, correlation between optical absorbance (1-R) calculated from the reflectance (R) data versus PA signal amplitude obtained for the blue LD (406 nm) was shown.

The correlation coefficients were 0.951 at 406nm, 0.914 at 532nm, 0.95 at 660nm for LDs, and 0.953 at 660nm, 0.949 at 590nm, 0.930 at 525nm, 0.961 at 470nm for LEDs.

4. Conclusion

Being LEDs and LDs as optical sources for PA measurement for 8-color specimens, good correlation coefficients (better than 90 %) between PA signal and optical reflectivity of the specimens at every wavelength was obtained. The results showed that the PA imaging system using LDs or LEDs as excitation light source is adequate for spectroscopic PA imaging.

References

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2. T. Hoshimiya and K. Miyamoto: IEEE UFFC, 53 (2006) 586.
3. Y. Sugitani et. al: J. Photoacoustics, 1 (1982)217.

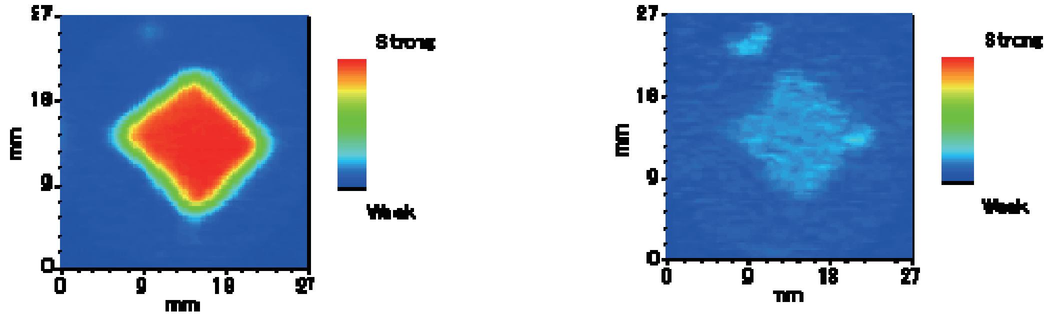

Fig. 2 (a) amplitude PA image of green paint (left), (b) red paint (right). Both images were obtained by excitation with red LED (625nm).

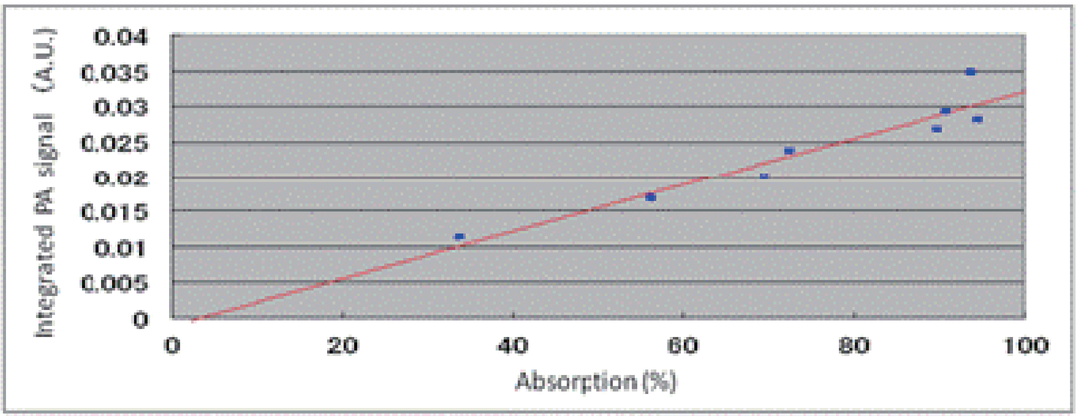

Fig. 3 Correlation between absorption data versus integrated PA amplitude signal (arbitrary units).