Plant and Environmental Monitoring Techniques Using State-of-the-art Laser Diagnostics

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1. Introduction

In operation of combustion systems and plants, enhancement of efficiency and lower burdens on the environment have been controlled on the basis of measured values of processes. Recently, trace elements at ppt to ppb levels existing in combustion exhausts have attracted considerable attention, and there is an increasing demand for advanced monitoring techniques.

Hitherto, for such measurements, samples were analyzed after a long period of sampling process and they usually required a complicated chemical treatment to obtain results. For plant monitoring and control, on-line measurement of these components is necessary, and it becomes increasingly important to develop quantitative measurement techniques to meet such needs.

This paper reports on real-time measurement techniques necessary for environmental monitoring and control of combustion systems and plants, which include laser-induced breakdown spectroscopy (LIBS), tunable diode laser absorption spectroscopy (TDLAS), and laser ionization time-of-flight mass spectrometry (TOFMS). Applications and their validity in combustion systems and plants used in industrial fields are also discussed.

2. Application of state-of-the-art laser diagnostics in plant and environmental measurements

In LIBSl technology, a laser beam is focused at the measurement point, and the measured material is transformed into plasma. At this process, the material in the plasma is atomized, and emits at individual atomic emission wavelengths. By spectral analysis of the plasma emissions, the concentration of the elemental components can be measured(1).

This technique is capable of measuring elemental composition with real-time and in-situ characteristics, and it is expected to be applied in a wide variety of fields including plant and environmental monitoring, such as refuse recycling processes. A LIBS measurement unit is shown in **Fig. 1**. It has been shown to be applicable in real-time component measurement in actual plants, such as measurement of trace heavy metals from fossil fuel or refuse combustion(2), and measurement of unburnt components of ash in coal firing thermal power plants(3).

In TDLAS technology, the laser wavelength is tuned to the infrared absorption wavelength of the target atoms and molecules, and the laser beam is passed through the measurement area. By measuring the laser beam absorption amount after passing through the measurement area, the temperature and concentration in the gas can be measured. In TDLAS technology, real-time and on-line measurement is possible. Since the apparatus is inexpensive and high response over the kHz time-resolution is possible, it is being developed as a measuring instrument for control of various plants.

For example, **Fig. 2** shows the results of CO and O_2 measurement in a refuse incinerator and its advanced control by using laser measurements(1). In comparison with the conventional O_2 concentration measurement, the laser measurement method can detect the concentration almost instantly, and showed detection capability of the fluctuations in the furnace about two or three minutes earlier than the conventional method (measurement at the bag filter outlet). In secondary air control using the laser measurement result, the number of peaks of CO concentration decreased and the CO concentration measured at the bag filter outlet dropped from 11.9 ppm to 8.0 ppm, showing the promotion of secondary combustion efficiency.

In laser ionization TOFMS technology, sample gas is introduced into a vacuum chamber, and the components to be measured are selectively ionized by a laser irradiation. An electric field is applied to the ionization area, and the ion mass and concentration are measured by the flight-time of ion and its signal intensity(4). Laser ionization TOFMS is a method with super high sensitivity at levels of ppt (10^{-12}), and has been applied to in the monitoring of aromatic hydrocarbons, dioxins(5), PCBs(4), and nano particles(6).

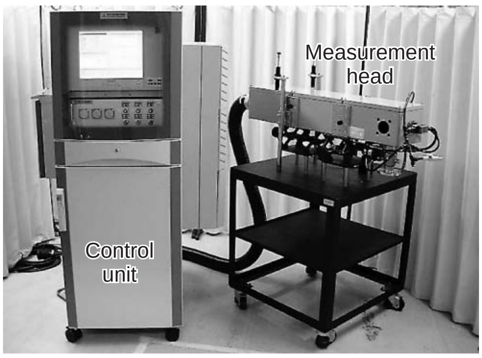

Fig. 1 LIBS apparatus
By separation into control unit and measurement head, applicability to actual fields is enhanced.

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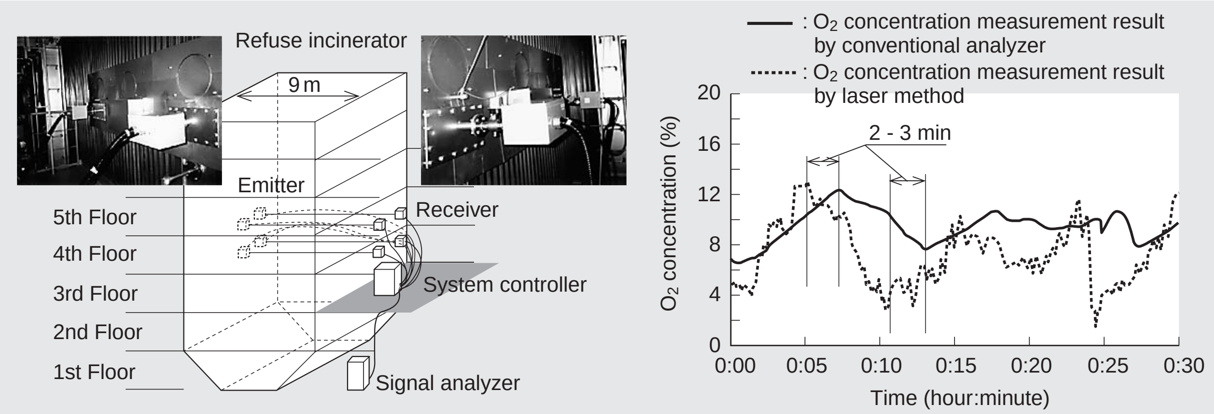
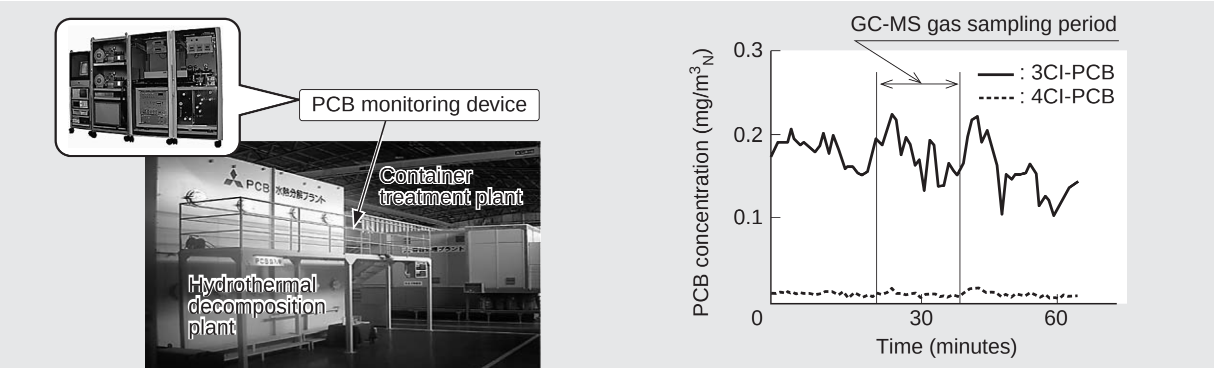


(a) Measuring instrument application point in refuse incinerators (b) O_2 concentration measurement result

Fig. 2 O_2 and CO monitoring system for refuse incinerator
Development of this system has made possible multi-point and real-time monitoring of O2 and CO, and CO reduction has been confirmed by feeding back its measurement results to the combustion control.



(a) Application in PCB treatment plant

(b) Measurement results for PCB hydrothermal decomposition exhaust gas (high concentration case)

Fig. 3 PCB concentration monitoring system in gas (MOHMS-21GP)
This apparatus consists of a laser device, TOFMS instrument, vacuum pump, control computer, and PCB gas calibration unit, and is capable of measuring PCB at detection sensitivity under 0.01 m/gm^3_N in real time.

Fig. 3 shows an example of PCB monitoring in PCB treatment plant[4]. The performance of this technique coincides very well with the conventional analysis results using "gas sampling + GC-MS" in both gases with high and low PCB concentrations, and the PCB gas monitoring performance in the PCB treatment plant has been successively demonstrated.

3. Conclusions

As for laser measuring technologies, LIBS, TDLAS, and laser ionization TOFMS were discussed, and their applications and the plant control using their measurement results were presented. Laser diagnostics features in-situ and real-time measurement, which was impossible using conventional methods, and its ability for plant and environmental monitorings has been confirmed. Laser measurement is realized by state-of-the art devices and instruments, and it has been associated with problems in stability and price. Recently, however, products with enhanced stability, reduced size and lower price are being rapidly developed, and such products are expected to be applied to a large number of practical application fields.

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