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論　文　内　容　要　旨

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学位論文題目	Study on multi-species hydrocarbon detection using tunable diode laser absorption spectroscopy (波長可変半導体レーザ吸収法による炭化水素他成分計測技術に関する研究)		

内容要旨

As the fundamental ingredients (either intermediate or final) or components of combustion products, hydrocarbon detection is useful in many aspects like chemical industry and combustion diagnostic. Hydrocarbons are organic compounds with many types. For example, methane (CH4) is a major intermediate species of hydrocarbon combustion products as well as the major components of natural gas. Ethylene (C2H4) is largely produced in industry as a basic chemical material. Its detection is also important in combustion chemistry since it is an important intermediate product in hydrocarbon oxidation. Plenty of propene (C3H6) can be detected in combustion gases due to its molecular stability and can be used as a marker of combustion inefficiency in engines. Hydrocarbons with higher molecular weight consists majority of fuel.

Laser absorption spectroscopy (LAS) have been developed to measure hydrocarbons since 1970s. Several hydrocarbons were detected using a He-Ne laser by Olson et al. But drawbacks restrict it to be applied into actual industrial fields. With the development of laser technology in the past decades, flexibility of detecting wavelength and reliability as well as robustness of detection system has been greatly improved. Better sensors and developed techniques provide more freedom for hydrocarbon detection. By far, many hydrocarbon species can be detected in various wavelength regions using different methods

Hydrocarbon species contain a C-H bond that has a fundamental vibrational mode. This C-H stretch results many absorption bands in 3μm and 10μm, making these regions easy for hydrocarbon measurement. Difference frequency generation (DFG) is a method for laser light generation based on nonlinear frequency conversion processes. DFG sources are suitable to 3-4μm region, which is exactly the wavelength region that strong absorption of hydrocarbon exists as mentioned above. Several tunable lasers based on difference frequency generation were developed to measure methane in wavelength region 3.1~3.7μm. A DFG laser source was used to detect hydrocarbon concentration by Klingbeil et al.

However, these mentioned systems either detection are limited by short scan range near 3μm or are operable under longer wavelength. In this study, we propose a novel mid-infrared DFG laser system operating near 3.3μm region with a wide scan range over 100nm. This range covers the C-H stretch region of hydrocarbons and makes it possible to detect multiple hydrocarbons at the same time.

In this work, the system performance was validated by measuring direct absorption spectra of various hydrocarbons like methane, propane, iso-butane, etc. Mixture detection from binary to trinary were also carried out. Concentration dependence experiments for both single and mixture were conducted to for quantitative analysis and to exemplify the potential to be applied in practical application.

By proving the capability of mixture measuring, it is demonstrated that proposed DFG laser system can be used for actual hydrocarbon measurement where different hydrocarbon species exists at same time.

By measuring engine exhaust after engine starts, it was proved that the proposed laser system can detect hydrocarbon components in exhaust gas. By examining spectra results, it was shown that both light hydrocarbon molecules like CH4 and heavier hydrocarbon molecules exists in exhaust gas, which shows the possibility of this laser system in analyzing the combustion process from exhaust gas.

By applying the laser system to coal powder heating process and analyzing the spectra results, it was shown that various hydrocarbon particles as well as water vapor exists in coal powder heating process. By examining different time stage, it proves that the laser system can help clarifying the chemical process during coal's pyrolysis and the volatilization and formation of different hydrocarbon components.