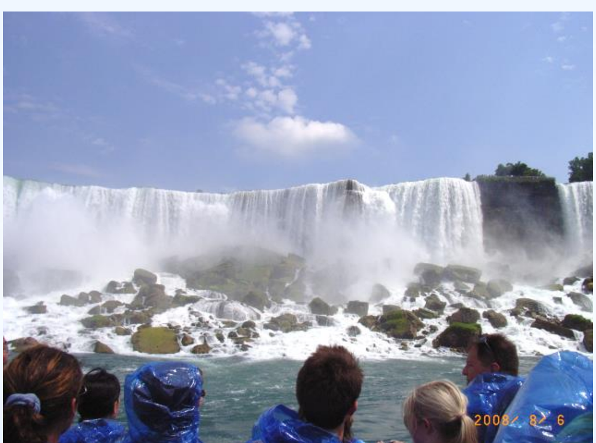
Preface

In recent years, global environmental problems, particularly global warming due to carbon dioxide (CO_2), have become substantially evident. It is therefore necessary to investigate novel and efficient energy utilization methods, to significantly suppress CO_2 emission, and thus preserve the environment.

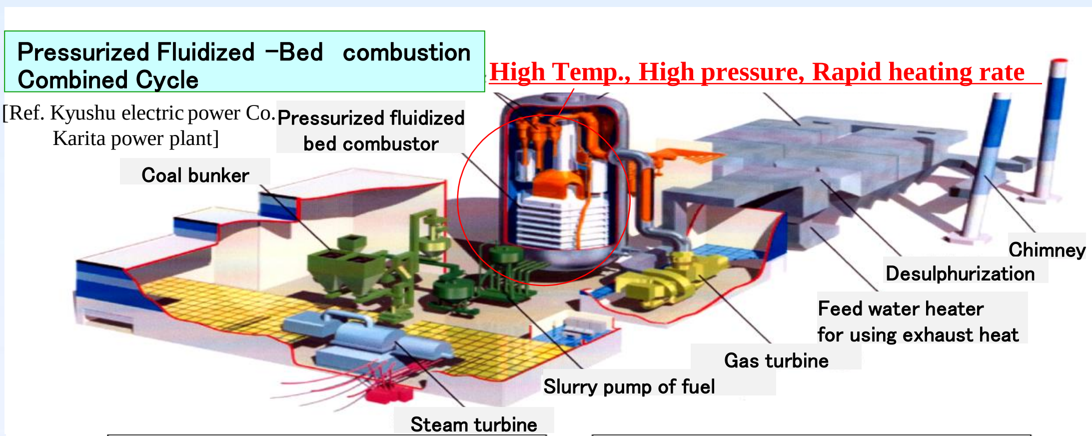
Our studies generally focus on environmentally friendly energy usage in terms of advanced combustion technologies, with our main research interests focusing on the following: **(1)** establishment of control technologies for clean coal/biomass combustion; **(2)** establishment of combustion technologies with the aim of investigating carbon capture and storage (CCS); **(3)** studies into renewable energy usage; and (4) development of high-powered diamond semiconductor devices.

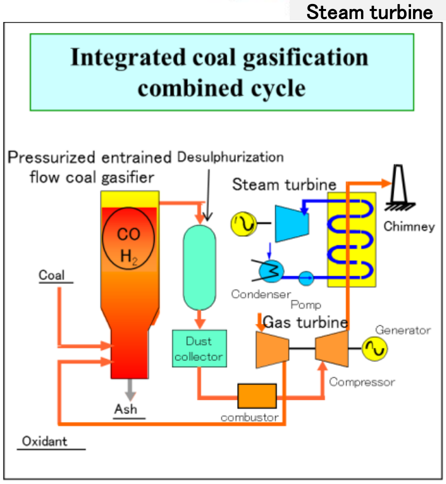
Environmental Energy Engineering Lab.

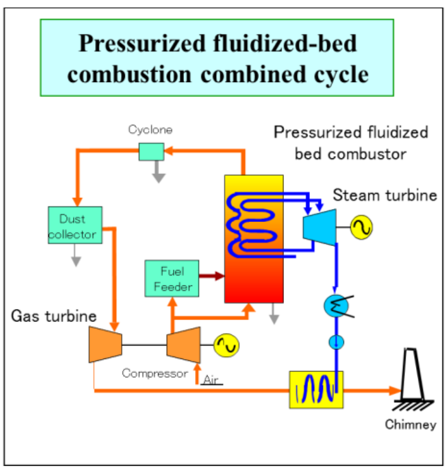


(1) Studies into highly efficient coal combustion and CCS combustion technologies

Coal has received attention as a suitable fossil fuel energy resource because of its evenly distributed rich deposits throughout the world. However, CO_2 emission from burning coal is extremely large (1800–2410 g/kg-coal). Novel combustion technologies which decrease the environmental loading are therefore highly sought-after. In this context, the following two methods are currently under investigation: (1) a method by which a plant can be operated at high thermal efficiency; and (2) CCS combustion technologies that combust coal using an oxy-fuel mixture composed of exhaust CO_2 and pure oxygen, followed by burying the exhaust CO_2 underground. Our main aims are to (1) elucidate the mechanism of pollutants formation in pulverized coal combustion employing pure oxygen and CO_2; and (2) clarify the phenomena in integrated coal gasification combined cycle (IGCC) and pressurized fluidized bed combustion (PFBC) system.







[Recent publications, Okumura]

(1) Effect of O_2/CO_2 Ratio on Fuel-NO_X Formation in Oxy-Coal Combustion, **Transactions of the Japan Society of Mechanical Engineers** (2011), Vol.77, No.778, pp.1397-1409.

(2) Prediction of Pyrolysis Products and Yields from Brown to Semi-Anthracite Coals by using Elemental Composition", **Journal of Japan Institute of Energy** (2010) , Vol.89, No.4, pp.364 –372.

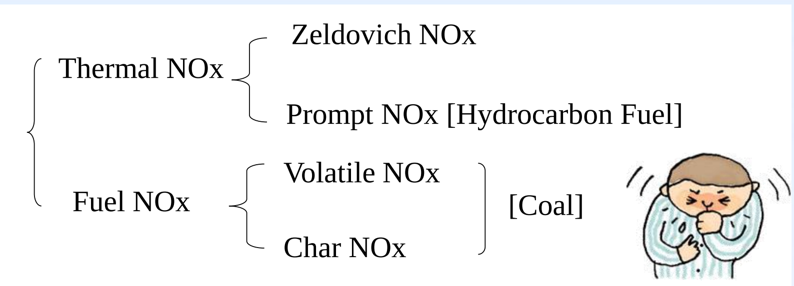
(3) Mechanism of Coal-Pyrolysis under Elevated Pressure and Rapid Heating Conditions, **Transactions of the Japan Society of Mechanical Engineers** (2005) , Vol.71, No.702, pp.702-710,

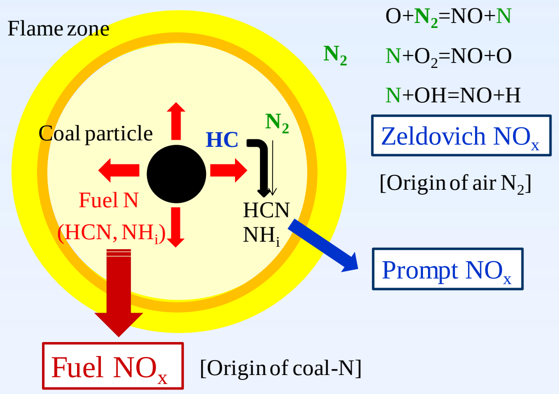
(4) Evolution Prediction of Coal-Nitrogen in High Pressure Pyrolysis Processes", **FUEL** (2002), Vol.81, No.18, pp.2317-2324.

etc.

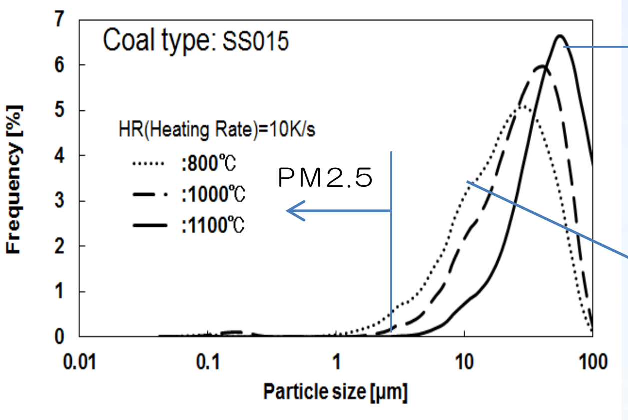
(2) Mechanism of pollutant formation, and suppression technologies associated with coal/biomass combustion

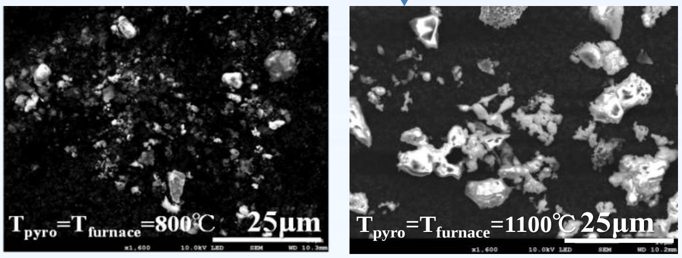
Rapid development of the heavy chemical industry has resulted in a number of pollution issues arising. During the high economic growth period from 1965 to 1984, Japan experienced a number of serious environmental crises, including Minamata disease, photochemical smog, acid precipitation, arsenic pollution, and water contamination (sludge). Although a number of novel technologies have been developed in recent decades, problems relating to new environmental pollutants such as PM2.5 and dioxin have developed. During our studies, we focus our attention on the environmental pollutants associated with coal/biomass combustion (PM2.5, nitrogen oxides, and sulfur oxides) and develop suitable suppression technologies. The mechanism of formation of the environmental pollutant must firstly be understood, after which the design of environmentally friendly equipment can be carried out.





Formation of nitrogen oxides from pulverized coal combustion





Ash emitted from pulverized coal combustion (including PM2.5)

[Recent publications, Okumura]

(1) Journal of Thermal Science and Engineering (2015), to be published.

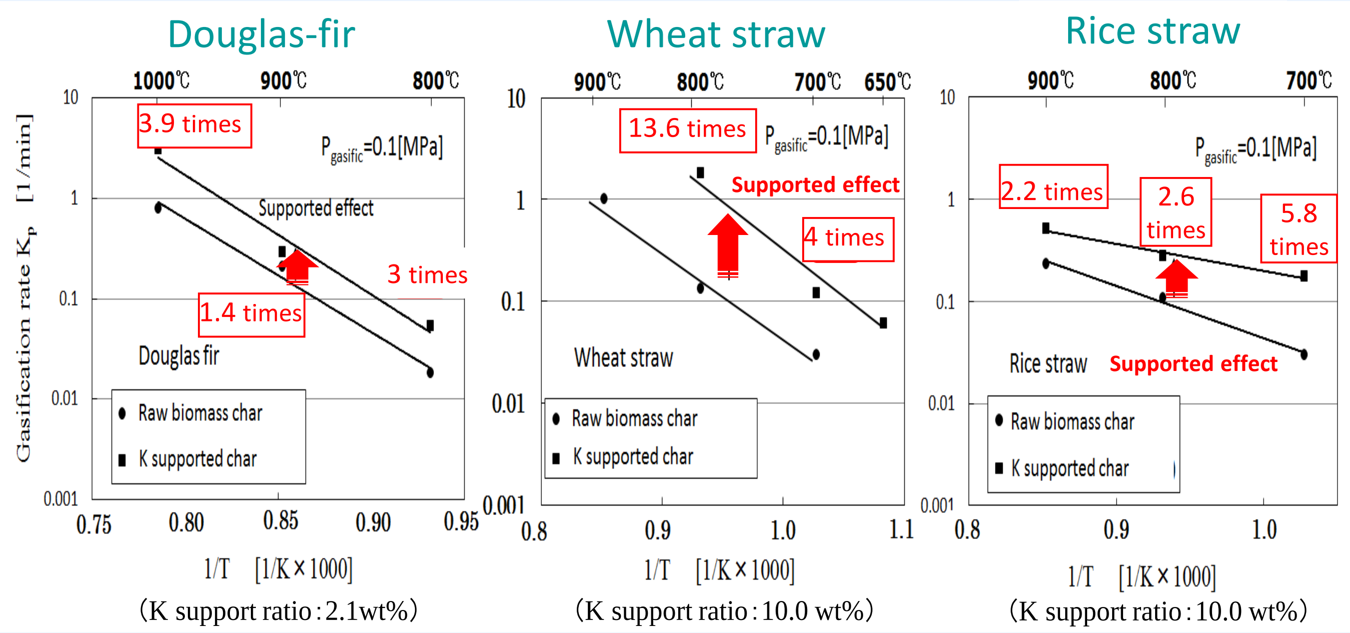
(2) Study on the N_2O Formation under Low Temperature Condition in Pulverized Biomass Combustion, **Transactions of the Japan Society of Mechanical Engineers** (2013), Vol.79, No.799, pp.465 -475. (in Japanese)

(3) Effect of O_2/CO_2 ratio on fuel-NOx formation in oxy-coal combustion, **Journal of Environment and Engineering**, Vol.5, No. 2, (2010), pp.417-430.

(4) Study on the N_2O formation under low temperature condition in pulverized biomass combustion, **Journal of Thermal Science and Engineering**, Vol.7, No.1, (2012), pp.75-89. etc.

(3) Development of renewable energy utilization technologies
(Low temperature, rapid biomass-gasification technologies)

To decrease CO_2 accumulation in air with the aim of reducing global warming, investigation of effective utilization of renewable energy (biomass resources) and efficient utilization of energy is required. For example, biomass power generation, biomass gasification technologies, and distributed biomass combustors are being actively developed. The gasification at low temperatures (below 600°C) is essential for constructing exergy-recuperative gasification systems for biomass. However, simultaneous achievement of both a “low temperature” and a ”rapid gasification” process is challenging, as the two generally contradict each other. Nowadays, gasification is carried out in a high temperature (partial combustion) at approximately 1000–1200 °C. We therefore aim to achieve a rapid gasification by lowering the temperature to approximately 600 °C for next-generation gasification.



[Recent publications, Okumura]

(1) Effect of metal content on CO_2 gasification behavior of K- and Fe-loaded bio-chars, **Journal of Thermal Science and Engineering** (2015), Vol.9, No.2, Journal Identification, DOI: 10.1299/jtst.2014jtst0006

(2) Enhancement of Gasification Rate of Biochar under Low-Temperature Conditions by Directly Supported Catalysts, **Transactions of the Japan Society of Mechanical Engineers** (2013), Vol.79, No.808, pp. 2798-2809.

(3) The effect of N_2/CO_2/O_2 content and pressure on characteristics and CO_2 gasification behavior of biomass-derived char, **Fuel Processing Technology**, (2012), Vol.104, pp. 287-294.

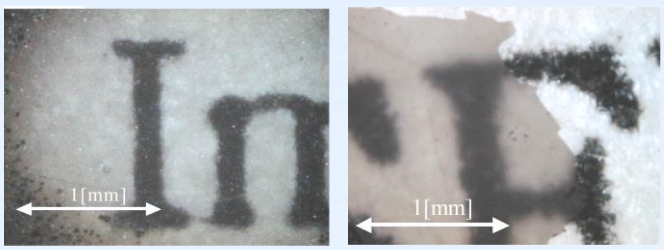
(4) Effect of pyrolysis conditions on gasification reactivity of woody biomass-derived char, **Proceedings of the Combustion Institute** (2009) , Vol.32, Issue 2, pp. 2013–2020.

(5) Effect of Pyrolysis Temperature and Pyrolysis pressure on Gasification Rate of Woody Biomass-Derived Char, **Journal of High Temperature** (2010), Vol.36, No.1, pp.18-24.

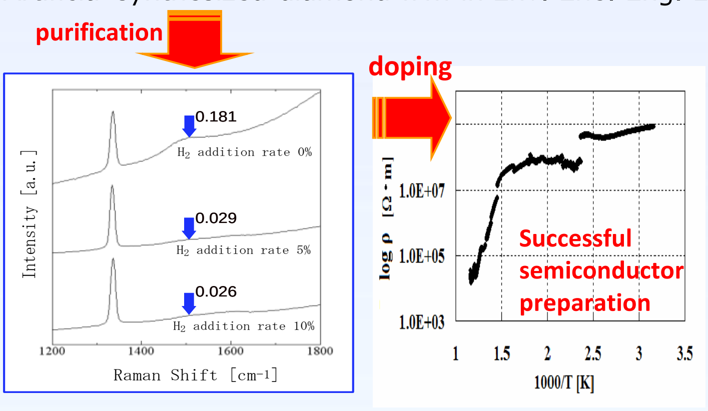
etc.

(4) Creation of a high-power semiconductor

The discovery of novel materials has led to the rapid development of new sciences and technologies. Such development began at the start of humankind, where stone was initially used for making tools, followed later by iron. Much further down the line, silicon was found to be useful for application in electric devices (semiconductors), with this discovery revolutionizing information and communication technologies, thereby ensuring a rich living environment for humankind. It is expected that in the near future, carbon materials (ex. diamond) will be important in the development of novel technologies. Our aim is to use an artificial synthesized-diamond-film to prepare semiconductors for use in high-powered electric equipment and electric trains driven by high voltages.



Artificial synthesized-diamond-film in Env. Ene. Eng. Lab.



[Recent publications, Okumura]

(1) Electrical Characteristic of Diamond Film Synthesized by Combustion Flame, **Combustion and Flame** (2010), Vol.157, Issue 6, pp.1052-1059.

(2) Effect of Synthesis Condition on Electrical Characteristic of Diamond Film Produced by C_2H_2/O_2 Combustion flame, **Journal of Thermal Science and Engineering** (2009), Vol.4, No.1, pp. 178-189.

(3) Electrical Characteristic of Diamond Film Synthesized by Combustion Flame – Effect of Synthesis condition on Electrical Resistivity –, **Transactions of the Japan Society of Mechanical Engineers** (2008), Vol.74, No.738, pp.461-468.

(4) Combustion synthesis of high quality diamond film suitable for application in electronic devices, **Proceedings of the Combustion Institute**, Vol.3, Issue 2, (2007), pp.1831-1838.

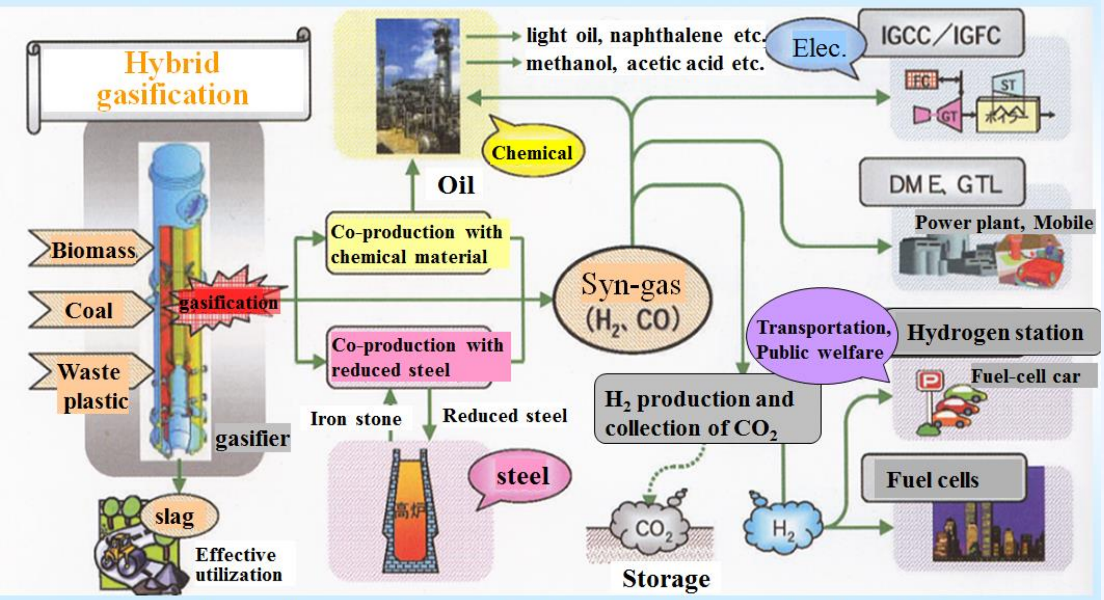
(5) Electrical Characteristics of Diamond Film Synthesized by Combustion Flame, **Transactions of the Japan Society of Mechanical Engineers** (2006), Vol.72, No.716, pp.1073-1080. (in Japanese)

(6) Nucleation Control of Diamonds by Reducing Flame with High Voltage Pulse, **Transactions of t** **Society of Mechanical Engineers** (2001), Vol.67, No.661, pp.2333-2339.

etc.

(5) Development of new energy utilization technologies for environmental conservation

Although natural energy sources such as solar, wind, and wave power in sea are considered ideal energy sources, they also have a number of issues, such as low energy density and large supply fluctuation. In this context, the hydrogen energy infrastructure has been developed to give an energy source with a stable infrastructure and small supply fluctuation. Toyota recently developed and sold the “Mirai” fuel cell car, and provided the patent for its technology free of charge. Honda and Nissan also plan to launch fuel cell cars in 2016 and 2017, respectively. Our studies focus on the development of an effective method for producing amounts of hydrogen from biomass and waste. In addition to these renewable sources, hydrogen is a storable clean energy source, which can also be obtained from natural gas and water electrolysis.



C3 Report of Japan's Ministry of International Trade and Industry, (2004), pp.1–12.

[Recent publications, Okumura]

(1) Modeling of Pyrolysis and Gasification Reactions of Many Types of Biomass, **Journal of Japan Institute of Energy** (2011), Vol.90, No.2, p.122-131.

(2) Pyrolysis and gasification experiments of biomass under elevated pressure condition, **Journal of Environment and Engineering** (2009) , Vol.4, No.1, pp.24-35.

(3) Hydrogen Production from Wood and Grass Biomasses and Construction of GTL Technology, **Final Report of Grants-in-aid for Scientific Research; scientific research fund (22560213)** (2014).

(4) Pyrolysis and gasification experiments of biomass under elevated pressure condition, **Transactions of the Japan Society of Mechanical Engineers: <Special Issue>The Forefront of Thermal and Combustion Engineering Strained for Technology Transfer** (2007), Vol.73, No.731, pp.1434-1441. (in Japanese)

(5) Effect of Cellulose, Hemi-cellulose and Lignin Compositions in Woody and Grass Biomass on Pyrolysis Process, **Journal of High Temperature: <Special Issue>** (2008), Vol.34, No.4, pp.160-165.

(6) Prediction of Pyrolysis Process for Wood and Grass Biomass by CPD Model, **Journal of Japan Institute of Energy** (2008), Vol.87, No.10, pp.852-861.

(7) Gas Release Characteristics of Various Species in Pyrolysis of Wood and Grass Biomass, **Journal of Japan Institute of Energy** (2009), Vol.88, No.4, pp.301-309.

etc.