Team of Coal Pyrolysis and Cascaded Utilization Research
Brief Introduction

Coal contains carbon and also volatile that takes most of its H. While coal is used to produce energy such as heat and power without differing the values of hydrogen-rich volatile and carbon, it is also used to produce various hydrogen-rich chemicals such as aromatics, ammonium, methanol and motor fuels. The cascaded utilization of coal refers to the respective uses of its volatile and carbon for the productions of chemicals and energy. This requires thus the extraction of coal volatile as the core technology for cascading the utilization. Coal pyrolysis is the most efficient way for extraction of coal volatile. The Coal Pyrolysis and Cascade Utilization Research Group, with its short name as Coal Group, in IPE is just devoted to the development and commercialization of coal pyrolysis and its products processing technologies. The activities of Coal Group cover the understanding of pyrolysis reactions, innovation of reaction control and reactor technologies, optimization of process and utilities, integration and scale-up for commercialization. The group also develops technologies including catalyst and process for utilization of gas and tar products generated by pyrolysis, environment protection of coal utilization processes such as flue gas cleaning, and applications of the technical methods developed for coal to biomass waste utilization.

Currently, the team has about 65 staff members, including 9 professors, 10 associate professors, about 20 assistant professors, 10 engineers and 15 administrative staffs. There are about 75 graduate students, with about one third being doctoral candidate and the others being master students. The team currently has 10 international students and 3 visiting foreign researchers, who are mainly from developing countries. Prof. Guangwen Xu is currently the chair scientist of the team.

Research Activities

1. Coal pyrolysis fundamentals and technology development

This is the core task of the team in IPE. Coal pyrolysis has been fundamentally investigated and technically developed for about 100 years in the world, but there is yet not commercially mature technology ready for industrial deployment. The related studies in IPE thus have covered the aspects from fundamentals to technical and engineering developments about coal pyrolysis. The so-called CAS Strategic Priority Project on High-efficient Clean Utilization of Low-rank Coal has supported the R&D activities greatly. While the fundamental studies are via both molecular dynamics simulation and experimental examination and characterization, the technical studies have involved tremendous experimental tests at laboratory to thousands t/a pilot scales. Usually, close cooperation with engineering companies is started from the pilot test stage, and this is then further extended to the scale-up and industrial design of demonstration plants with capacities from hundred thousand tons to tens of million tons per year. Currently, several companies including China coal Group Company and Shanxi Chemical Engineering Design Institute are in close cooperation with the coal research group to develop and demonstrate a new pyrolysis technology called the internals moving bed coal pyrolysis. With the support of
a 973 project, the technology is being also extended to the pyrolysis of small-size oil shale to produce shale oil with high yield and low dust.

2. Value-added processing of pyrolysis tar and gas

The team simultaneously studies the processing fundamentals and technologies for coal pyrolysis tar and gas. Considering the distinctive characteristics of tar from low-temperature coal pyrolysis, which has high content of phenols, the tar processing studies in IPE has focused on understanding the complicated chemical compositions of the tar and also the development of a comprehensive technical scheme to use its phenols by separation and its aromatics and aliphatic species via hydrogenation. Making substitute natural gas (SNG) is a high-efficient and high-value use of the pyrolysis gas. With the financial supports from 863 and National Key Technology Development Programs, IPE is devoted to developing a high-efficient two-stage methanation process combining a transport bed reactor and a tail-end fixed bed reactor. This is very like the FCC process for catalytic processing petroleum oil, and it is expected to greatly simplify the currently commercialized multi-stage adiabatic fixed bed methanation process and obviously reduces the catalyst consumption. The research work covers on development of the attrition-resistance methanation catalyst for transport bed methanation, which has never been studied before in the world, and the high-efficient fixed bed catalyst for the tail-end clean-up of CO which requires the catalysts for good low-temperature activity and stability. Process development is highly challenging because the transport bed methanation and its integration with a tail-end fixed bed methanator are both innovative studies of the field. The researchers in IPE have done systematic laboratory tests and now a pilot test is being performed for the transport bed methanation. An industrial verification of the entire two-stage system at a capacity of 2000 Nm3/h feeding gas is planned to finish in 2016.

3. Gasification of pyrolysis char and coal for fuel gas

The char from pyrolysis can be used as the original coal to fuel boilers and gasifiers. As a matter of fact, the suitable ways for using char comprise the critical factor which determines whether the cascaded utilization of coal based on pyrolysis is practically possible or not. The CAS Strategic Priority Project on High-efficient Clean Utilization of Low-rank Coal thus has had great financial supports to the combustion and gasification technology developments for pyrolysis char. The team in IPE has long worked on gasification of coal, biomass and recently char for fuel gas production. The pyrolysis char is actually a good feedstock for fuel gas production because it can eliminate the tar problem of coal gasification at temperatures below, for example, 1000 °C, but it needs to intensify the reactions due to the relatively low gasification reactivity of char than of original coal. Consequently, IPE researchers have extensively studied the ways such as by pre-oxidation for implementing the reaction intensification for gasification of char as well as coal. Systematic work has been further done on gasification process characteristics through laboratory and pilot tests to clarify, for example, how the process performance varies with reaction conditions and fuel properties. These studies have resulted in the innovation of the so-called pre-oxidation gasification technology. Through licensing the technology to an engineering company, now the research group is in moving the technology into optimization, integration and scale-up for its industrial demonstration and applications.

4. Flue gas denitration catalyst with wide working temperatures

In coal pyrolysis process such as coking oven there has to be flue gas emission from heating furnaces, and its temperature is usually below 300 °C so that the existing commercial catalyst for selective catalytic reduction (SCR) of NOx from flue gas of power boilers can hardly work for many industrial heating furnaces. The team in IPE has long worked on developing the denitration SCR catalyst adapting for the heating furnace flue gases that have the exhausting temperatures of 200-300 °C. The study and development of such low-temperature denitration catalysts represents also
one of the hot research topics in the area of air-pollution control. Financially supported by 863 program, the researchers of IPE have made efforts to reconfigure the catalyst micro and meso structures through different catalyst preparation techniques. This has resulted in a new catalyst production processing technology, and the produced catalyst has been shown to be able to work at 220-400°C for flue gas containing both SOx and steam vapor. The IPE researchers have innovated as well the utilization of Ti-bear blast furnace slag for making the basic material of denitration catalyst. Thus, a denitration catalyst with low cost and wide working temperature is seeing success and also commercialization in IPE.

Infrastructure

With the continuous accumulation in several decades and the particularly extensive development in last ten years, the team has been well facilitated to conduct the proceeding works on fundamental researches and technical developments. In addition to those commonly shared large and expensive characterization instruments like SEM, TEM and XPS, the team has equipped nearly all the other analysis and characterization instruments that are necessary to studies of coal thermal conversion or for the individual experimental operations. These include, for example, the Element / Gas / Oil analyzers, TGA, GC-MS, XRF, FTIR, TPD-PTR, Process MS, GC and so on.

Most importantly, the team has lots of self-made experimental facilities, as shown above with a few pictures of them, for testing various thermal and catalytic fuel conversion reactions, including, for example, drop tube furnace, downer pyrolyzer, multi-stage pyrolyzer, pre-oxidation reactor, residual oil cracker, high-pressure pyrolysis / gasification plant, pressurized fluidized bed methanator, honeycomb catalyst evaluator, mini-production line of catalyst, etc. Especially, the team has built and run several sets of pilot plants, including 30 kg/a and 3000 t/a pilot plant for solid heat carrier pyrolysis, 1000 t/a internals moving bed pyrolysis pilot, 1000 t/a pre-oxidation fluidized bed gasification pilot, 500 kg/a powder and 300 m3/a monolith pilot line for denitration catalyst production, and some others for such as activated carbon production and hydrothermal treatment. All these laboratory and pilot facilities directly supported the successful development of many applied technologies in the group.

Some self-made testing facilities in Coal Group for performing varies experimental studies.

Particularly, the team has for the first time in the world proposed the use of micro fluidized bed (MFB) for gas-solid reaction analysis in 2005, and has then continuously worked on development of the so-called micro fluidized bed reaction analyzer (MFBRA) in series, as shown in the following picture. The National Scientific Instrumentation Program greatly supported this development. Now three modes of MFBRAs are available as commercial products, which are MFBRAs adapting for steam agent (MFBRA-S), integrated with a mass spectrometer (MFBRA-M) and enabling on-line particle sampling (MFBRA-P), respectively. Of them, all can be used for conventional non-steam and non-corrosive reactant gases like N₂, CO, CO₂, CH₄, H₂ or the mixture of any two or more of them, while both MFBRA-S and MFBRA-M are equipped with the on-line injection feed of particle reactant. The Coal Group is still working on product design and development of MFBRAs.
with more extended functions, such as with external field, for liquid reactant, enabling reaction decoupling, etc.

Development history of micro fluidized bed reaction analyzer (MFBRA) in series since 2006.

**Research Progress**

1. Innovation of internals moving bed pyrolysis and pilot verification for producing high-quality tar and gas

Coal pyrolysis for high-quality tar and gas products is the core technology for cascaded utilization of coal based on direct conversion, but there is yet not commercially ready mature technology especially for powder coal below 10 mm. The team has innovated the internals moving bed coal pyrolysis technology. With enhanced heat transfer and optimized gas flow inside the reactor, the new technology enabled the production of high-quality and high-yield pyrolysis tar and gas. On the basis of systematic laboratory studies, a 1000 t/a pilot testing system for the internals moving bed pyrolysis technology was built and successfully operated in 2013 (see figure). Using low-rank coal of 0-10 mm, the realized tar yield in pilot tests reached 85% of the Gray−King assay yield, and the produced tar had its density smaller than 1000 kg/m³, dust content below 0.3 wt.% and light fraction (boiling points <360 °C) over 70 wt.%. The co-produced pyrolysis gas contained H₂ and CH₄ totally about 70 vol.%. These results well verified the innovation and technical superiorities of the newly developed pyrolysis technology, which show in fact the advanced performance parameters comparing to all other available powder coal pyrolysis technologies. The technology can be scaled up by simply adding up a standardized module, and it is thus easy to realize its industrial application at capacities above 1000 kt/a. All of these demonstrate a prospective breakthrough of the pyrolysis technology for treating powder coal. A 200 kt/a demonstration plant is thus under engineering design and will be commissioned into continuous running in 2015.

2. Construction and commission to continuous running of a 3000 t/a pilot plant for downer coal pyrolysis

The IPE-indigenous coal pyrolysis technology in downer reactor with solid heat carrier particles from its integrated riser combustor can provide a practical way and mode for coal cascade utilization. On the basis of continuous research and development for tens of years, IPE has launched the construction of a pilot testing system treating 10 t/d coals in Langfang pilot site of IPE since 2011. Through tests in this pilot testing system, it is expected to investigate and verify the core technologies related to scale-up. The construction of the plant was finished in the first half year of 2013, which integrated the parts or sub-systems of coal drying, coal pyrolysis, char combustion, gas-oil separation, tar refining, detection and controlling, and sampling and analysis. Commission tests for the plant have been performed in the second half of 2013, and a continuous running for about one week was achieved by the end of 2013. Testing a few different
kinds of coals were conducted in 2014 using this plant. The results show that treating 1.0 ton of the tested low-rank coal produced 80-90 kg tar and about 130 Nm3 pyrolysis gas. In the tar the light fraction was 78 wt.%, and the pyrolysis gas contained 34 vol.% CH4, 21 vol.% H2 and 17 vol.% CO to give a heating value of 6700 kcal/Nm3. The power generation unit at 50 MW is widely used to co-supply power and heating. Applying the developed pyrolysis technology to such plants it is expected to implement the poly-generation of tar for chemicals and heat (steam) through burning the pyrolysis char and gas. Considering the 2×25 MW back-pressure type generator system, the investment due to pyrolysis will increase 34.3%, but the unit annual after-tax profit increases 50.73%. These cause the internal rate of after-tax return (against investment) to increase 0.93%, showing the economic feasibility of the technology for commercial applications.

3. Demonstration of fluidized bed two-stage gasification technology for fuel gas incorporated with gas burning treating 40 kt/a industrial biomass waste.

The team has successfully developed the so-called fluidized two-stage gasification on the basis of dual fluidized bed technology. The technology consists of oxidative pyrolysis or pre-oxidation of fuel in a fluidized bed and in turn the gasification of char and also cracking of tar in a riser. After successful pilot verification, the technology has been demonstrated to use distilled spirit lees (DSL), a typical fermentation waste that is amounted to 1800 t/a in China. Considering its characteristics of containing 60 wt.% moisture and 3-7 wt.% N, the fluidized bed two-stage gasification for DSL was modified into a gasification-based combustion system. It first gets the pre-oxidizing gas form the fluidized bed and in turn the gas was arranged to burn at the upper section of the riser gasifier. By increasing the amount of air into the riser, here the riser becomes also a combustor. Thus, the modified process also called the circulating fluidized bed (CFB) decoupling combustion that is particularly suitable for low-NOx combustion of N-rich fuel. Under the financial support of National Key Technology Development Program, systematic studies...

Denitration of flue gas is one of the key tasks for air pollution control. The commercial catalysts for selective catalytic reduction (SCR) of NOx are composed of vanadium, tungsten and titanium oxides and their preparation are all based on the technology early developed by a Japanese company in 1970-1980s. For them the applicable working temperature is 300-420 °C, and they can hardly work with the flue gas of power boilers running at low-load (including start-up and shut-down) and of various industrial combustion facilities including industrial boilers, ovens and furnaces. Through innovations in catalyst structure, surface active components and preparation technology, the team successfully developed a new denitration SCR catalyst that can work at 220-420 °C for flue gas containing steam vapor and SOx. The research group further developed the manufacture technology for both powder and monolith of the catalyst, and demonstrated that the new catalyst does not only decrease the viable working temperature for denitration by 50-100 K but reduces also the catalyst cost by 20-40% in comparison with that of the currently in-use commercial SCR catalyst. Based on solid fundamental and technical work, a pilot production line for 300 t/a powder catalyst and 500 m3/a honeycomb catalyst was built and successfully run in 2013 in Hebi, Henan province. The formed catalyst production technology has been licensed to two companies respectively in Guiyang and Zhangjia-gang to have two commercial production lines for 3000 Nm3/a monolith catalyst, and the commercial catalyst product will be available in 2014.

5. Great progress in heterogeneous catalyst and process developments for value-added processing of tar and pyrolysis gas

Low-temperature coal pyrolysis produces tar which contains about 20 wt.% phenols and about 60 wt.% neutral oil, with low pitch content. Based on characterization of the physiochemical properties of the tar, an integration processing scheme was proposed for the tar to produce high-value fine chemicals by separation, clean liquid fuel through hydrogenation of the neutral and carbon-based materials, such as carbon fiber from converting the left pitch. Catalysts with high stabiility and selectivity for pyrolysis oil upgrading are developed, which passed the lifetime-test of 1000 hours. A
pilot plant for separation (700 kg/d) and hydrogenation (400 kg/d) has been built and are in the process of commission into running (see figure).
On the other hand, methanation of pyrolysis gas into substitute natural gas has achieved as well. Through innovating the strategies of catalyst preparation, including the lattice doping of support, selective deposition of CeO$_2$ promoters and impregnation of VOx and ZrO$_2$ on Ni particles, an optimal catalyst was prepared to meet the requirements of practical application not only in good resistance to coking, sintering and deactivation but also in the expected physical properties like shape and mechanical strength (see figure). The mechanical strength and hydrothermal stability of the catalyst are found to be very close to the commercial catalyst, but its low-temperature activity is obviously better and its production cost is below one-third of the price of the commercial catalyst. For transport bed methanation, obvious progress was also made in preparing the granulated powder catalyst (like FCC). For catalyst manufacture, a mini catalyst production line, including extrusion and spray granulation has been built. A 200 Nm$^3$/h pilot testing system for the transport-fixed bed two-stage methanation is also under way of construction, which will be used to test the developed fixed and transport bed catalysts.

**Selected Publications and Achievements**

3. 2010, Best Paper Award, Isothermal and differential characteristics of the reaction in a micro fluidized bed reactor (Jian Yu, Xi Zeng, Junrong Yue, Tony Li, Qiang Li, Guangwen Xu), Second International Symposium on Gasification and Its Applications, Fukuoka, Japan.


Research Professors

Prof. Guangwen Xu (Team Leader), born in 1967, got his bachelor degree in 1991 from Tsinghua University and doctor degree in 1996 from Chinese Academy of Sciences. He has worked in Japan and Germany between 1996 and 2006, as visiting scholar, NEDO industrial technology researcher, Alexander von Humboldt (AvH) research fellow and senior research scientist in IHI Corporation. He has become a professor in Institute of Process Engineering (IPE), Chinese Academy of Sciences (CAS) since 2006 when we joined the institute through the “hundred-talent program” of CAS. He mainly works on fuel thermochemical and catalytic conversion, environmental catalysis, multiphase reaction and reaction analysis. His work has generated numbers of technologies and instruments, including the internals moving bed pyrolysis of coal and oil shale, fluidized bed two-stage gasification of coal and biomass, transport-fixed bed two-stage syngas methanation for SNG, wide working-temperature flue gas denitration catalyst, and micro fluidized bed reaction analyzer. Of them, most are in or being put into practical applications. He has published 200 journal papers, applied for about 90 patents including 9 PCTs and delivered more than 40 invited speeches or keynotes in various academic conferences. His work is widely cited in the fields of energy & fuels and chemical engineering. He has been awarded the Excellent Implementation Award of the Hundred-talent Program, the First-class Science and Technology Award of China Analytical Instrument Society, the Best Paper Award in 2nd International Symposium on Gasification and Its Application (Japan), The China Excellent Patent Award and the First-class Invention Award of Chinese Academy of Sciences.

Affiliation
Member of expert team for National High-tech R&D Program of China (863 Program).
Chair of Advisory Board for International Symp. on Gasification and its Applications.
Member of Internal Advisory Board of Circulating Fluidized Bed Technology.
Member of Editorial Board for CISEC Journal (China).
Deputy Director of Board Council, China Technol. Innovation Alliance for Biofuel Gas.

Research Interests
Thermochemical conversion including Coal pyrolysis for liquid, Coal gasification for fuel gas; Biomass waste combustion and carbonization for energy and bio-carbon materials; Applied catalysis for flue gas denitration, syngas methanation; Fluidization and gas-solid flow including fluidized bed hydrodynamics and fluidized bed reactors for applications; Reaction analysis including characterization and kinetics using micro fluidized bed and quick mass spectrometer.

Prof. Weigang Lin was born in 1956 and obtained his Ph.D degree in Department of Chemical Engineering, Delft University of Technology, in Netherlands. He worked as assistant and associate professors in Department of Chemical Engineering, Technical University of Denmark from 1994 -1998. From the end of 1998, he became a professor of Institute of Process Engineering, Chinese Academy of Sciences, through the 100-Talent program of Chinese Academy of Sciences. He is currently the principle investigator of the sub-theme of Biomass Thermal within the theme of sustainable energy in Sino-Danish Center for Education and Research. He has published more than 60 papers in peer-reviewed international journals, and has been awarded three times of best paper in the International conference on FBC in 1997, 2001 and 2003.

Research Interests
Emissions of SO₂, NOx in coal and biomass combustion; Ash chemistry; Co-combustion of coal and biomass; Biomass pyrolysis and gasification; Bio-oil upgrading; Coal polygeneration; CO₂ capture and storage.
Prof. Fabing Su was born in 1968 and received his Bachelor degree from the Department of Chemical Engineering at the Tsinghua University in 1991, and his Ph.D. degree from the Department of Chemical and Biomolecular Engineering at the National University of Singapore (NUS) in 2005. He was a postdoctoral fellow at the NUS (2005-2006) and the University of Liverpool (UK, 2006-2008), and a research fellow at Institute of Chemical and Engineering Sciences (Singapore, 2008-2009). He has been a professor of IPE and a research group leader (Group of Catalysis and Porous Materials for Energy, http://cpme.mpcs.cn/) since 2009. He was awarded the Evonik Particulology Innovation Award 2012. By far he has published 110 papers (3300 citations and 29 H-index) in the peer-reviewed journals, including Journal of the American Chemical Society, Angewandte Chemie International Edition and Advanced Materials. He is holding 51 patents.

Research Interests
Nanostructured materials and their applications in Heterogeneous catalysis; Li-ion batteries; Fuel cells; Super capacitors, and environment.

Prof. Wenli Song, Deputy Director of State Key Laboratory of Multiphase Complex Systems, was born in 1959, Shandong Province. Graduated from Harbin Institute of Technology, receiving a Master Degree in Thermal Energy Engineering in 1985; obtained Doctor Degree of Process Engineering from Institute National Polytechnique de Lorraine, France. He was worked as an engineer at Herman Research Laboratory, Melbourne Australia, between 1986 and 1987. Then moved to Beijing Research Institute of Coal Chemistry, China Coal Research Institute, as an Engineer, then Senior Engineer and Deputy Director of Combustion Laboratory. Since 1997, he joined Institute of Process Engineering, Chinese Academy of Sciences as a Senior Engineer and then Professor. He was awarded the First Prize of invention of Chinese Academy of Sciences in 2001 for the development of Coal Decoupling Combustion technology and equipment. He has published 60 papers, 2 co-authored books, and held 28 patents.

Affiliation
Member of Commission of Coal Chemical Engineering, China Coal Society
Council committee member of the Chinese Society of Particuology
Member of Commission of Biomass, China Renewable Energy Society

Research Interests
Clean coal technology, including coal decoupling combustion, coal gasification, coal and biomass pyrolysis; NOx emission control and VOC emission control by adsorption; Invented IPE Power – a Pyrolysis Bridged Hybrid Power System for Low rank coal.
Prof. Shiqiu Gao, born in 1964, got his bachelor degree in 1987 from Shenyang Institute of Chemical Technology and master degree in 1990 from Dalian University of Technology. Then he worked in the Department of Chemical Engineering of Shenyang Research Institute of Chemical Industry until he began an oversea student in Japan in 1992. He got his doctor degree from Faculty of Engineering of the Gunma University in 1996. He has worked in Japan between 1996 and 2000, as an assistant professor in Gunma University for two years and research associate in Koei Chemical Co., Ltd. for two years. He joined the Institute of Process Engineering of CAS in 2000, first as an associate professor and then a professor in 2006. He has published more than 50 refereed papers in journals, coauthored four books and applied for more than 40 China invention patents.

Affiliation
Deputy Editor-in-Chief, the Chinese Journal of Process Engineering (2004-)
Guest Professor, School of Chemistry & Chemical Engineering, Xinjiang University (2012-)
Member, National Technical Committee of Standardization for Combustion, Energy Saving and Purification (2013 - 2018)
Member, National Technical Committee of Standardization for Coal (2013 - 2017)

Research Interests
Coal pyrolysis and gasification; Coal combustion, Clean coal utilization; Flue gas cleaning; Fluidization and gas-solid two-phase flow.

Prof. Songgeng Li was born in 1973. He received his Bachelor degree in 1996 and Master degree in 1999 from Northeastern University in Shenyang. He obtained Ph.D in chemical technology from IPE of CAS in 2004. He worked at National Power Plant Combustion Engineering Research Center (Shenyang) as research engineer from April 1999 to Aug. 2000. He was at Western Kentucky University from 2004 through 2006 as a visiting scholar and at The Ohio State University from 2006 through 2009 as a postdoctoral researcher. In the late of 2009, he was selected into Hundred Talent Program of CAS and joined in IPE of CAS as a professor. He has published over 40 papers in peer reviewed Journals and international conferences, and applied for over 10 patents.

Research interests
Coal and biomass thermal conversion and related pollution control including pyrolysis; Gasification; CO₂ capture and Mercury control technologies.
Prof. Chunshan Li was born in 1977 and received his Ph.D. degree in Chemical Engineering from Institute of Process Engineering in 2006. He was a postdoctoral fellow at Federal Institute for Materials Research and Testing, BAM (2006-2007), JSPS fellow at Nagoya University, Japan (2007-2009). He joined in IPE, CAS and has been a professor as the Hundred Talents Project of IPE since September 2009. His research mainly focus on Cleaner Energy Catalytic process (coal tar conversion, Biomass conversion and so on), Chemical Process Design and Integration. Several new kinds of efficient catalysts were designed and applied in the catalytic upgrading process of coal tar, oil and so on. He won Scopus Young Researcher Award in 2011, and Beijing Nova in 2012. He also was selected as TWAS Young Affiliates in 2013. He has published 58 peer-reviewed journal articles, such as AIChE J., Ind. Eng. Chem. Res., and held 28 patents.

Research Interests
Cleaner Energy Catalytic process; Catalysts development; Chemical process design and integration.

Prof. Xiaoxing Liu was born in 1978, Professor, a recipient of the “Hundred Talents Program” awarded by Institute of Process Engineering (IPE), Chinese Academy of Sciences (CAS). Dr. Liu obtained his Bachelor’s and Master’s degrees in Chemical Technology from Tianjin University (2000, 2003), and Ph.D in Chemical Engineering from IPE, CAS (2008). From 2008 to 2012 Dr. Liu worked as a postdoctoral research fellow in Grenoble Institute of Technology (France) and in The University of Queensland (Australia) respectively. In Sept. 2012, Dr. Liu joined IPE as a recipient of the “Hundred Talents Program” awarded by IPE, CAS.

Affiliation
Member of Chinese Society of Particuology.

Research interests:
Coal hierarchical utilization; Fluidization; Granular material; Computational Multiphase Fluid Dynamics.