
## Our Mission

To provide the next generation of combustion researchers, engineers and technologists with a comprehensive fundamental knowledge of the fluid mechanics and chemical kinetics of reacting flows, for application in issues related to energy and the environment.

## The 2022 Session

The 2022 session will offer the following seven courses (virtual):

- Fundamentals of flames
- Combustion chemistry and kinetic mechanism development
- Current status of ammonia combustion
- Soot
- Combustion fundamentals of fire safety
- Combustion in microgravity and microscale
- Mechanism reduction and stiff chemistry solvers

## Intended Participants

Graduate students, postdocs and faculty members in universities; combustion professionals in research organizations; R & D engineers in industries.

## Program Dates

Classes and enrichment activities will be held from Monday, July 11 to Friday, July 15, 2022

## Application

Due to the impact of the epidemic, the Summer School will be held online. Applications should be made online at http://www.cce.tsinghua.edu.cn/en/Outreach/Combustion_Summer_School/Overview.htm starting from Friday, April 1, 2022 to Saturday, April 30, 2022. Admission decisions will be sent by Monday, May 16, 2022. Admitted applicants will be notified of the date by which the registration fee is due to complete the registration. Late applications may be considered depending on space availability.

## Expenses

**Registration:** 500 RMB for students and 800 RMB for all other participants.

## Note on Course Selection

The courses on **Fundamentals of Flames** and **Combustion Chemistry and Kinetic Mechanism Development** are the foundational combustion courses, suggested to be taken by first-timers especially first-year students. The others are advanced, enrichment courses.

## Further Inquiries

For inquiries on the academic program or the logistics of participation, please contact the program administrator, Ms. Hong Tian, (86)10-62796768, ccess@tsinghua.edu.cn, or the program co-organizer,
Prof. Yu Cheng Liu, ycliu7@mail.tsinghua.edu.cn

## Course Descriptions (All times are Beijing times)

### Fundamentals of Flames (14:00~17:00, July 11~13)

**Lecturer: Professor Suk Ho Chung, KAUST, Saudi Arabia**

**Course Content:** This course aims at the understanding of fundamental characteristics of flames. It covers the molecular view of diffusion and reaction, governing equations, chemical kinetics, homogeneous explosion, premixed flame propagation, factors affecting premixed flames and extinction, basic structure of diffusion flames, droplet combustion and extinction, instabilities, flame stabilization in jets, autoignition in inhomogeneous systems, and understanding of engine fuel specifications.

### Combustion Chemistry and Kinetic Mechanism Development (19:00~22:00, July 11~15)

**Lecturer: Professor Tiziano Faravelli, Politecnico di Milano, Italy**

**Course Content:** The course aims at showing the main steps of the development of detailed chemical kinetic mechanisms to describe the oxidation of both fossil and bio fuels. To this goal, thermodynamics and kinetics fundamentals will be presented. Molecular and radical stability, classes of reactions, kinetic constant estimation, analogy and rate rules and lumping techniques will be discussed in detail. The course will cover hydrogen and simple fuels, expanding to large hydrocarbons, possibly oxygenated, to analyze their behavior, like ignition and laminar flame speed. Surrogate definition will allow discussion on the oxidation characteristics of real fuels. Mechanisms of the formation of main pollutants, like nitrogen oxides, polycyclic aromatic hydrocarbons and soot, will also be illustrated. Tools to support this mechanism development activity will be part of the course.

### Current Status of Ammonia Combustion (14:00~17:00, July 14~15)

**Lecturer: Professor William L. Roberts, KAUST, Saudi Arabia**

**Course Content:** There is considerable interest in understanding the combustion properties of ammonia. Ammonia may be an ideal means of transporting green and blue hydrogen from point of generation to point of use. To avoid the energy penalty and complexity of decomposing the ammonia back to hydrogen, there is interest in using it directly in IC engines, gas turbines, and industrial processes. In this lecture, we will review the issues with ammonia combustion (e.g., high autoignition temperature, low flame speed, narrow flammability range) and discuss the state of the art including kinetic mechanisms with an emphasis on NOx emissions, and important laminar and turbulent flame simulations and experiments. We will also discuss some of the practical issues associated with ammonia as a fuel, including co-firing with traditional fuels, partial cracking, nitridation, and health hazards. Currently operating large scale facilities for production, distribution, and use will also be discussed.

### Soot (14:00~17:00, July 11~12)

**Lecturer: Professor Markus Kraft, University of Cambridge, UK**

**Course Content:** The carbonaceous products of incomplete combustion have fascinated and frustrated many. Interest in their positive aspects like illumination, pigments and heating gave way to dissatisfaction as they filled our cities with toxic air. My lecture attempts to capture this fascination and frustration by examining one of the least well understood aspects of incomplete combustion: the formation of soot or carbon black. I shall briefly review the history of the field and discuss relevant areas in which soot and carbon black play an important role. In my lectures I will describe the formation of precursor, nanoparticle, primary particle, and aggregates with an emphasis on mathematical model building and the corresponding computational aspects.

### Combustion Fundamentals of Fire Safety (19:00~22:00, July 11~14)

**Lecturer: Professor José L. Torero, University College London, UK**

**Course Content:** The fire safety of our built environment, urban wildland interface and forests is underpinned by the combustion processes controlling fires. Fire is a combustion phenomenon that evolves in space and time that has the potential to negatively affect people and property. Fire safety is our capacity to affect this combustion phenomenon in a manner that damage can be controlled to levels acceptable to society. Like other combustion processes, fire is controlled by complex chemical kinetics occurring in degrading fuels (pyrolysis) and in the gas phase (combustion), is determined by turbulent transport covering a wide range of turbulent intensities and results in complex heat exchange processes. These processes are strongly coupled and cover time scales from the nano-second to hours and length scales from the micro-metre to kilometres. Through this course the different processes will be explored in the context of fire safety application. Case studies will be presented where the combustion principles behind fire will be used to explain the phenomena and to address the technologies commonly used to mitigate the destructive capability of the fire.

### Combustion in Microgravity and Microscale (14:00~17:00, July 14~15)

**Lecturer: Professor Kaoru Maruta, Tohoku University, Japan**

**Course Content:** The unique behaviors of nonadiabatic and super-adiabatic flames under microgravity or in microscale will be discussed by using experiment, modeling and simple flame theory. The flammability limit mechanism, ordinary flames, flame ball, weak flames, micro-scale flame dynamics and kinetics, flameless combustion, and lean ignition will be overviewed.

### Mechanism Reduction and Stiff Chemistry Solvers (08:00~11:00, July 13 and July 15)

**Lecturer: Professor Tianfeng Lu, University of Connecticut, USA**

**Course Content:** This course will provide an introduction to selected tools for mechanism reduction. Strategies and common pitfalls will be discussed for eliminating unimportant components from large reaction networks based on connectivity analyses and sensitivity analyses, identifying and solving for exhaust fast chemical processes based on time-scale analyses, optimization/tuning/training reduced models to fit selected targets, and developing analytic frameworks for automated differentiation and stiff chemistry solvers. Roles of such critical flame behaviors as ignition, extinction and premixed reaction front propagation in mechanism reduction will also be discussed.