UNNC - SARI, CAS Doctoral Training Partnership

It's essential that you have contacted the UNNC and/or SARI supervisors before applying.

Formal applications should follow the instructions in 'How to apply' section.

Research areas

1) Energy Storage and Conversion
2) Energy and Environment

Available PhD topics

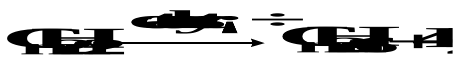
PhD topic	**Catalytic conversion of CO_2 into high value-added chemicals and fuel products**
SARI Supervisor	Wei Wei
UNNC Supervisor(s)	Xiaoxia Ou Xiaolei Fan
Short introduction & description of PhD project	The conversion of CO_2, an abundant carbon resource, into high value-added chemicals or liquid fuels is an attractive way to mitigate carbon emissions, which is also a sustainable approach for the cyclic utilization of carbon resources. However, the selective activation and controllable conversion of CO_2 is challenging because of the inertness of CO_2 and the high C–C coupling barrier. Although CO_2 can be hydrogenated to various chemicals, such as methanol, ethanol, dimethyl ether, liquefied petroleum gas, and low-carbon hydrocarbons, the lack of an efficient catalyst has made it difficult to achieve high CO_2 hydrogenation activity and controllable C–C bond coupling. To address this issue, this project will focus on i) developing novel catalytic systems with highly efficient catalysts to achieve CO_2 conversion into high value-added chemicals or fuel products and ii) investigating the catalytical mechanism through experimental study and computational simulation.
Contact points	Informal inquiries may be addressed to Nannan Sun (sunnn@sari.ac.cn) and Xiaoxia Ou (Xiaoxia.Ou@nottingham.edu.cn).
PhD topic	**Combined experimental and DFT understanding of CO_2/CH_4 conversion**
SARI Supervisor	Nannan Sun
UNNC Supervisor(s)	Muhammad Sajjad
Short introduction & description of PhD project	The increased use of fossil fuels and natural gas has led to the production of greenhouse gases (i.e., CO_2 and CH_4), which contribute to global warming. This has forced scientists to explore and identify technologies for converting CO_2 and CH_4 into

	alternative carbon-neutral and high value-added products. Catalytic conversion of CO_2/CH_4 is an attractive prospect because it can provide an alternative to fossil feedstocks and benefit the conversion and cycling of greenhouse gases on a large scale. Since the conversion of CO_2 requires hydrogen, while CH_4 conversion requires oxygen, the conversion of both gases is an ideal combination of an oxygenation reaction and a reduction reaction. To achieve this, a catalyst is required to facilitate the reaction. This project will focus on investigating the catalytical mechanism through experimental study and density functional theory calculation.
Contact points	Informal inquiries may be addressed to Nannan Sun (sunnn@sari.ac.cn) and Muhammad Sajjad (muhammad.sajjad@nottingham.edu.cn).
PhD topic	**Compact high-ratio high efficiency automotive EV/ HEV and rail planetary gear transmission**
SARI Supervisor	Dr. Yue Wu
UNNC Supervisor(s)	Prof. Dr. Christos Spitas, Dr. Richard Adjei, Dr. Adam Rushworth
Short introduction & description of PhD project	Currently the industry is aiming to integrate compact 50,000-80,000 rpm electromotors in EV/ HEV powertrains for automotive and rail traction drives, with practical limits reached at around 30,000 rpm because of the compliance of the transmissions, the complexity of the housings, and the resulting worsening system dynamics beyond that speed limit. Magnetic gear drives and other exotic solutions can meet the speed requirement, but are costly, heavy and lack the power density to fulfil this role. A new type of compact geared mechanical transmission is needed to break through the current technology barriers wrt lubrication and cooling, efficiency and dynamics. We propose a novel radially preloaded Wolfrom-type double-helical stub-tooth compound planetary configuration in a vacuum environment with atomised lubricant mist injected in-situ at the tooth mesh via the planet carrier to simultaneously achieve unprecedented efficiency, smooth dynamics and very low wear characteristics in an encapsulated, symmetrical and rigid externally cooled housing that may be incorporated with ultra-high-speed electromotors in automotive EV/ HEV and rail transmissions. Next to the contact mechanics and system dynamics, the effects of different lubricants on the lubricant film formation, cooling efficiency, and gear wear under vacuum will be studied. The investigation will use computational methods (FEA) for lubrication, contact mechanics and structural dynamics, to optimise the design parameters (tooth form, housing and lubrication circuit) and will extend to the electromotor + transmission system-level design. An in-the-loop system demonstrator model for the gearbox subsystem, integrated with a lubrication circuit, will be developed.
Contact points	Informal inquiries may be addressed to Prof. Dr. Christos Spitas (christos.spitas@nottingham.edu.cn) and Dr. Yue Wu (wuy@sari.ac.cn).
PhD topic	**Design of catalysts for selective degradation and conversion of polyolefin plastic into lubricants**
SARI Supervisor	Prof. Jiusheng Li
UNNC Supervisor(s)	Prof. Kok-Hoong Wong
Short introduction & description of PhD project	Polyolefin (mainly polyethylene and polypropylene), as nonbiodegradable plastics, exist in nature for a long time after being discarded causing serious pollution and entering the

	ecosystem through the biological cycle. Recently, the degradation of polyolefin and the recycling of carbon resources get growing concern. Therefore, the development of catalysts with high activity and selectivity for the degradation and conversion of waste polyolefin into clean fuels, lubricants and other high value-added chemicals has become a huge challenge. The core problem is how to destroy the high chemical stability of polymer carbon chains, selectively cleave the C-C bonds and controllably transform to valuable products. Zeolites with regular channels and adjustable acidity are a type of efficient catalysts wildly used in catalytic reactions. This project will focus on the design of metal and zeolites bifunctional catalysts with high activity and selectivity in polyolefin breakdown into valuable lubricant-range hydrocarbons.
Contact points	Informal inquiries may be addressed to Kok-Hoong Wong (Kok-Hoong.Wong@nottingham.edu.cn) and Jiusheng Li (lijs@sari.ac.cn).
PhD topic	**Development of an additively manufactured multifunctional SiC ceramic foam for Joule heated catalytic reactions**
SARI Supervisor	Dr Lei ZHENG
UNNC Supervisor(s)	Dr Kean How CHEAH Dr Yi NIE
Short introduction & description of PhD project	According to International Energy Agency (IEA), chemical industry is the largest energy consumer and the third largest direct CO_2 emission source. By using a suitable catalyst (such as Rh-, Pt-, and Ni-based), CO_2 reforming of methane provides significant environmental benefits as two major greenhouse gases, i.e. CO_2 and methane, are consumed to produce synthesis gas. By replacing fossil fuel combustion, Joule heating, driving by renewable energy, has intrinsically high thermal efficiency and ensures excellent heat transfer for endothermic reactions towards process intensification, making it an attractive strategy to implement in the catalytic reactor. Nevertheless, the issues of uniform heating, mechanical strength, and thermal stability of the state-of-the-art catalyst washcoated ceramic foam remain the key limitations for the development of a high-performance reactor system. This project aims to develop a multifunctional SiC based ceramic foam, which has the desired properties to serve as the key enabling tool for efficient Joule heated catalytic reactions. The research content will cover: (1) Formulation of a polycarbosilane based photopolymer resin mixture for 3D printing of precursor for SiC ceramic foam; (2) Characterizations of the multifunctional SiC ceramic foam to elucidate the catalytic activity, electrically conductivity, porosity, mechanical strength, etc; (3) Application of the newly developed SiC ceramic foam in a Joule-heated catalytic reactor and evaluation of its performance and efficiency. The potential PhD candidate is expected to work in both institutions. UNNC has the facilities for additive manufacturing studies while SARI has facilities for catalytic reaction related studies.
Contact points	Informal inquiries may be addressed to Dr Kean How CHEAH (kean-how.cheah@nottingham.edu.cn) and Dr Lei ZHENG (zhengl@sari.ac.cn).
PhD topic	**Electrocatalytic reduction of CO_2 in aqueous solutions under ambient conditions**

SARI Supervisor	Prof. Wei Chen
UNNC Supervisor(s)	Dr. Mengxia Xu
Short introduction & description of PhD project	Electrochemical CO_2 conversion to valuable chemicals is of significance as a research hotspot since it not only can convert CO_2 under mild conditions, but also store renewable electricity as high energy density chemicals, exhibiting great potentials for renewable energy consumption. In this project, a new strategy on CO_2 electroreduction to multicarbon oxygenates in acidic systems is proposed here using the porous copper-based catalysts. The copper active sites and gas-solid-liquid three phase interfaces will be designed and constructed to favor key intermediate formations and subsequent coupling reactions.
Contact points	Informal inquiries may be addressed to Dr. Mengxia Xu (Mengxia.Xu@nottingham.edu.cn) and Prof. Wei Chen (chenw@sari.ac.cn).
PhD topic	**Electrofermentation: a novel technology to improve 1,3-propanediol biosynthesis**
SARI Supervisor	Jian Hao
UNNC Supervisor(s)	Enrico Marsili
Short introduction & description of PhD project	1,3-Propanediol (1,3-PDO) is an important chemical with applications in the cosmetics, pharmaceutical, and especially polymer industries. 1,3-PDO can be produced by feeding glycerol to anaerobic bacteria, including *Lactobacillus* sp., without the need for expensive co-factors. However, the productivity is low, thus improvements of the microbial strain or the process are needed to increase the productivity, thus lowering the unit cost. The major limitations in anaerobic 1,3-PDO production are the slow growth and redox imbalance caused by the low potential of the terminal electron acceptor. Our recent work has shown that both limitations can be addressed through electrofermentation (EF). In EF, *Lactobacilli* biofilms are grown on conductive surface, like graphite or stainless steel, which are poised at mild oxidative potential (e.g., 0.4 V vs. Ag/AgCl), in presence of a biocompatible redox mediator that facilitate extracellular electron transfer between biofilm and the conductive surface. At this potential, the conductive surface serves as an effective electron acceptor, increasing the NAD+ pool, thus the growth rate and metabolic activity of *Lactobacilli*. Similar considerations apply to *Klebsiella* sp., as both microorganisms are weak electricigens, i.e., their metabolism can be driven by an applied electrochemical potential. In this project, the student will work with both supervisor to set-up and optimize a laboratory-scale EF system for production of 1,3-PDO. In the first part of the project (month 1-18), the candidate will work with Prof Hao (SARI) to choose a suitable strain for the process such as *Lactobacilli* sp. or *Klebsiella* sp. and determine the optimal process conditions in absence of electrochemical stimulation. The 1,3-PDO secreted will be characterised for purity and a preliminary process simulation study will be carried out. In the second part of the project (month 19-36), the student will work with Assoc Prof Marsili (UNNC) to set-up and optimize the EF based on the results of his/her work at SARI. It is expected to carry out local bioelectrochemical investigation of the *Lactobacilli* sp. or *Klebsiella* sp. biofilm to determine local reactivity and 1,3-PDO production, thus supporting the EF optimization study. If the lab-scale bioprocess is successful, an industrial partner for feasibility study and scale-up of the process to pilot scale will be identified in the Shanghai or Ningbo area. Both supervisors will fund the research expenses for this project. The PhD candidate will have access to high-end equipment and

	receive excellent training, which will help in securing a position in the Bioprocess industry at the end of the PhD or to engage in the academic career. Both supervisors are expert Biochemical Engineers with 40+ year combined experience in Bioprocess, Biofilm science, and Bioelectrochemistry. They have supervised to completion 8 PhD students. University of Nottingham Ningbo is the first Sino-foreign University in China, and comprise both international and Chinese scholars with strong research experience. China Beacons Institute is a newly opened research centre focused on ecological transition and sustainable technology. Shanghai Advanced Research Institute of Chinese Academy of Sciences (SARI) is a young research institute jointly established by Chinese Academy of Sciences (CAS) and Shanghai Municipal government in 2012. SARI focuses on innovative research and core technology R&D in the fields of accelerator science, photon science, energy science and information science.
Contact points	Informal inquiries may be addressed to Assoc Prof Enrico Marsili (enrico.marsili@nottingham.edu.cn) and Dr/Prof Jian Hao (haoj@sari.ac.cn).
PhD topic	**Encapsulated hydraulic multi-DOF mechanical actuation**
SARI Supervisor	Dr. Yue Wu
UNNC Supervisor(s)	Prof. Dr. Christos Spitas, Dr. Donglei Sun, Dr. Adam Rushworth
Short introduction & description of PhD project	We propose to develop a novel multi-DOF (3-6 DOF) mechanical actuation system using encapsulated hydraulic linear actuators in the form of bellows supported by sliding guide beams. By configuring the mechanism in a manner that allows both explicit forward and inverse kinematics, coupled with real-time adaptive control, we shall resolve long-standing accuracy, compliance and controllability problems of Stewart platform and other multi-DOF configurations, while achieving superior accuracy and larger working envelope. The design will be elaborated with CFD and structural FEA and MBD studies, including adaptive control, and will be demonstrated in a scaled multi-DOF hydraulic-mechanical test bed set up - also using a simpler electromechanical benchmark for comparison. Of particular significance to the study will be the hysteretic effects introduced by the fluidic system, where the hydraulic fluid (incl. air etc) plays a major role and its characterisation and testing will be a key point in the research. From a machine design and controllability point of view, this demands a multidisciplinary approach (mechanism theory – solid mechanics – fluid mechanics – control) and will overcome the main hinderance to-date for the use of power hydraulics in multi-DOF actuation systems and test beds, esp. at frequencies >30 Hz.
Contact points	Informal inquiries may be addressed to Prof. Dr. Christos Spitas (christos.spitas@nottingham.edu.cn) and Dr. Yue Wu (wuy@sari.ac.cn).
PhD topic	**High ratio high efficiency robotic drive rotary transmissions**
SARI Supervisor	Dr. Yue Wu
UNNC Supervisor(s)	Prof. Dr. Christos Spitas, Dr. Dunant Halim, Dr. Donglei Sun
Short introduction & description of PhD project	With increasingly accurate manufacturing processes becoming affordable at scale, cycloidal gear drives have been gaining prominence in rotary transmissions for robotic drives over involute planetary transmissions and strain wave transmissions due to their high stiffness, torque density and durability, among other characteristics. However, they

	introduce unwanted torque ripple, unduly high non-torque loads and corresponding friction losses, and are sensitive to errors in the centre distance, resulting in compromised dynamics, efficiency and heat management, accuracy/ precision, and overall controllability of the robotic system. To address these shortcomings, we propose to develop a novel high-ratio cycloidal drive with double-helical stub involute gear teeth in a self-balancing pre-loaded zero-backlash configuration and radial preloading using friction wheel elements with identical kinematics for unprecedentedly high-efficiency high-precision robotic transmissions. An integrated driver electronic circuit will be used in combination with machine learning to calibrate the system, in order to compensate for manufacturing variations and dynamic errors during operation based on reading by an absolute encoder on the electromotor side - in addition to feedback control options using external encoders. Next to the contact mechanics and system dynamics, the effects of different lubricants on the lubricant film formation, cooling efficiency, and gear wear will be studied – incl. steady state and transient effects. The investigation will use computational methods (FEA) for lubrication, contact mechanics and structural dynamics, to optimise the design parameters (tooth form, housing and circuit) and will extend to the electromotor + transmission system-level design. ML and control techniques will also be applied, resulting in highly versatile, dynamically stable, accurate, adaptive, controllable and cost-effective robotic systems. An in-the-loop system demonstrator model will be developed.
Contact points	Informal inquiries may be addressed to Prof. Dr. Christos Spitas (christos.spitas@nottingham.edu.cn) and Dr. Yue Wu (wuy@sari.ac.cn).
PhD topic	**High-efficient dehydroaromatization of alkanes to aromatics and pure hydrogen with metal-free catalysts**
SARI Supervisor	Prof. Zhao Hong
UNNC Supervisor(s)	Dr. Zhang Honglei
Short introduction & description of PhD project	n-Alkanes are by-products of both oil refining industry and coal to oil industry. Catalytic transformation of inexpensive and available n-alkanes to aromatics remains a significant and challenging task in current industrial and fine chemical processes. It is an ideal approach to molecular construction to directly transfer n-alkanes into the corresponding aromatics and four equivalents of hydrogen without any need for stoichiometric oxidants, hydrogen acceptors or functionalization of alkanes (Eq.1)  However, because of the poor reactivity of C (sp3)-H bonds, n-alkane aromatization is greatly challenged by the atomic economy, not to mention the dehydrogenation aromatization of saturated alkanes for eq.1. Catalysts play a privileged role in selective C-H bond activation, and dominating the reaction pathways to improve the selectivity. Recently, we found for the first time that P doped activated carbon catalysts (P@AC), could be used as metal-free acid catalyst to high-efficiently catalyze the dehydroaromatization of n-hexane to benzene and hydrogen. The unrivalled direct aromatization of n-alkane, to our knowledge, has never been reported before. This project plans to concentrate on exploring the active sites, catalytic mechanism, and catalytic processes of P@C catalysts over the dehydroaromatization reactions to

	reveal the unprecedent performance of P@C and unravel the basic electronic features of the C-H cleavage process to the targeted aromatics, and to develop a new type of metal-free catalytic materials, which selectively activate C-H bonds but not C-C bonds for the dehydroaromatization of Cn n-alkanes with n > 6 into aromatics and hydrogen gas ahead of the world.
Contact points	Informal inquiries may be addressed to Prof. Zhao Hong (zhaoh@sari.ac.cn) and Dr. Zhang Honglei (Honglei-zhang@nottignham.edu.cn).
PhD topic	**Integration of compressor-turbine rotors and fluidic (aero/ hydro-static) bearings, incl. lubrication and cooling**
SARI Supervisor	Dr. Yue Wu
UNNC Supervisor(s)	Dr. Richard Adjei, Prof. Dr. Christos Spitas
Short introduction & description of PhD project	Although micro-turbines, esp. when combined with alternate clean fuels, are a very promising solution for efficient, power-dense and sustainable propulsion and have good service intervals, they fail frequently due to improper lubrication and inadequate internal clearance for the bearing system. Bearing failure in turn impacts the component's friction and fatigue life. Air bearings (and hydrostatic bearings for higher loads in compact configurations) are known to reduce friction to nearly zero with no heat build-up. However, current fluidic bearing design implementations are complex, can be prone to 'whirl' instability and have not been successfully applied to compressor-turbine systems. We envision a 3-d printed integrated compressor-turbine system featuring a single integrated rotor and mounted on antagonistic preloaded hydrostatic bearings, having a multifunctional role in a) providing stiffness, vibration damping and dynamic stability across a wide range of operating speeds, incl. by introducing a redundant bearing in the configuration, having a different-sized gap, to introduce an essential non-linearity into the system and prevent 'whirl' instability typ. of similar bearing configurations, b) effective dynamic sealing of the compressor and turbine circuits, c) cooling and prevention of wear – by eliminating component friction and improper lubrication that leads to heat build-up. The design will be elaborated with multiphysical CFD, structural FEA and MBD studies, incl. heat transfer, and will be demonstrated in a micro-turbine system-in-the-loop set up. The proposed innovative architecture, combined with the affordances of 3-d printing to provide the very complex monolithic component geometries required by the same, will drastically reduce the size, complexity and cost of compressor-turbine systems and increase their robustness, efficiency and dynamical performance, allowing the realisation of unprecedentedly compact power powertrains, incl. hybrids, with applications to high performance fixed-wing, rotor-wing ad tilt-rotor aircraft and UAVs, and liquid fuel rocket engines, as well as a host of marine, automotive and rail applications.
Contact points	Informal inquiries may be addressed to Dr. Richard Adjei (richard-amankwa.adjei@nottingham.edu.cn) and Dr. Yue Wu (wuy@sari.ac.cn).
PhD topic	**Torque-density-, vibration- and efficiency- optimised planetary gear aircraft transmission**
SARI Supervisor	Dr. Yue Wu

UNNC Supervisor(s)	Prof. Dr. Christos Spitas, Dr. Richard Adjei, Dr. Shanshan Long
Short introduction & description of PhD project	Aircraft transmissions (geared turbofan, turboshaft, geared electric fan, auxiliary), typ. operating at scales of tens of MW and few tens of thousands rpm, are generally limited by the efficiency of the gears, insofar as it is very difficult to manage the lubrication and dissipate the produced heat. To address this, we propose a radical air-cooled design, whereby external air from the fan inlet carrying an in-situ injected oil mist is driven directly at the tooth interface, with the cyclone effect of the outgoing air flow used to recover the oil as the heated air is ejected. Where normally the presence of air would contribute only to windage losses, with this design it serves an essential convective heat transfer effect. The effects of different lubricants on the lubricant film formation, cooling efficiency, and gear wear will be studied – incl. steady state and transient effects. This radical innovation is expected to reduce the complexity and weight of the transmission considerably, while improving cooling and load capacity. The investigation will use computational methods (FEA) for coupled heat transfer and fluid dynamics (inlet air flow, mist dispersion, lubricant film formation, outlet and cyclone separation), next to contact mechanics and structural dynamics, to optimise the design parameters (tooth form, housing and fluid circuit) and will extend to the aeroengine system-level design. An in-the-loop scaled system demonstrator model for the gearbox subsystem, integrated with an open airflow circuit, will be developed. This technology can play a crucial role to enable the Chinese industry to develop native geared turbofan high bypass ratio engines, e.g. for C929, and meet the ambitious aviation emissions goals that have been set for the coming decades.
Contact points	Informal inquiries may be addressed to Prof. Dr. Christos Spitas (christos.spitas@nottingham.edu.cn) and Dr. Yue Wu (wuy@sari.ac.cn).