Helmholtz - OCPC - Programme 2017-2021
for the Involvement of Postdocs in Bilateral Collaboration Projects with China

PART A

Title of the project:
Lignin degradation of lignocellulosic biomass in a two-stage semi-continuous process

Helmholtz Centre and institute:
Karlsruhe Institute of Technology (KIT), Institute of Catalysis Research and Technology (IKFT)

Project leader:
Prof. Nicolaus Dahmen, Institute of Catalysis Research and Technology (IKFT)
KIT- Hermann-von-Helmholtz-Platz 1
76344 Eggensten-Leopoldshafen

Web-address: www.ikft.kit.edu

Description of the project (max. 1 page)**:**

In order to produce platform chemicals from renewable, biogenic resources new biorefinery concepts for lignocellulosic material need to be established. There are two general routes to split lignocellulose in its main fractions' cellulose, hemicellulose and lignin: Route A to solve the lignin in a first step like the in the conventional pulping processes or by the organosolv process. By route B mono-sugars are directly obtained from cellulose and hemicellulose via acid hydrolysis. In most approaches the biotechnological usage of cellulose derived glucose is prevailing and the recovery and further decomposition of lignin is applied in a separate downstream process like the hydrothermal or base catalyzed lignin depolymerization. In this work the focus is on the lignin conversion, in which both biorefinery approaches will be compared. For the organosolv process a new, innovative approach will be followed, allowing for continuous processing, which is most relevant in regard to further process development. By using miniplant equipment, relevant for scale-up, the process fundamentals should be elaborated in the project. Conversion rates and kinetic in dependence of temperature, catalyst concentration, flow rates, solvent composition and other parameters need to be quantified and optimized. Not also the products obtained in the effluent, but also the quality of the remaining, carbohydrate fraction (e.g.

in terms of hydrolysability to produce glucose) are to be evaluated.
In process A, in a first step, lignocellulosic material will be delignified by organosolv pulping conditions supported by phosphoric acid. The biomass is subjected to a 100 ml reactor and is purged by the pulping solution in order to solve and degrade the lignin, which is fragmented to mono-phenolic compounds, dimers and trimers and, to lesser extent, into oligomers of higher molecular weight. Additionally, this reaction is accompanied by the degradation and solution of hemicellulose. In a consecutive reactor the solved hemicellulose will serve as reducing agent and internal hydrogen donor in a catalytic reaction with the help of Pd-catalyst on a carbon carrier. Additionally, alternative catalysts will be tested based on chars from pyrolysis as solid support material. The remaining cellulose can be enzymatically hydrolyzed to glucose.
In the second approach, B, hydrolysis lignin from acid hydrolysis gained from the University of Hohenheim will be subjected into the semi-batch reactor for hydrothermal liquefaction (HTL). The hydrolysis lignin is the residue after extraction of the sugars from lignocellulosic material in order to convert them into Hydroxymethylfurfural and Furfural. It is not expected that the mild organosolv pulping conditions can be applied to the hydrolysis lignin, because it is already thermochemical treated, therefore the reaction conditions should be close to hydrothermal liquefaction conditions of temperatures and pressures around 350 °C and 250 MPa, respectively. KIT has already experience with the HTL of lignin, but not in a semi-batch approach with consecutive catalytic reduction.

Innovation:
Treating lignocellulose in continuously operated devices usually leads to problems due to particulates and solid depositions formed during the reactions or left over from the feedstock. This hinders steady-state operation as required for long-term experiments (e.g. to evaluate catalyst performance and kinetic measurements) and further scale-up for process development to higher Technology Readiness Levels.
Also, the yield of monomeric aromatic compounds of lignin decomposition reactions is usually much lower than the theoretical yield. Catalytic hydrogenation by using carbohydrates from hemicellulose appears as elegant approach to facilitate the production of higher amounts of mono-phenolic compounds.

Scientific questions:

- What are the optimum reaction conditions for both biorefinery approaches?
- How large is the effect of internal hydrogen transfer facilitated by hemicellulose?
- Can Pd/C be substituted by cheaper catalysts based on biochar?
- Which biorefinery concept is better to gain mono-phenolic compounds?

Preliminary work plan

- Route A: Adaption of an existing miniplant. Determination of optimized reaction conditions for both reaction units. Catalyst variations: commercial Pd/C catalyst versus pyrolysis chars doped with Pd, product characterization

KIT – International Affairs (INTL) Contact: Oliver Kaas Phone: +49 721 608 45323 Email: oliver.kaas@kit.edu

- Route B: construction of a high-pressure semi batch reactor for liquefaction of lignin under near critical conditions (250 MPa), Determination of optimized reaction conditions for both reaction units. Catalyst variations: commercial Pd/C catalyst versus pyrolysis chars doped with Pd, product characterization
- Comparison of both approaches: Techno-economic assessment for both approaches, derive further demand on research and development

Description of existing or sought Chinese collaboration partner institute:

Required qualification of the post-doc:

- PhD in chemistry or chemical engineering,
- Experience with biomass conversion, in particular lignocellulose utilization, lignocellulose biorefining, pulping, organosolv or hydrothermal processing of biomass
- Additional skills in chemical characterization like gas chromatography, Mass spectrometry, HPLC, size exclusion chromatography,

PART B

Documents to be provided by the post-doc, necessary for an application to OCPC via a postdoc-station in China, which is affiliated to a research institution like a university:

- Detailed description of the interest in joining the project (motivation letter)
- Curriculum vitae, copies of degrees
- List of publications
- 2 letters of recommendation
- Proof of command of English language

All documents are included in separate PDF-document.

PART C

Additional requirements to be fulfilled by the post-doc:

- Max. age of 35 years
- PhD degree not older than 5 years
- Very good command of the English language
- Strong ability to work independently and in a team

All requirements are fulfilled by the applicant. The confirmations are attached in the separate document.

KIT – International Affairs (INTL) Contact: Oliver Kaas Phone: +49 721 608 45323 Email: oliver.kaas@kit.edu