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Ash and bed material research in fluidized bed gasification of biomass from lab- to industrial scale

Matthias Kuba

COMET

Competence Centers for Excellent Technologies

Research locations

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Topics:

- Ash chemistry
- Ash – bed material interaction
- P-rich feedstock
- P-recovery

Ash research at lab- to pilot scale

Equipment from lab- to pilot-scale

Micro

4mm micro-scale apparatus for catalysis and kinetic investigations,.

Lab BFB

5cm lab-scale fluidized bed reactor for investigation of agglomeration behavior

Bench BFB

14cm bench-scale fluidized bed reactor for long-term (40 h) investigation of ash chemistry

100kW DFB

100kW dual fluidized bed (DFB) reactor for investigation of ash chemistry in DFB gasification

Pilot DFB

300kW dual fluidized bed reactor for long-term experiments with utilization of product gas in downstream process chains.

+ complete process chains

EXISTENT | PLANNED

Ash research at industrial-scale gasification plants

8 MW
demonstration plant
Güssing

8.5 MW
commercial plant
Oberwart

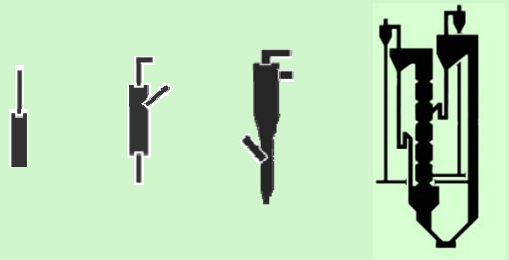
15 MW
commercial plant
HGA Senden

Development through scientific research

1.) Sampling, measurements

Industrial-scale

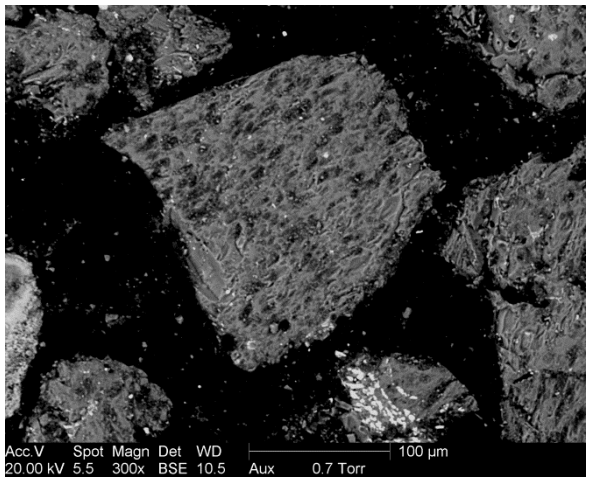
2.) Investigations, experiments



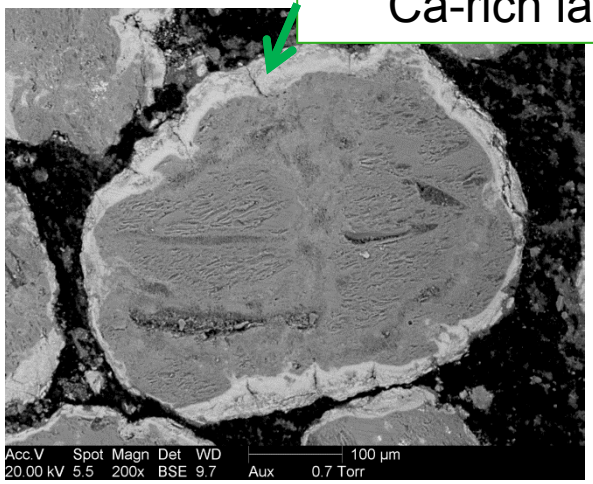
Lab-scale

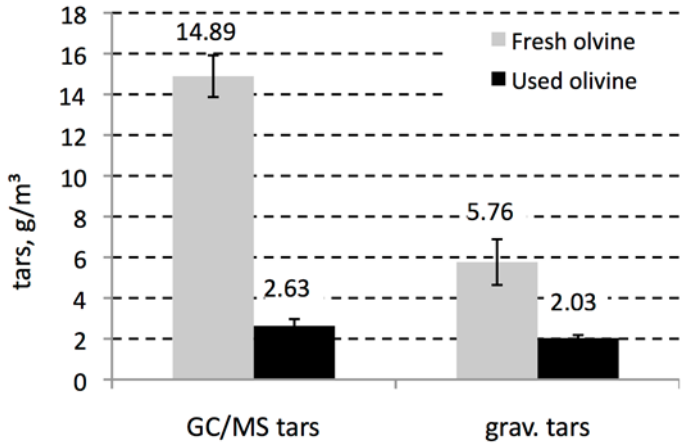
3.) Implementation measures

Bed material – ash intraction in gasification



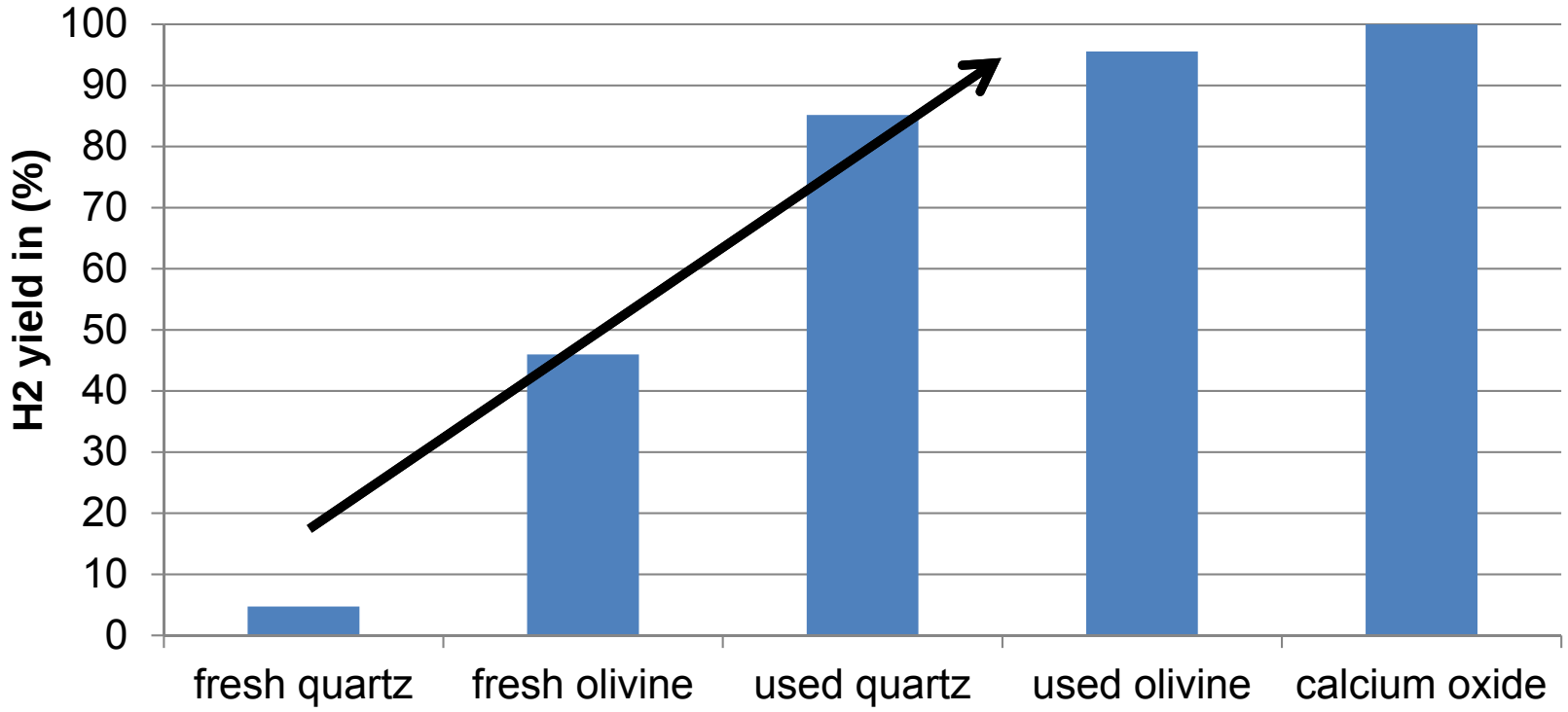
Interaction with biomass ash





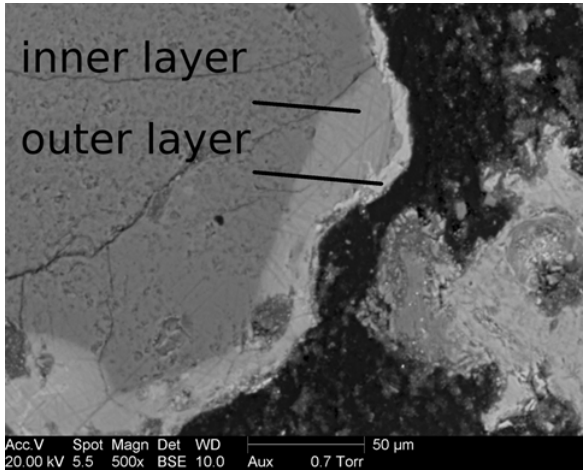
H_2 production based on CaO (benchmark)
Water-gas-shift reaction (800°C)

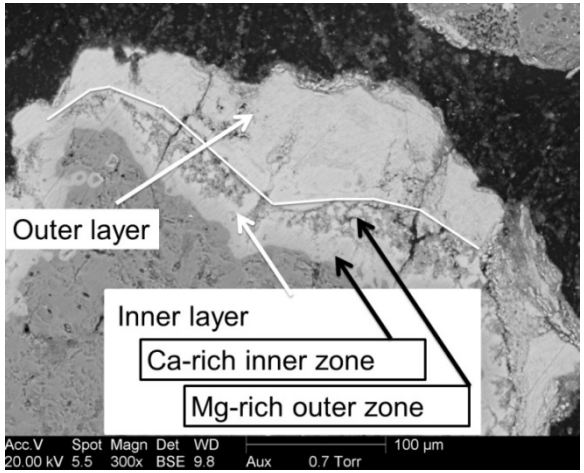
$$CO + H_2O \rightarrow CO_2 + H_2$$

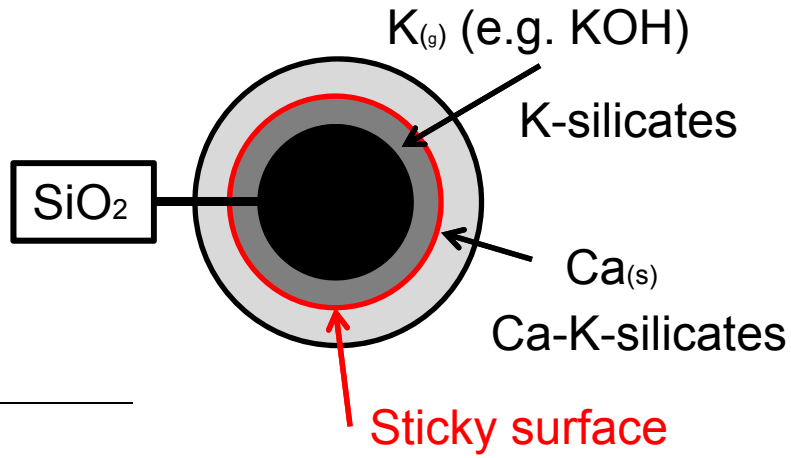


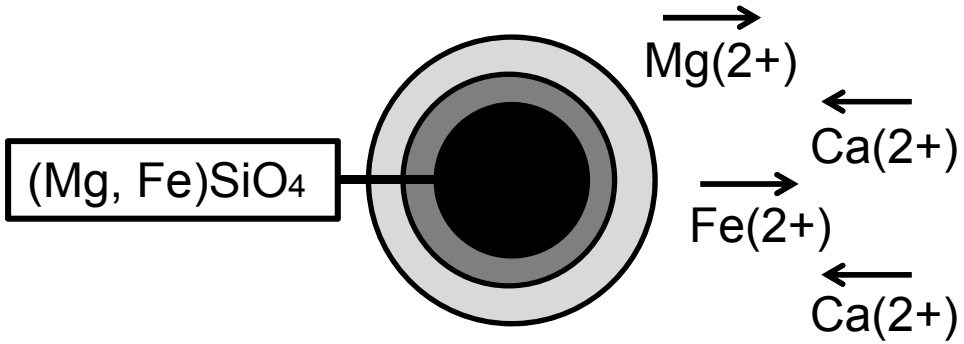
Also proven for steam reforming of tar model compounds!

Layer formation mechanisms (quartz vs. olivine)

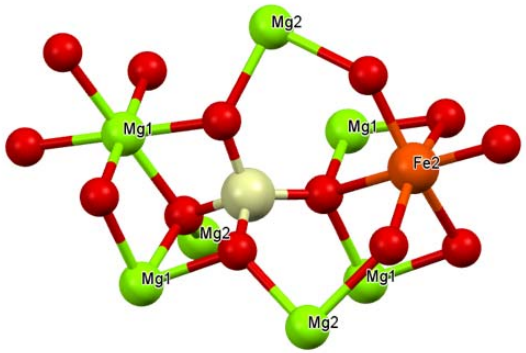


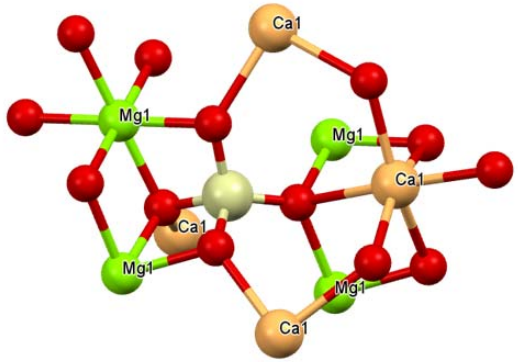






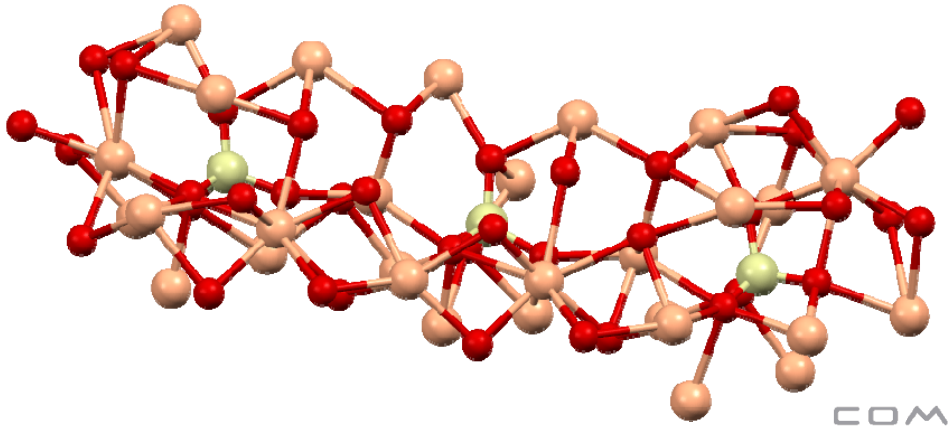
Substitution reaction (olivine)



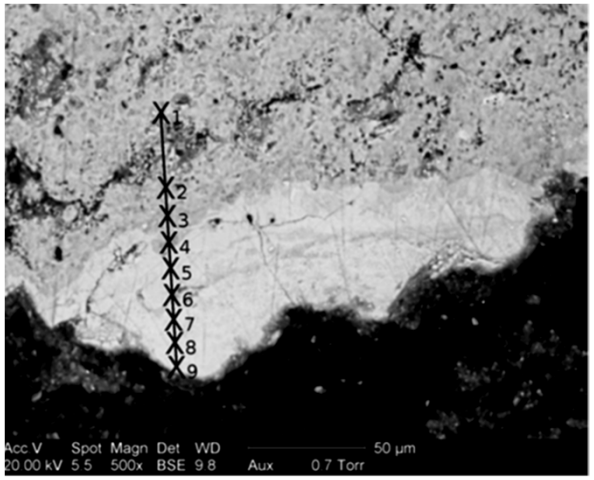


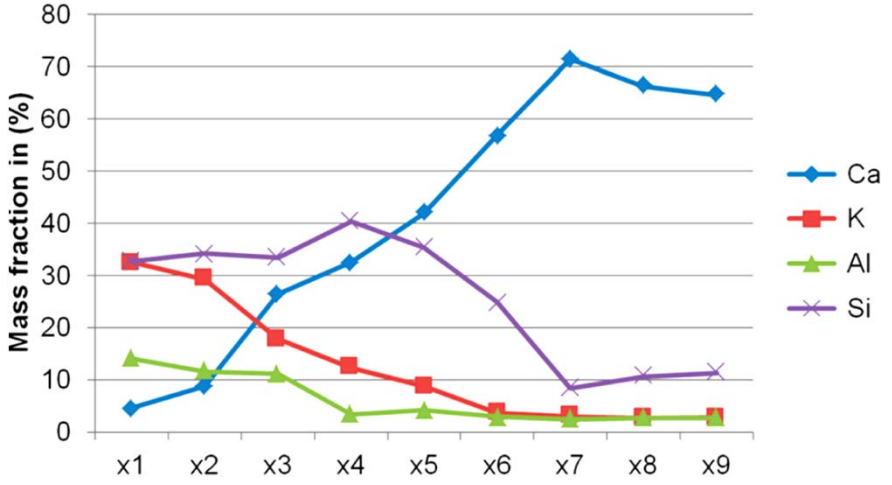
- Simple substitution reaction:
  Ions located at one of the exchangeable sites M1 or M2 in the crystal structure of olivine
- Ca(2+) substitutes Fe(2+) and Mg(2+)

Crystal structure of complete substitution: $CaSiO_4$



Layer formation (K-feldspar)

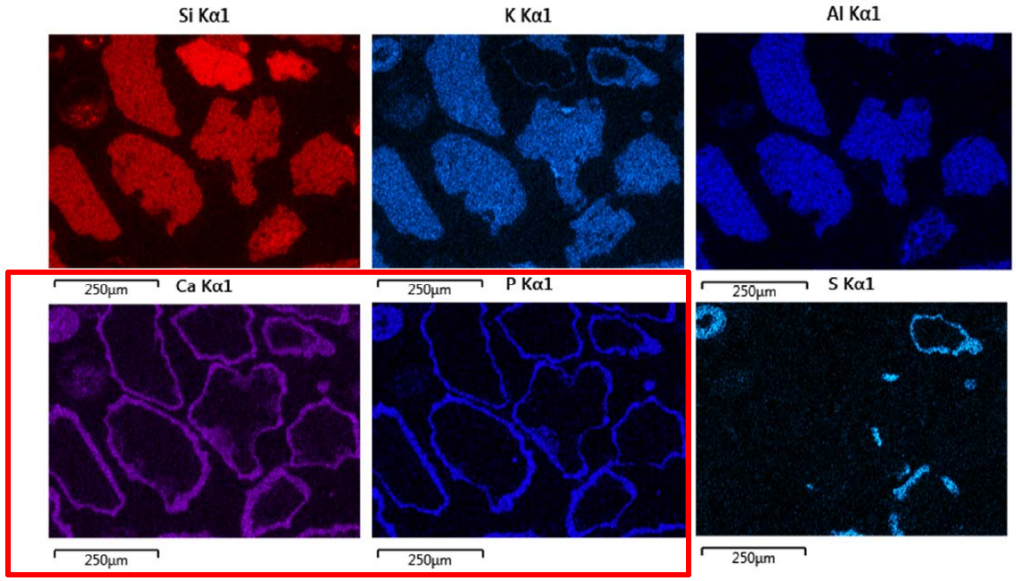




- Current investigation:

  Coupled substitution reaction involving Ca(2+) and K(1+)

Ash chemistry using P-rich feedstock



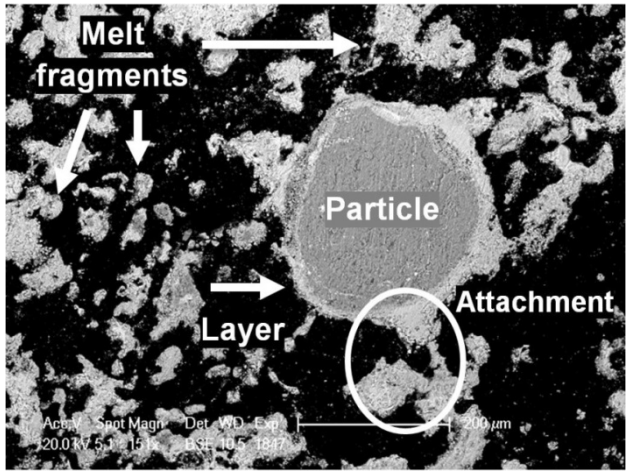
Bed material: **K-Feldspar**

Feedstock: **Chicken manure**

Phosphate formation strongly influences ash chemistry and layer formation!

Problems to avoid in long-term operation

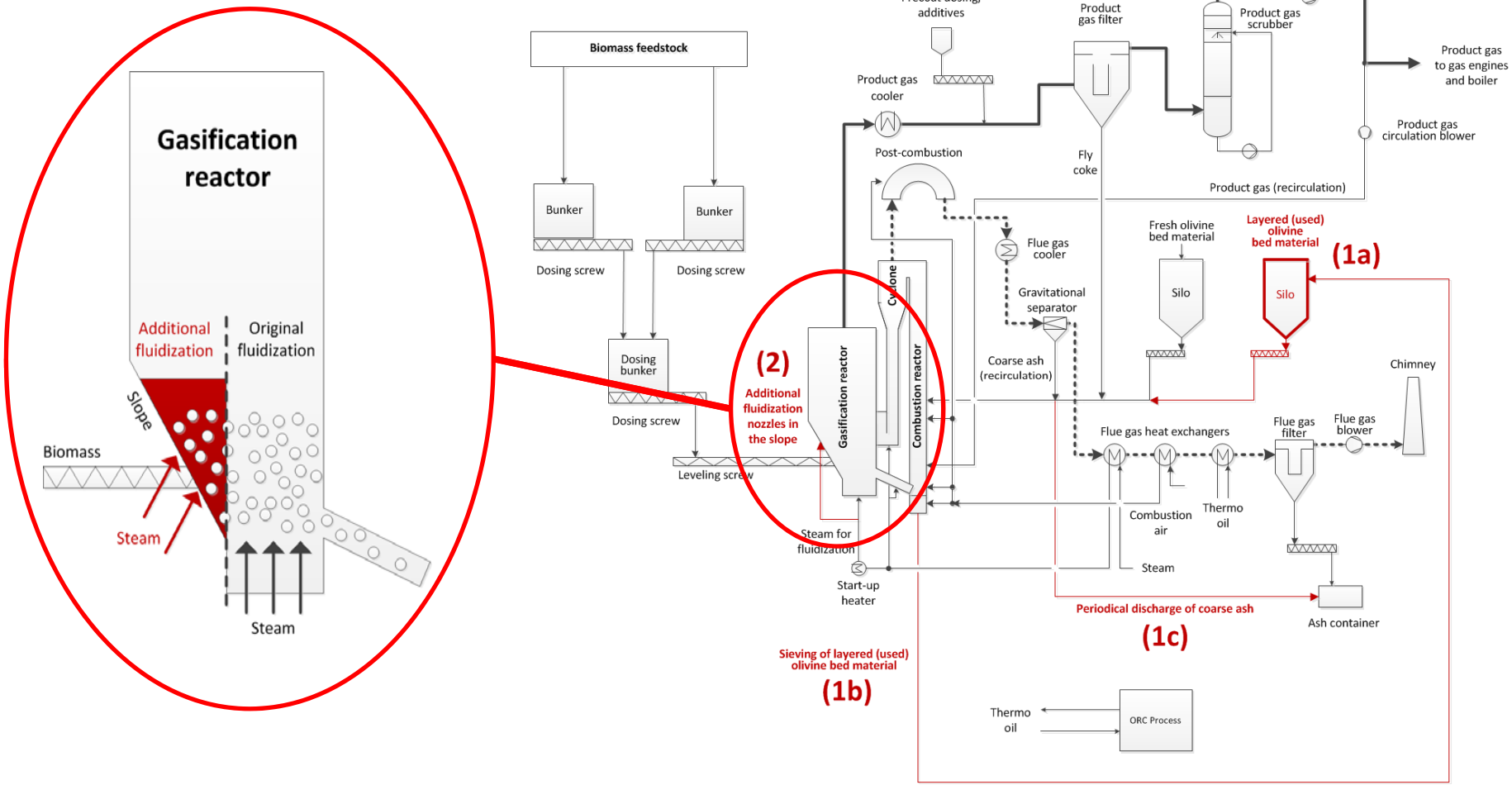
Deposit formation (post-combustion chamber)



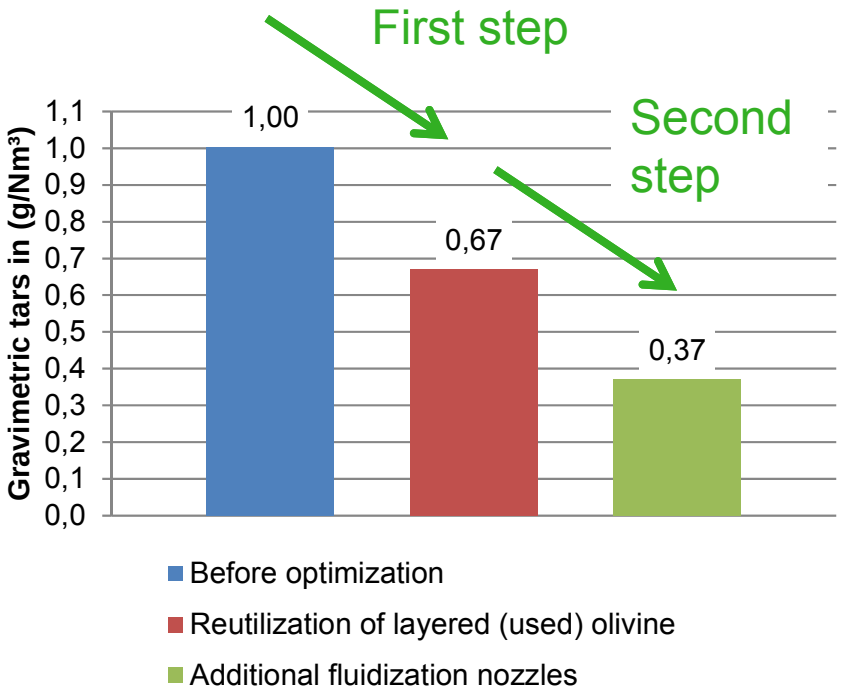
SEM-image

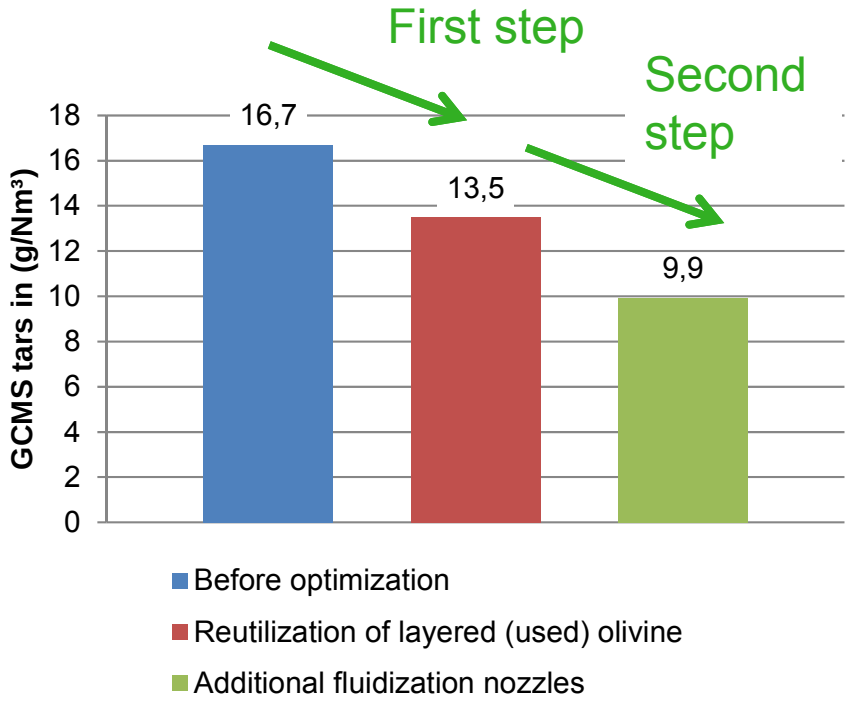
	Deposit average	Bed material average	Coarse ash average	Fine ash average	Fly coke average	Impurities average
			mass ratio in (%)			
NiO	0.0	0.2	0.2	0.0	0.2	1.6
Fe_2O_3	2.4	6.8	6.3	2.0	6.5	2.5
Cr_2O_3	0.1	0.2	0.2	0.1	0.2	0.6
CaO	34.0	13.8	11.0	54.6	16.5	22.9
K_2O	5.1	0.7	0.9	2.9	0.9	8.2
SO_3	0.1	0.1	0.1	0.4	0.1	0.3
P_2O_5	0.9	0.3	0.3	1.5	0.3	0.4
SiO_2	40.8	34.3	38.1	22.8	34.6	47.0
Al_2O_3	4.3	0.9	1.1	3.1	1.0	5.6
MgO	10.5	39.5	40.5	10.3	38.2	4.7
Na_2O	1.1	2.2	0.8	1.0	0.9	3.9
$Others$	0.7	1.0	0.5	1.3	0.6	2.3
Sum	100.0	100.0	100.0	100.0	100.0	100.0

Optimization measures in industrial-scale DFB



Results of optimization





Outlook

- **Selection of alternative bed materials**
  - Clarification of mechanism
  - Prerequisites for catalytic activity

- **Broaden the feedstock spectrum**
  - P-rich residues (e.g. manures, sewage sludge)
  - Agricultural residues (e.g. straw)
  - Industrial residues (e.g. lignin)

Journal papers on those topics

Published:

- Kuba, M., Kraft, S., Kirnbauer F., Maierhans F., & Hofbauer, H. (2017). *Influence of* ***controlled handling of solid inorganic materials and design changes*** *on the product gas quality in DFB gasification of woody biomass*, Applied Energy
- Kuba, M., He, H., Kirnbauer, F., Skoglund, N., Boström, D., Öhman, M., & Hofbauer, H. (2016). ***Mechanism of Layer Formation on Olivine*** *Bed Particles in Industrial-Scale Dual Fluid Bed Gasification of Wood*. Energy & Fuels, 30(9), 7410-7418.
- Kuba, M., He, H., Kirnbauer, F., Skoglund, N., Boström, D., Öhman, M., & Hofbauer, H. (2016). *Thermal stability of* ***bed particle layers on naturally occurring minerals*** *from dual fluid bed gasification of woody biomass*. Energy & Fuels, 30(10), 8277-8285.
- Kuba, M., Kirnbauer, F., & Hofbauer, H. (2017*). Influence of coated olivine on the* ***conversion of*** *intermediate products from decomposition of biomass* ***tars during gasification***. Biomass Conversion and Biorefinery, 7(1), 11-21.
- Kuba, M., Havlik, F., Kirnbauer, F., & Hofbauer, H. (2016). *Influence of bed material coatings on the* ***water-gas-shift reaction and steam reforming*** *of toluene as tar model compound of biomass gasification*. Biomass and Bioenergy, 89, 40-49.
- Kuba, M., He, H., Kirnbauer, F., Boström, D., Öhman, M., & Hofbauer, H. (2015). ***Deposit build-up*** *and ash behavior in dual fluid bed steam gasification of logging residues in an industrial power plant*. Fuel processing technology, 139, 33-41.

Submitted or in preparation:

- Kuba M. & Hofbauer H. *Experimental* ***parametric study*** *in industrial-scale dual fluid bed gasification of woody biomass: Influences on* ***product gas and tar composition****.* Biomass and Bioenergy, submitted
- Wagner et al. ***Layer formation, K-feldspars, P-rich biomass*** *(chicken manure)*
- Häggström et al. ***P-chemistry, P-distribution*** *(chicken manure)*

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K1-Zentrum im Rahmen des COMET Programms
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ideen mit zukunft

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