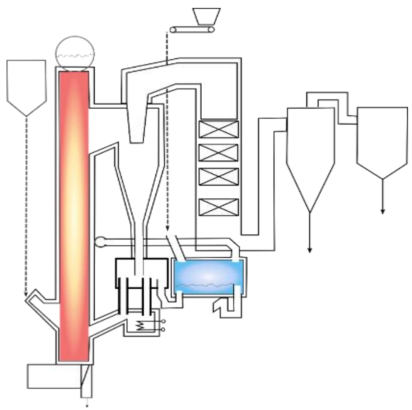
Bed material-alkali interactions during fuel conversion in fluidized bed

Pavleta Knutsson

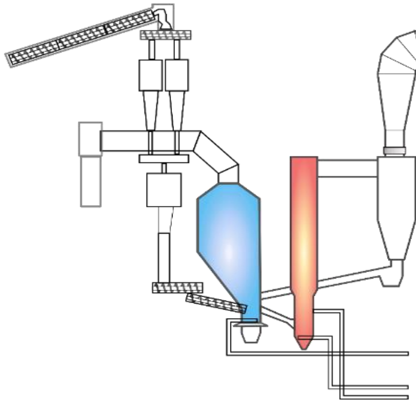
Through curiosity and knowledge
towards a sustainable world

Gasification units in Gothenburg

Chalmers Unit



GoBiGas Unit



	Bed inventory	Temperature in the bed, gasifier [°C]	Fuel flow, [kg daff /h]	Fluidization level [kg_{steam}/h]	Temperatur in the boile [°C]
Chalmers	Olivine	810	268	160	880
GoBiGas	Calcinated Serpentine	870	4600	2300	960

Bed materials:
Sand, bauxite, feldspar, ilmenite, manganese ores, iron ores
Fuel:
Coal, biomass, waste,

Bed material role in fluidized bed

Gasification

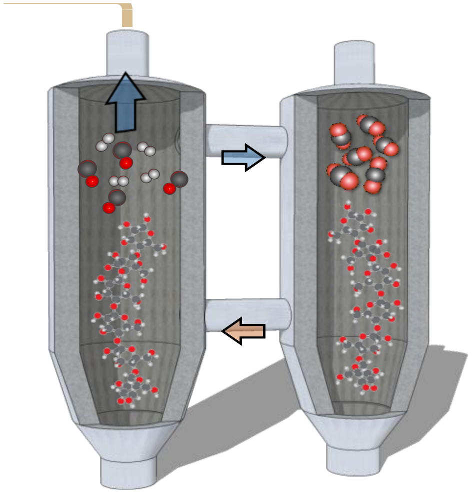
- Tar formation in the product gas
- Agglomeration

Bed material role

✓ Tar removal – catalytically active material

✓ Low agglomeration potential

Olivine , $FeMgSiO_4$



Combustion

- Hot and cold spots in the reactor
- Agglomeration

Bed material role

✓ Oxygen transport within the reactor

✓ Low agglomeration potential

Ilmenite, $FeTiO_3$

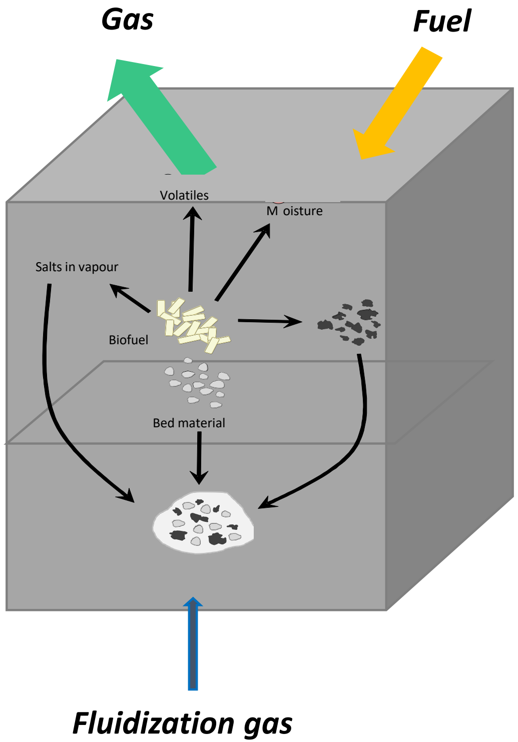
Bed materials

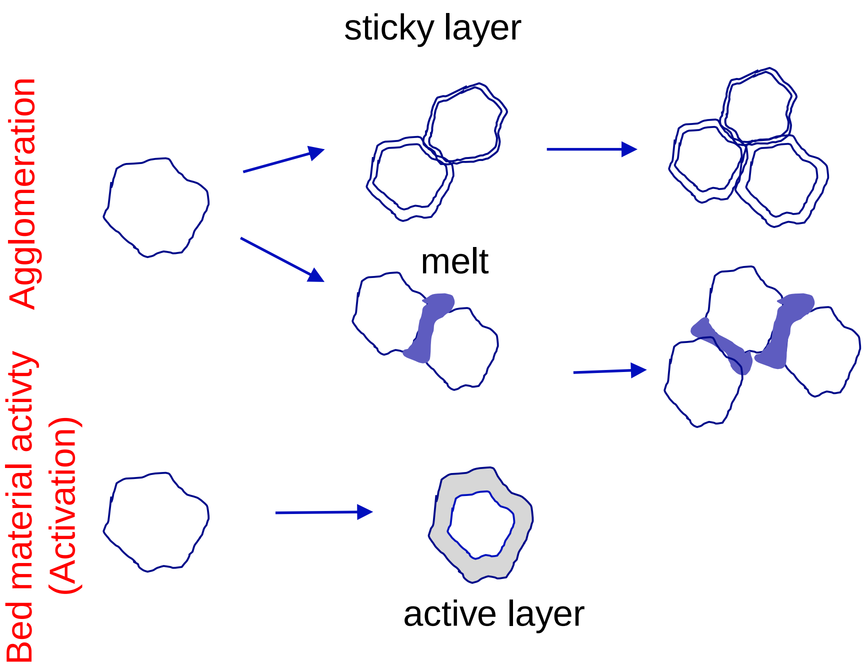
Sand, bauxite

Biomass components

K and Ca

Bed material interactions

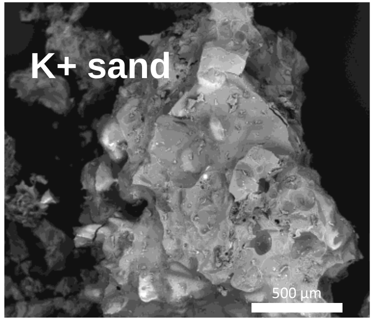


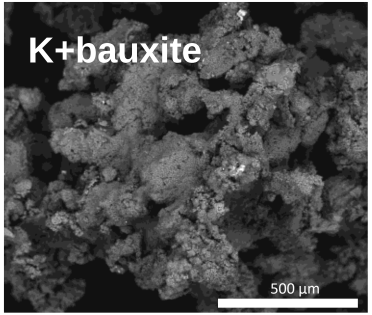


- Bed material interactions are crucial for both agglomeration and activation

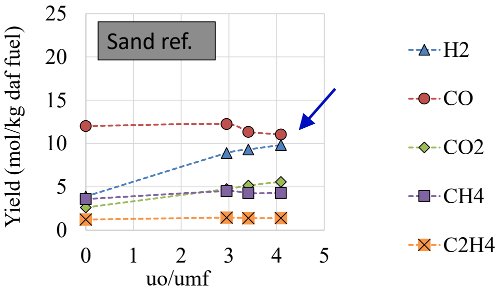
Role of Ca and K for agglomeration

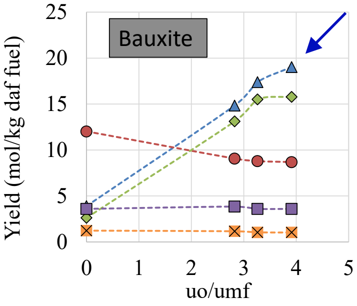
	Bed material + ash	XRD	FactSage	Agglomeration potential
K^+	K_2CO_3+silica sand	$KSiO_4$	$K_2Si_2O_5$(s)	strong
K^+	K_2CO_3+bauxite	$KAlO_2$	$KAlO_2$ (s)	medium
K^+	K_2CO_3+silica sand+bauxite	$KAlSiO_4$	$KAlSiO_4$ (s), $KAlO_2$ (s)	medium
Ca^{2+}	$CaCO_3$ + silica sand	$CaCO_3$, SiO2	Equilibrium composition not obtained	none
Ca^{2+}	$CaCO_3$+bauxite	$CaCO_3$, Al_2O_3, AlO(OH)	$CaAl_2O_4$	none
Ca^{2+}	$CaCO_3$+silica sand+bauxite	$CaCO_3$, SiO_2, Al_2O_3, AlO(OH)	$CaAl_2Si_2O_8$ (s), $Ca_2Al_2SiO_7$ (s)	none

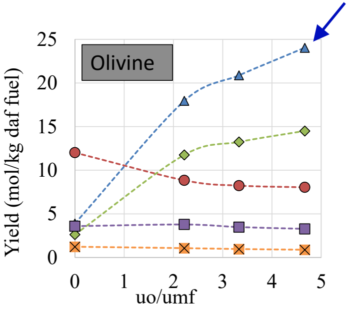




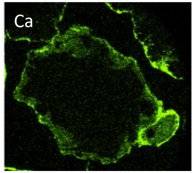
Role of Ca for material activation

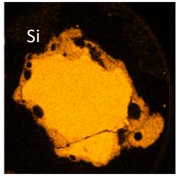




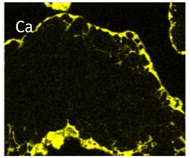


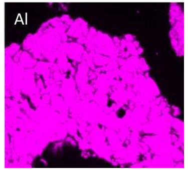
Courtesy of Teresa Berdugo



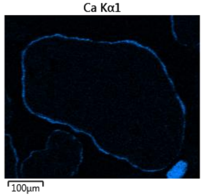


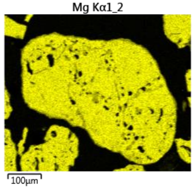
Silica sand





Bauxite



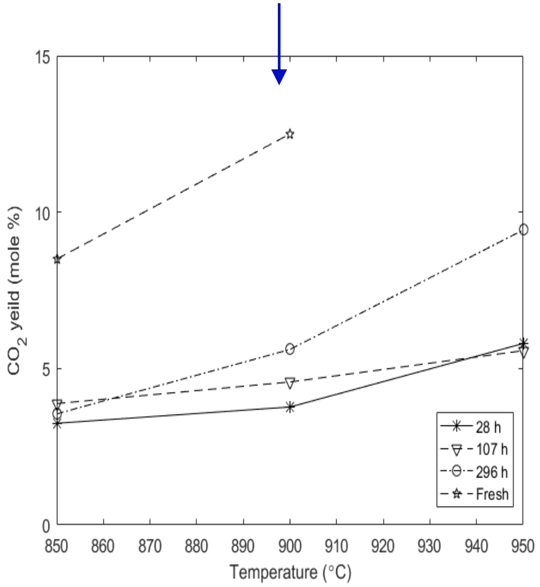


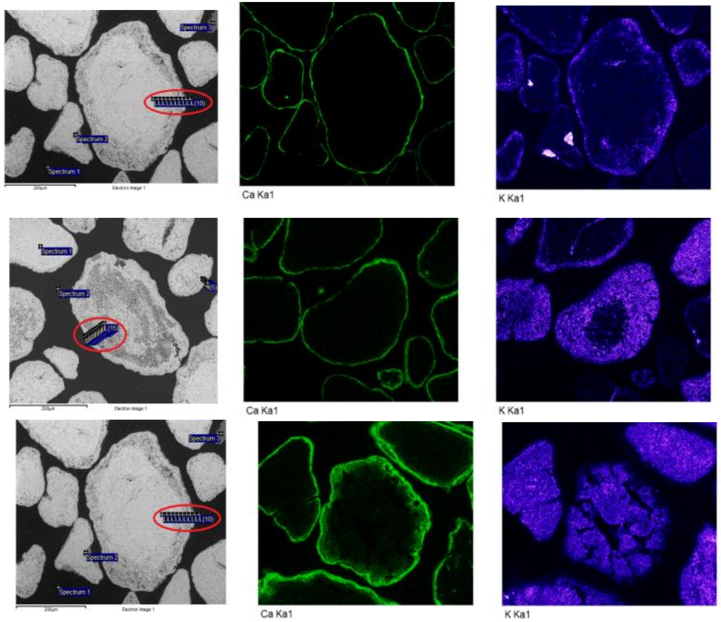
Olivine

- Ca-layer has been observed at ”active” state around multiple bed materials particles

Knutsson, P., Schwebel, G., Steenari, B.M., Leion, H. Effect of bed materials mixing on the observed bed sintering (2014) CFB-11: Proceedings of the 11th International Conference on Fluidized Bed Technology, pp. 655-660.

Combustion – ilmenite case, activation





24h

107h

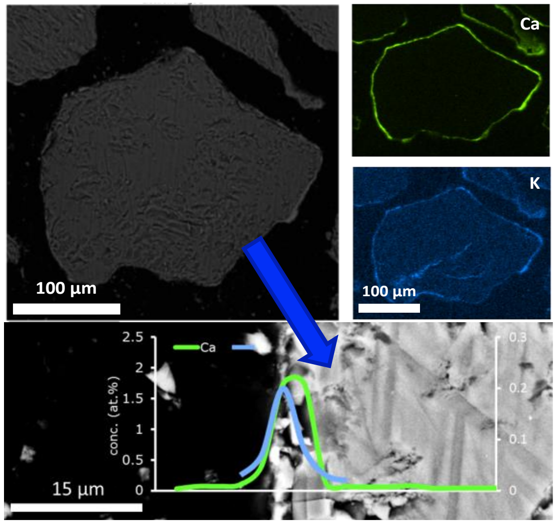
296h

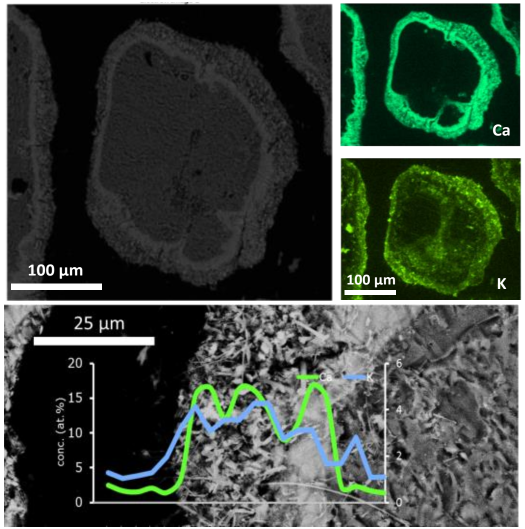
Courtesy of Angelica Corcoran

- No agglomeration is observed
- Oxygen carrying ability increases with time of exposure
- K,Ca-enriched layer (ash layer) increase in thickness with time of exposure

Corcoran, A., Marinkovic, J., Lind, F., Thunman, H., Knutsson, P., Seemann, M. Ash properties of ilmenite used as bed material for combustion of biomass in a circulating fluidized bed boiler (2014) Energy and Fuels, 28 (12), pp. 7672-7679

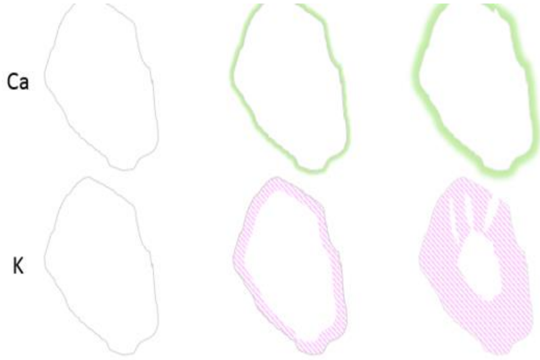
K and Ca distribution in the coating





- Ca and K signal found at the same locations in the outer layer

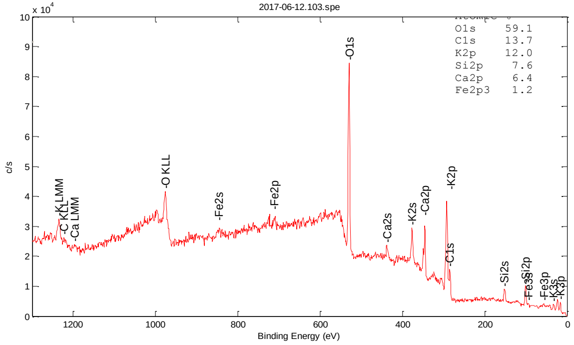
Coating changes with time

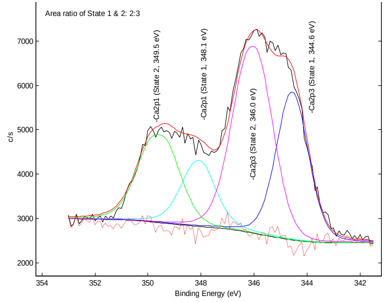


SiO_4^{4-}
AlO_2^{-}
O^{2-}
or?

- Ca and K signal found at the same locations in the outer layer

Ca and K state in the formed layers

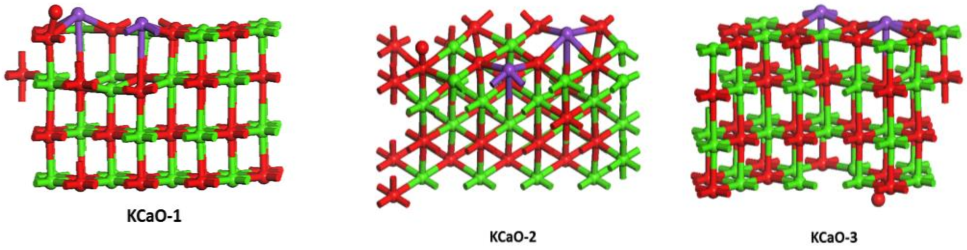




- Coexistence of mixed Ca and K at the ”activated” materials
- K and Ca are predominantly as oxides at the outermost layer

Knutsson, P., Cantatore, V., Tam, E., Seemann, M., Panas, I. Role of potassium for enhancement of the catalytic effect of calcium oxide for tar reduction (2018), Applied Catalysis B: Environmental

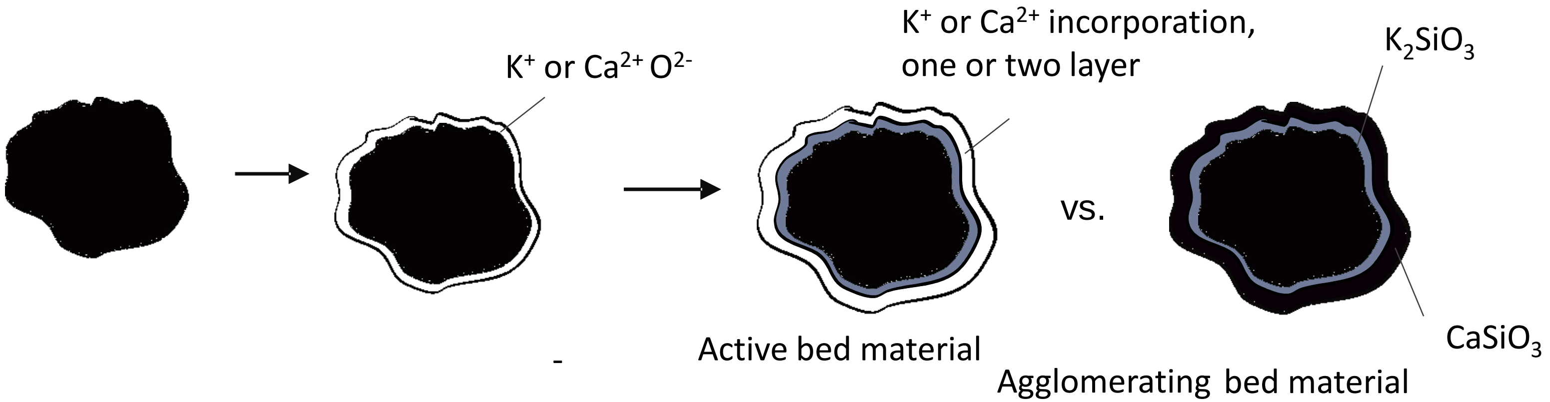
Role of K in CaO



- Replacing two Ca^{2+} ion in the lattice by two K^{+} is able to activate O_2 by binding it to the vacancy
- Theoretical calculations predict the oxidizing capacity of a K-enriched CaO

Knutsson, P., Cantatore, V., Tam, E., Seemann, M., Panas, I. Role of potassium for enhancement of the catalytic effect of calcium oxide for tar reduction (2018), Applied Catalysis B: Environmental

Mechanism challenges



- Formation of mixed oxide – initiating ion structure? Is it CaO?
- Where is the border line between activation and agglomeration?

Thank you for your attention!

CHALMERS

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