4 Presentations from the project: Biomass Combustion Chemistry with Oxygen Carriers

- Ash components and oxygen carriers, main challenges, Henrik Leion
- Gas-phase alkali interactions with reactor walls and OC in a laboratory reactor, Viktor Andersson
- Alkali emissions measurements in continuous CLC operation, Ivan Gogolev
- CLC with K, Na impregnated charcoal in a batch fluidized-bed reactor, Daofeng Mei

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Biomass Combustion Chemistry with Oxygen Carriers

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Ash components and oxygen carriers, main challenges

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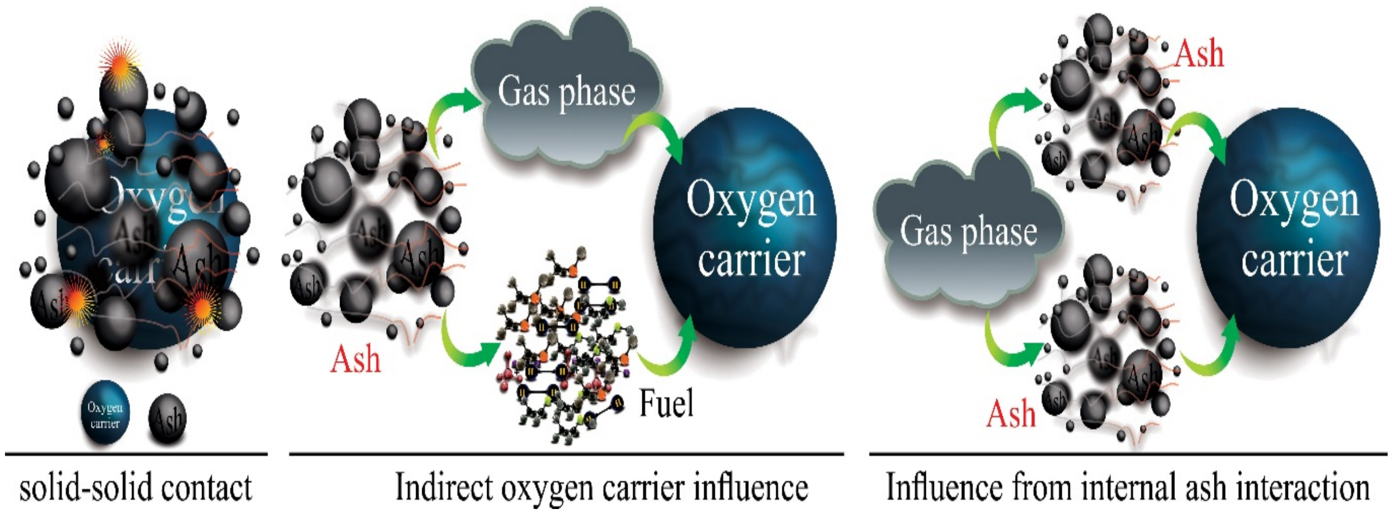
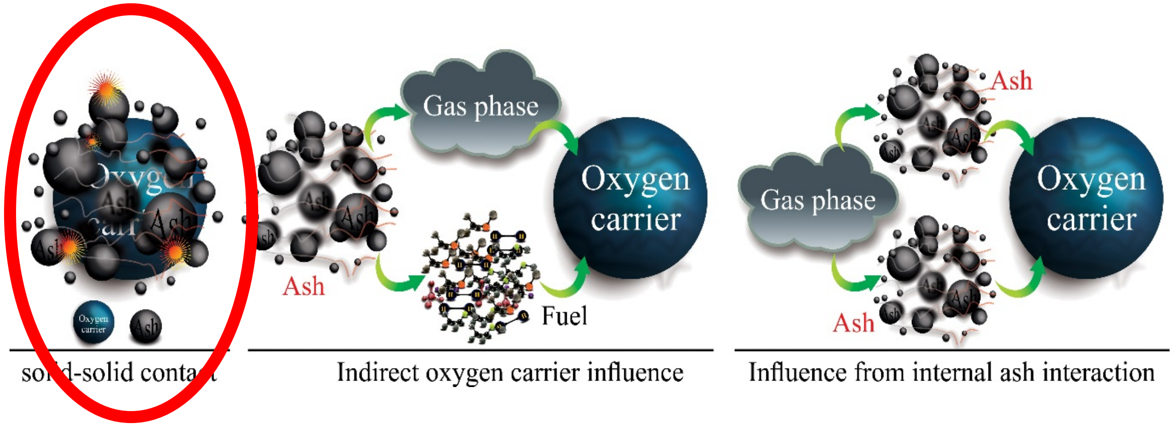
Outline of this presentation:

- General mechanism on oxygen carrier ash interaction with known examples
- Example of results on oxygen carrier ash interaction in fixed bed
- Challenges with oxygen carrier ash interaction

Suggestions for main mechanisms.





Examples:

Quartz and clay minerals generally don’t react with the oxygen carrier

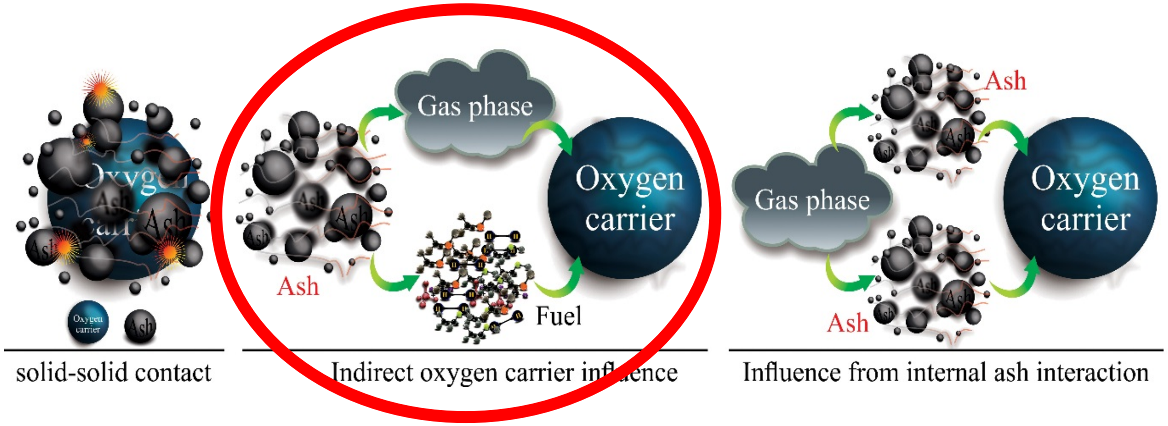
Keller et al. Chem. Eng. Research and Design 92, 2014

Fe_2O_3 or $CaSO_4$ can add oxygen carrier ability

Rubel et al., Fuel, 88, 2009; Bao, Applied Energy 115, 2014

CaO can form a shell on carriers (but without affecting reactivity)

Azis, Chem. Eng. & Technology 36, 2013



Examples:

K penetrating ilmenite accelerating Ti-Fe separation

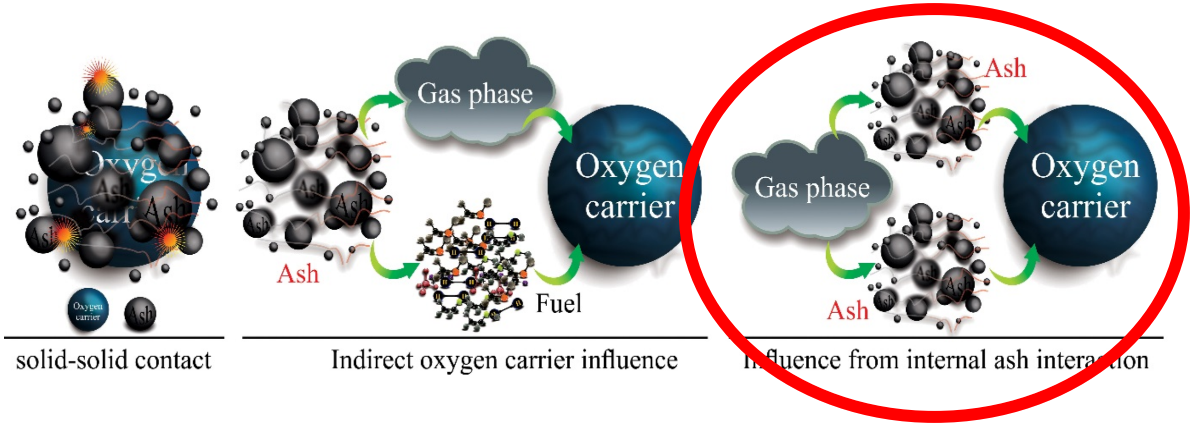
Knutsson et al. Applied Energy 157, 2015

K enhances gasification

Keller et al. Combustion and Flame 158, 2011

CaO enhances water-gas-shift reaction

Teyssié et al. Energy and Fuels 25, 2011



Examples:

Alkali creates melts with SiO_2

P + K can, more or less, block the oxygen carrier

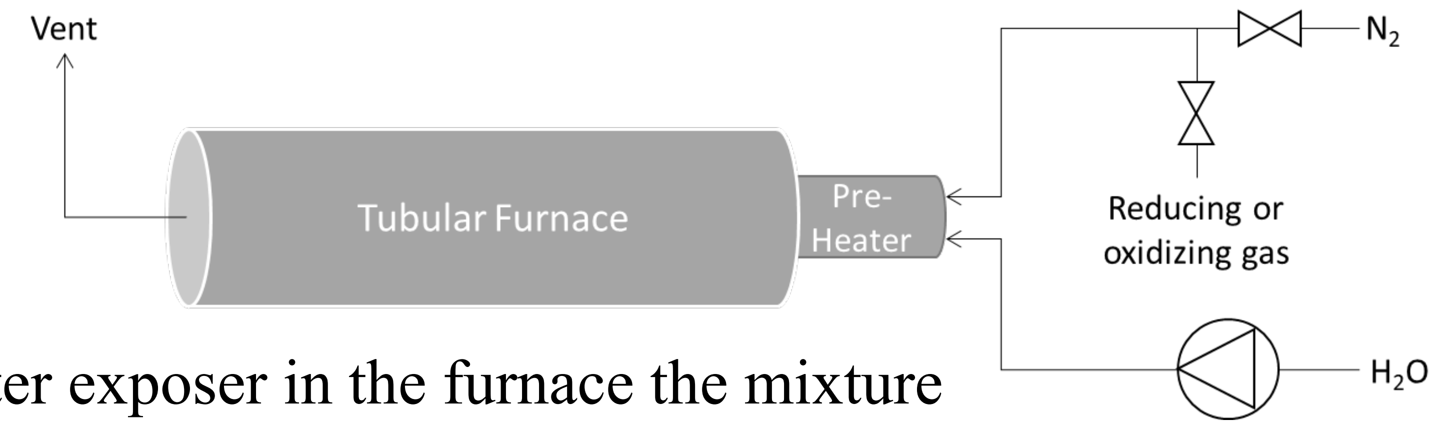
Hildor et al. ACS Omega 5, 2020; Störner et al. Energy and Fuels 34, 2020

P + Ca can, more or less, block the oxygen carrier

Staničić et al. Chem. Eng. Research and Design 149, 2019

Fixed bed experiment:

Oxygen carriers are mixed with ashes or ash components (salts)



After exposer in the furnace the mixture is investigated with XRD, SEM etc.

Fixed bed provides high solid-solid contact (worst case scenario)

Easy to compare different cases

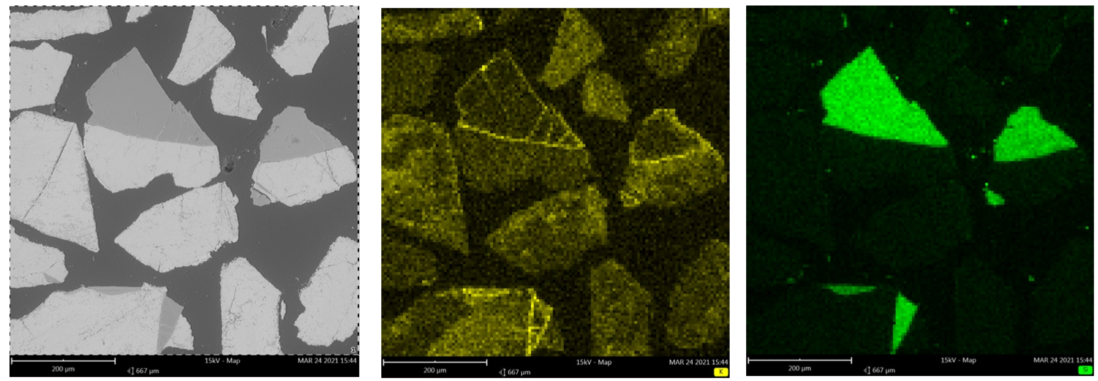
Simple to compare with thermodynamic data

Cross sections of partials casted in epoxy

Ilmenite (with sand) mixed with K_2SO_4

Reducing condition

H_2 in H_2O, 900°C



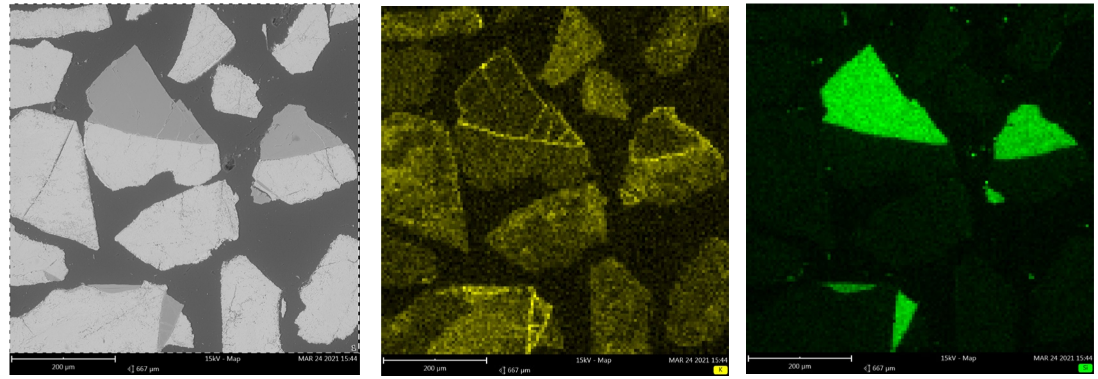
SEM K-map Si-map

Ilmenite absorbs K just as well or better than sand

Unpublished results

Cross sections of partials casted in epoxy

Ilmenite (with sand) mixed with K_2SO_4



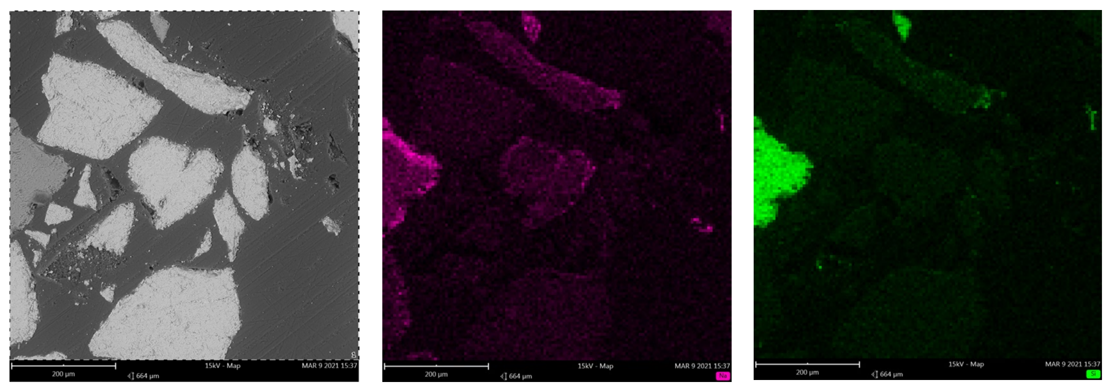
Reducing condition
H_2 in H_2O, 900°C

SEM

K-map
Na-map

Si-map

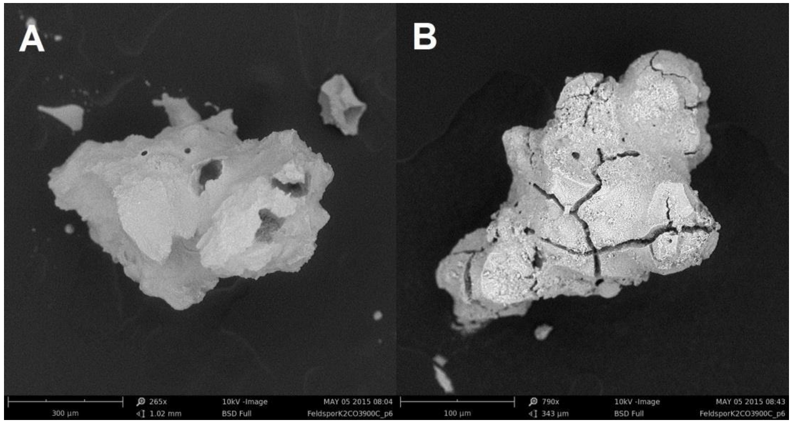
Ilmenite (with sand) mixed with Na_2SO_4



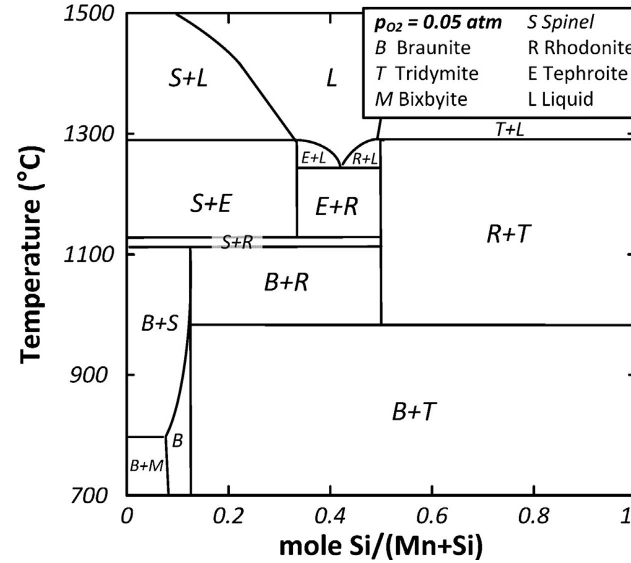
Ilmenite absorbs K but Na stays on the surface

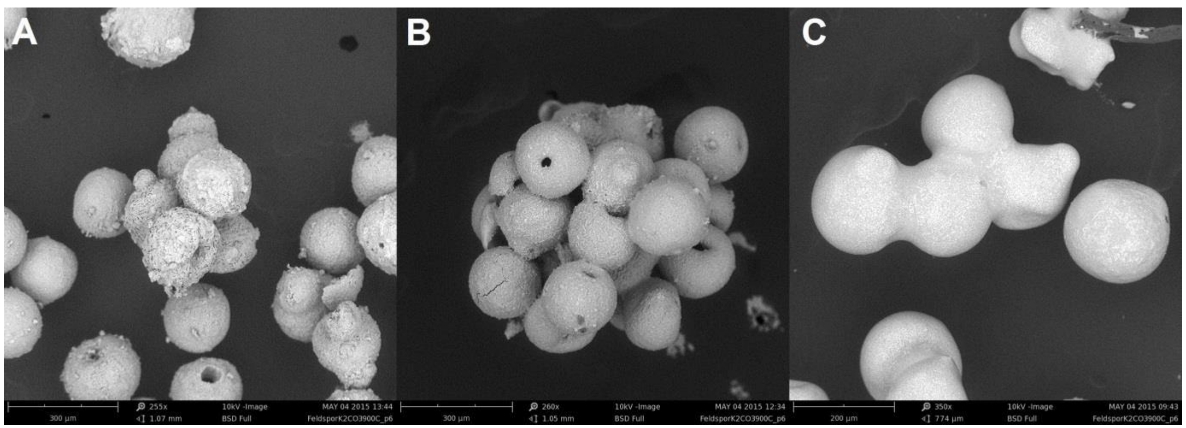
Unpublished results

Overview SEM images



Sand mixed with K_2CO_3 Mn_3O_4 mixed with K_2CO_3





Reducing condition
H_2 in H_2O, 850°C

94%wt Mn_2O_4 6%wt SiO_2
90%wt Mn_2O_4 10%wt SiO_2
75%wt Mn_2O_4 25%wt SiO_2

Leion et al. 25th EUBCE, 2017

Challenges with oxygen carrier ash interaction

Ash is generated in the fuel reactor, hence reducing conditions are most relevant. (similar to gasification but with solid oxygen present)

Conventional combustion ash is generated in the presence of air (similar to OCAC, CLOU or the air reactor)

Trends from conventional ash chemistry might not hold since ash components can interact with the metal oxide.

Impurities in the oxygen carrier might be just as important

A strategy for depleted oxygen carriers is needed

Measuring ash component and is challenging

We have a lot of different Oxygen Carriers and several of different ashes

$CuO/Cu_2O/Cu$

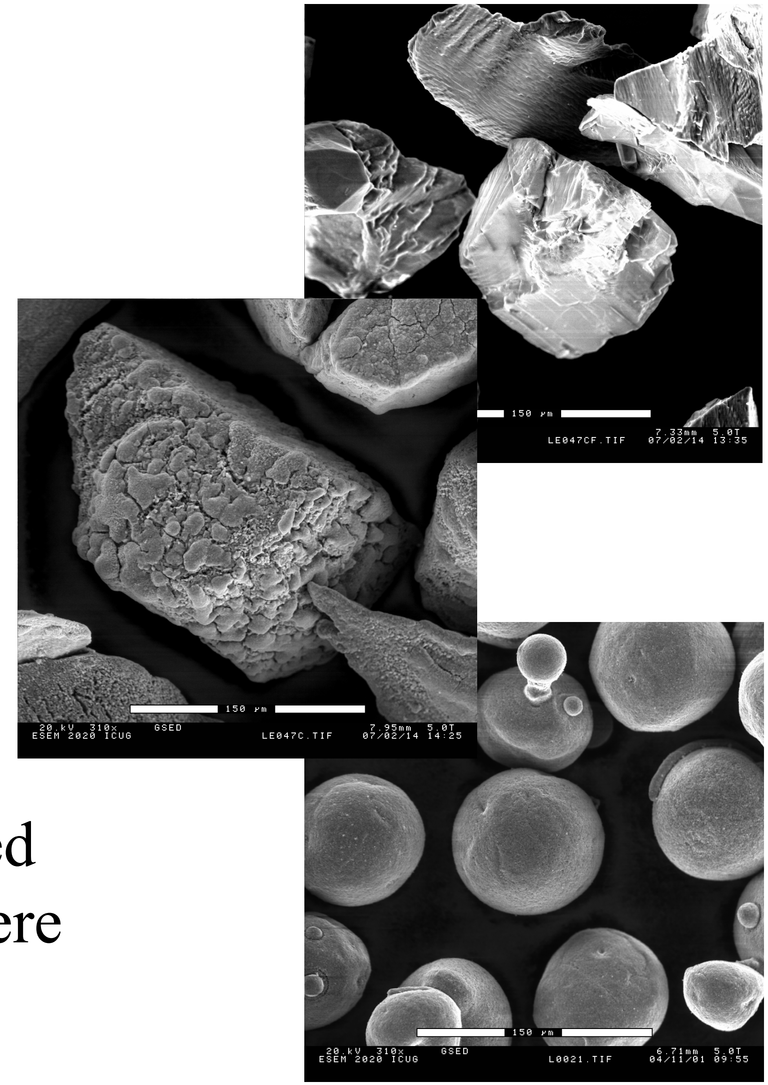
$FeTiO_3/Fe_2TiO_5+TiO_2$

$MnFeO_3/(MnFe)_3O_4$

NiO/Ni

$Fe_2O_3/Fe_3O_4/FeO/Fe$

$CaMnO_3/CaMnO_{3-\delta}$



Vassilev et al. (Fuel, 208, 2017) presented 141 different ash compositions (some were mean values)

Thank you for your attention!

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