Sustainable Materialisation of Residues from Thermal Processes into Carbon Sinks

Rafael Santos[1], Jan Elsen[2], Rudy Swennen[2], Tom Van Gerven[1]
[1]Department of Chemical Engineering, K.U. Leuven
[2]Department of Geology, K.U. Leuven

KATHOLIEKE UNIVERSITEIT LEUVEN

SMaRT-Pro² Sustainable Materialization of Residues from Thermal Processes into Products

Abstract

Mineral carbonation involves the capture of carbon dioxide in a mineral form. The principal aim and advantage of this approach is the chemical stability (reduced free lime and improved leaching resistance) and storage safety of mineral carbonates, the opportunities for process integration presented by the technology, and the potential for valorisation of otherwise low-value resources (virgin or waste) into useful products. A class of waste materials that has good potential for implementation as a feed material for mineral carbonation are steel slags. An integrated on-site mineral carbonation approach is envisaged as a possibly economically favourable solution in this work.

Innovative mineral carbonation routes

H_2CO_3																	He
Li_2CO_3	$BeCO_3$											B	C	N	O	F	Ne
Na_2CO_3	$MgCO_3$											$Al_2(CO_3)_3$	Si	P	S	Cl	Ar
K_2CO_3	$CaCO_3$	Sc	Ti	V	Cr	$MnCO_3$	$FeCO_3$	$CoCO_3$	$NiCO_3$	$CuCO_3$	$ZnCO_3$	Ga	Ge	As	Se	Br	Kr
Rb_2CO_3	$SrCO_3$	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag_2CO_3	$CdCO_3$	In	Sn	Sb	Te	I	Xe
Cs_2CO_3	$BaCO_3$		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl_2CO_3	$PbCO_3$	Bi	Po	At	Rn
Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Uuq	Uup	Uuh	Uus	Uuo
		↓															
		$La_2(CO_3)_3$	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
		Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

Goals:

- ✓ CO_2 sequestration;
- ✓ Product quality improvement (strength, leaching);
- ✓ Valuable materials formation (waste valorization).

Approaches:

i. Optimal introduction of CO_2 along the hot-stage to cold stage process;

ii. Process integration key to reducing operating expenses and garnering industrial interest;

iii. Focus on process barriers (rate and yield) by applying localized energy;

Barriers:

- Lack of legislative mandates in place;
- High energy intensity;
- Low reaction conversion;
- Slow reaction kinetics;
- Complexities of the production chain;
- Process adaptability;
- Competition for attention with alternative carbon capture technologies.

Solution: **P**rocess **I**ntegration x **P**rocess **I**ntensification (**π²**)

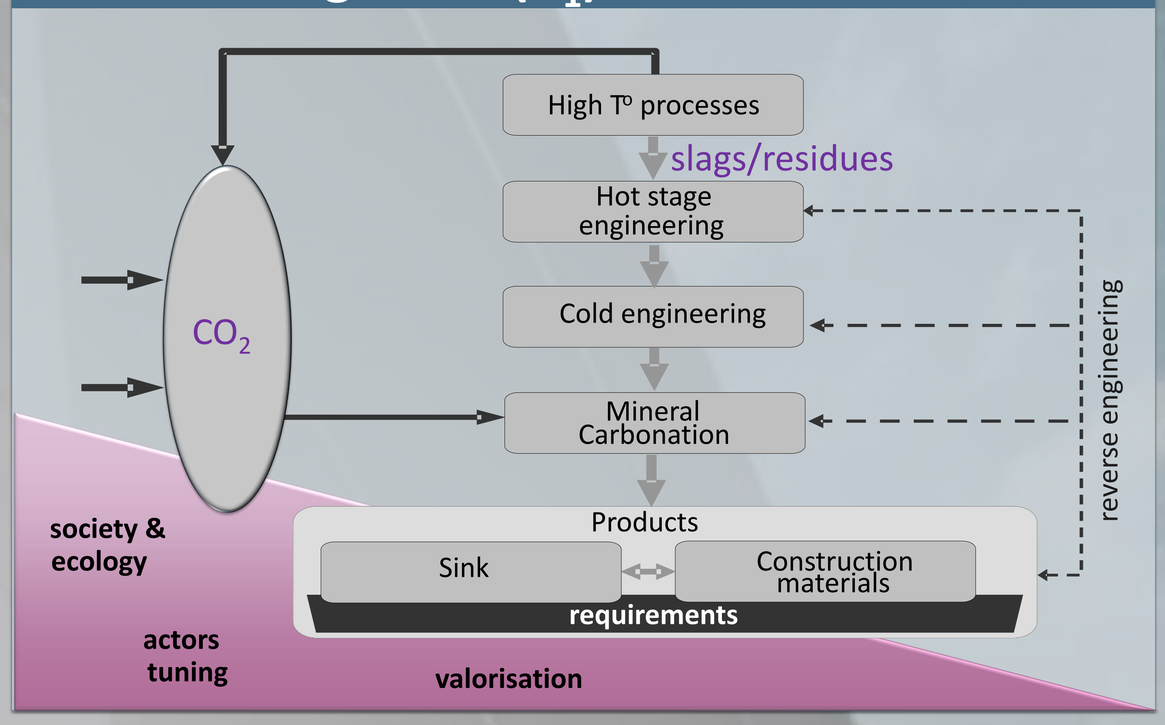
Materials:

- ➢ Basic Oxygen Furnace (BOF) slag (steel)
- ➢ Argon Oxygen Decarburization (AOD) slag (stainless steel);
- ➢ Ladle Metallurgy / Continuous Casting (LM/CC) slag (stainless steel).

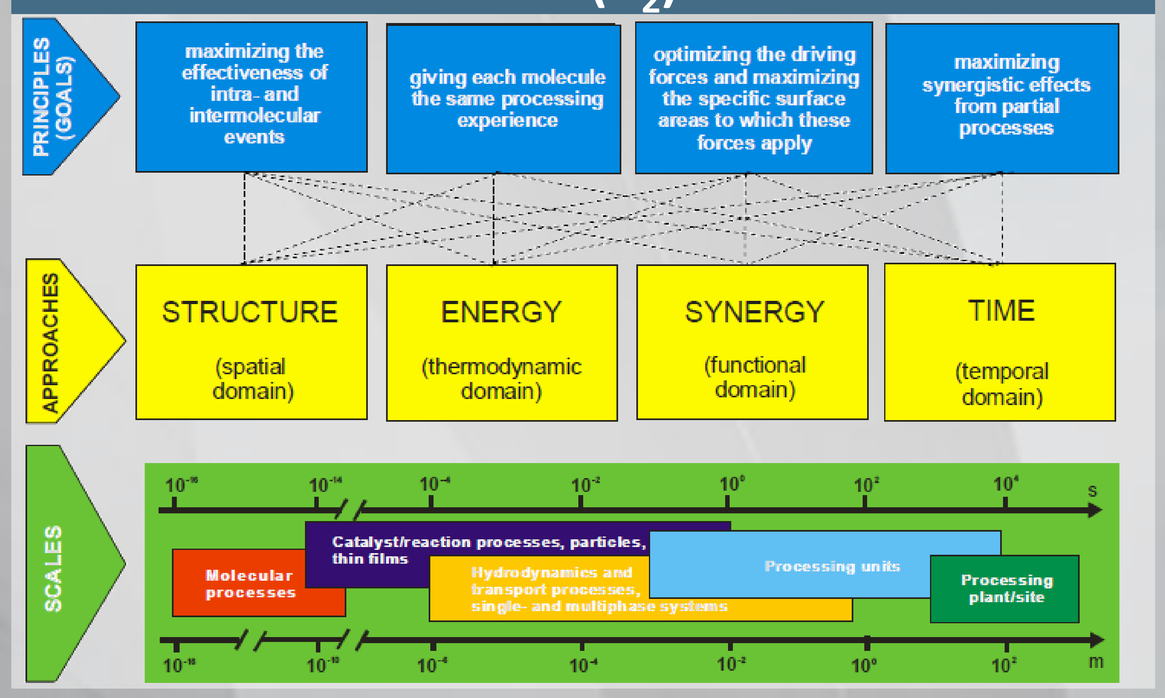
Table 1: Carbonation potential of steel slags

Slag	BOF	AOD	LM/CC
CaO wt%	53.9%	56.8%	60.3%
MgO wt%	1.0%	7.5%	8.9%
t_{CO2} / t_{slag}	0.60	0.71	0.76

Process Integration (π_1)



Process Intensification (π_2)



Accelerated Mineral Carbonation by SMaRT-Pro²

- **Slurry Carbonation:**
  - Buchi Ecoclave 300 Type 3E reactor.
  - 20 to 250°C, 0 to 60 bar_{CO2}.
  - High carbonation conversion.
  - Ideal for carbon capture application and valorization of fine powder waste residues.

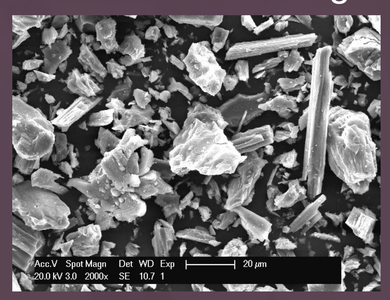
- **Sonicated Carbonation:**
  - Hielscher UP200S ultrasound processor.
  - 200 W, 24 Hz, 105 W/cm², 125µm amp.
  - Localized energy (high T, P): turbulence, erosion, break-up, reaction activation.
  - Ideal for changing and tuning particle and crystal morphology.

- **Moist Carbonation:**
  - Sanyo CO_2 incubator MCO-17.
  - 20 to 50°C, 0 to 0.2 bar_{CO2}.
  - Low cost, passive carbonation.
  - Ideal for waste valorization (leaching reduction, swelling stabilization and pH neutralization).

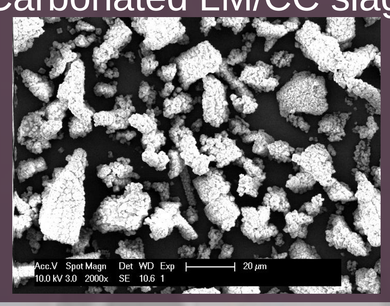
- **Hot-stage Carbonation:**
  - Horizontal tube furnace.
  - 20 to 800°C, 1 bar_{CO2}.
  - Fast carbonation + waste heat use.
  - Ideal for free lime stabilization and valorization into aggregates.

The Result

Fresh LM/CC slag



Carbonated LM/CC slag



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