AMAP P5 - Precompetitive Research on Pyrolysis and Melting

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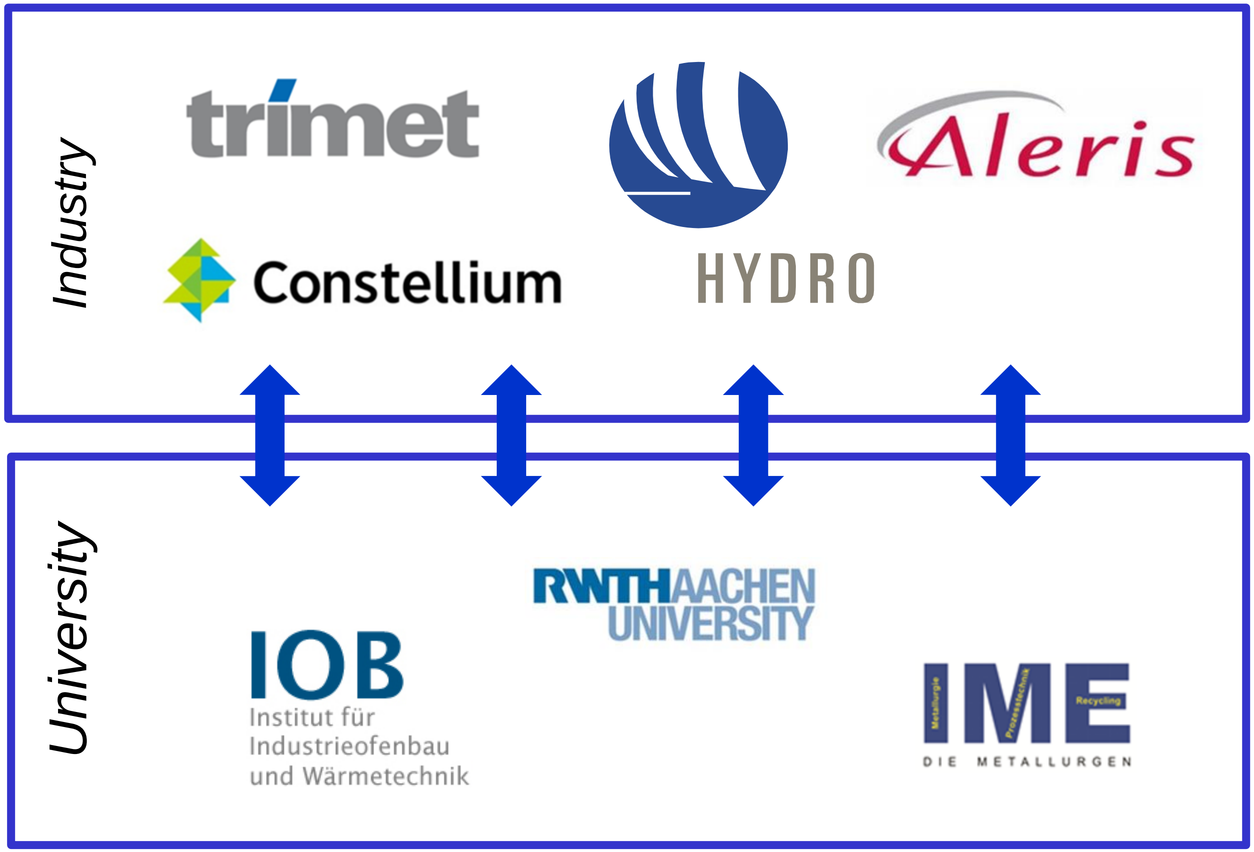
P5 Project Consortium

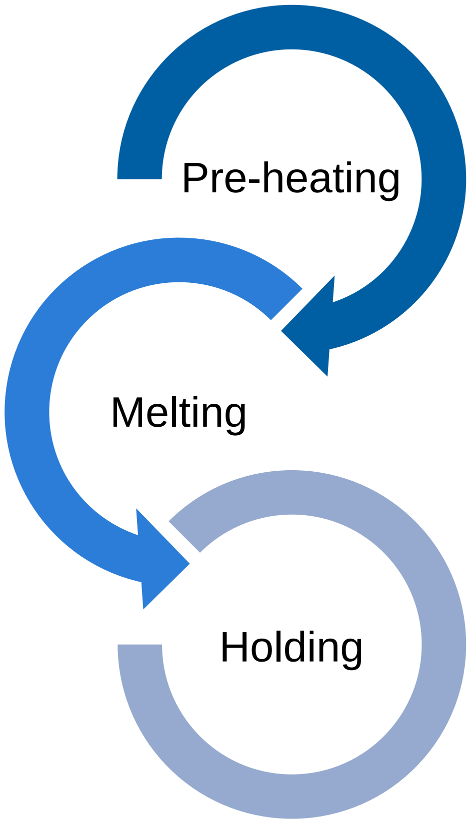


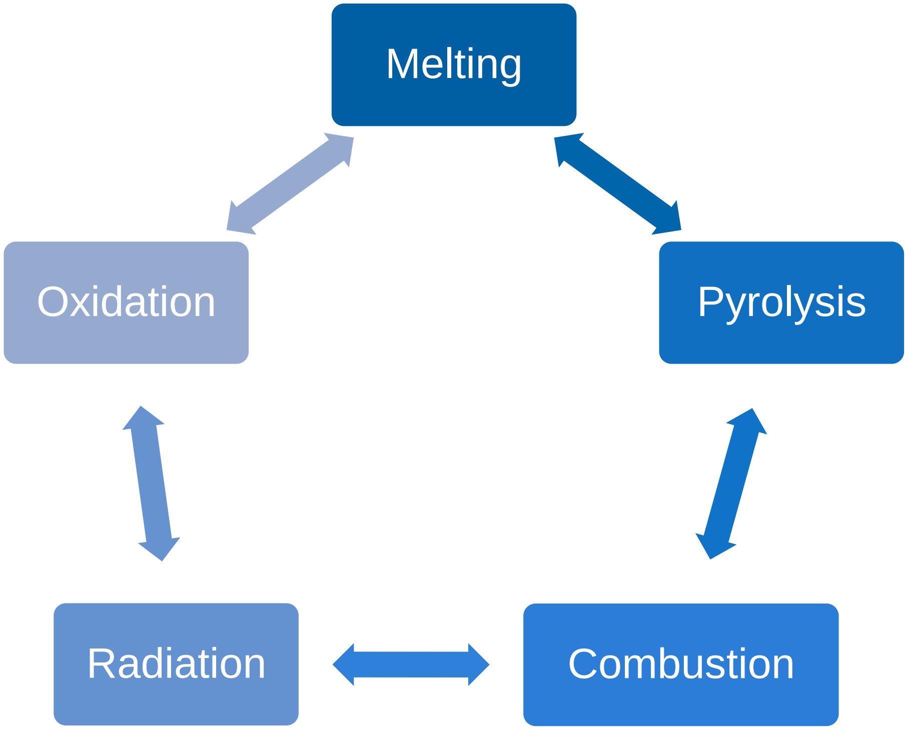
- **Process:**
  Al-Melting in hearth-type melting furnace

- **Material:**
  Used organic coated baverage cans (UBCs)

- **Scope:**
  Understanding of scrap behaviour and furnace metallurgy
  Detailed description and CFD simulation of present phenomena

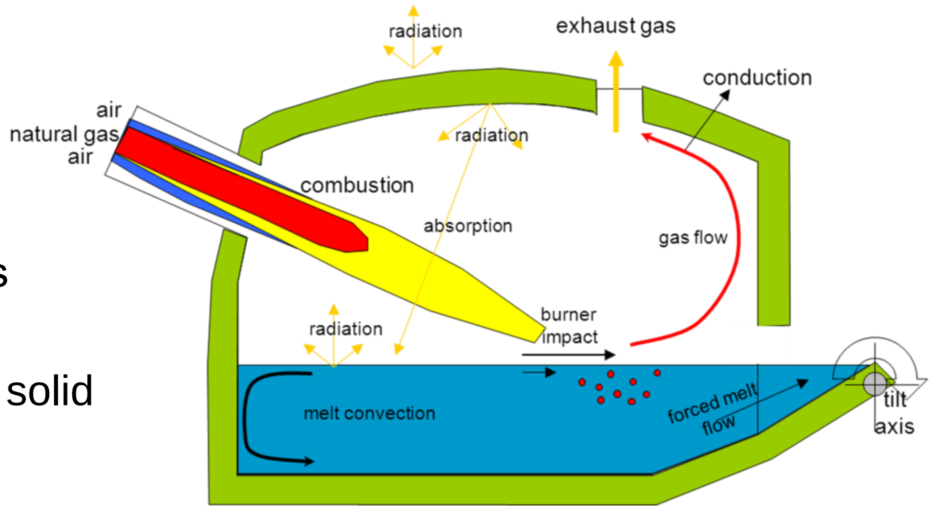
Process sequences and phenomena





Integrated Model Approach

- Gas reactions (thermolysis and organics decomposition)
- Dross formation related to scrap input / solid liquid interactions
- Dross formation depending on organic residues / gas liquid interactions
- Dross formation related to salt usage
- CFD furnace model
    - Combustion and heat transfer
    - Free surface melting
    - Organic gas release



Project Work Structure

Literature research | Experiments + Evaluation | Analytic Determination | Modelling


[1]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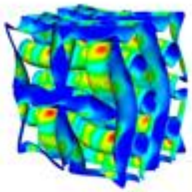
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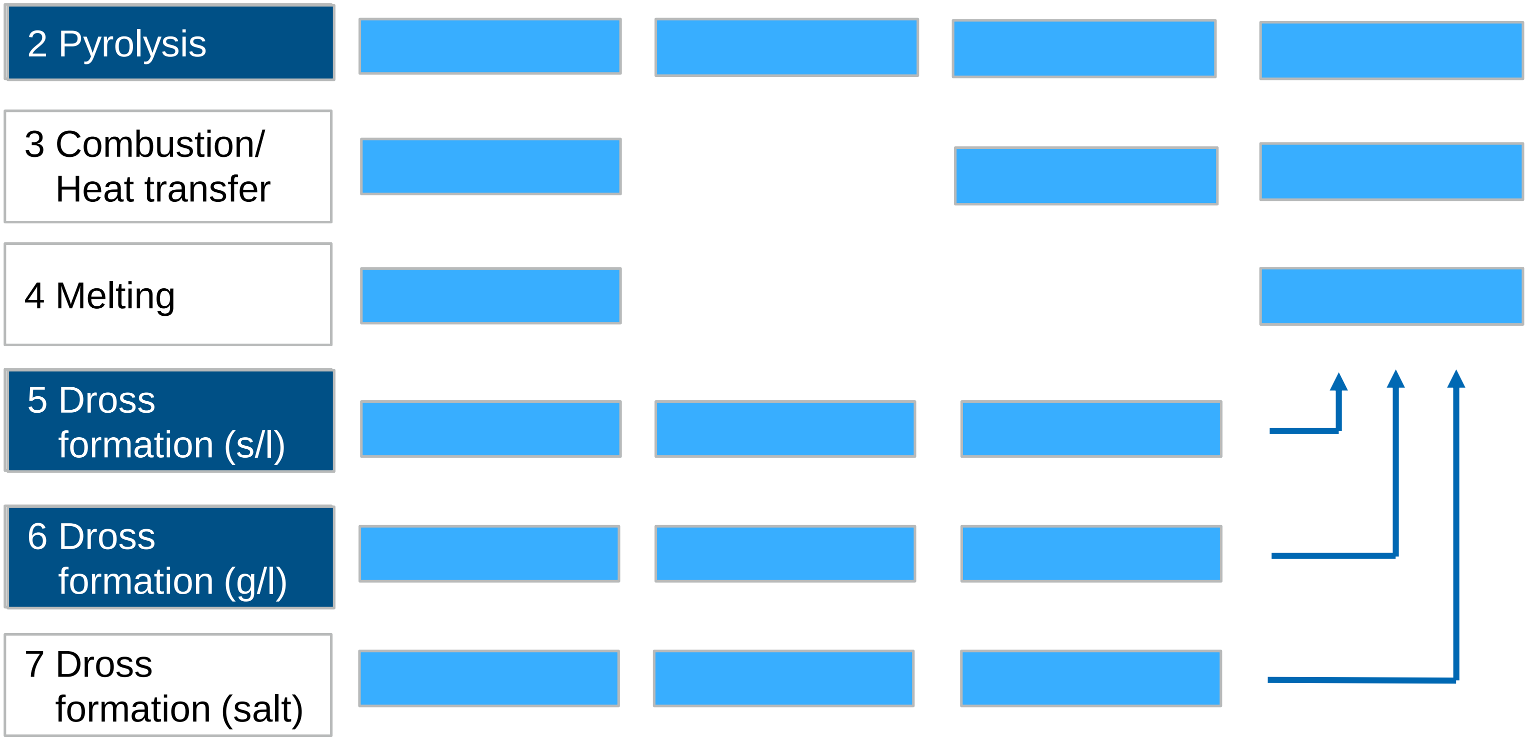
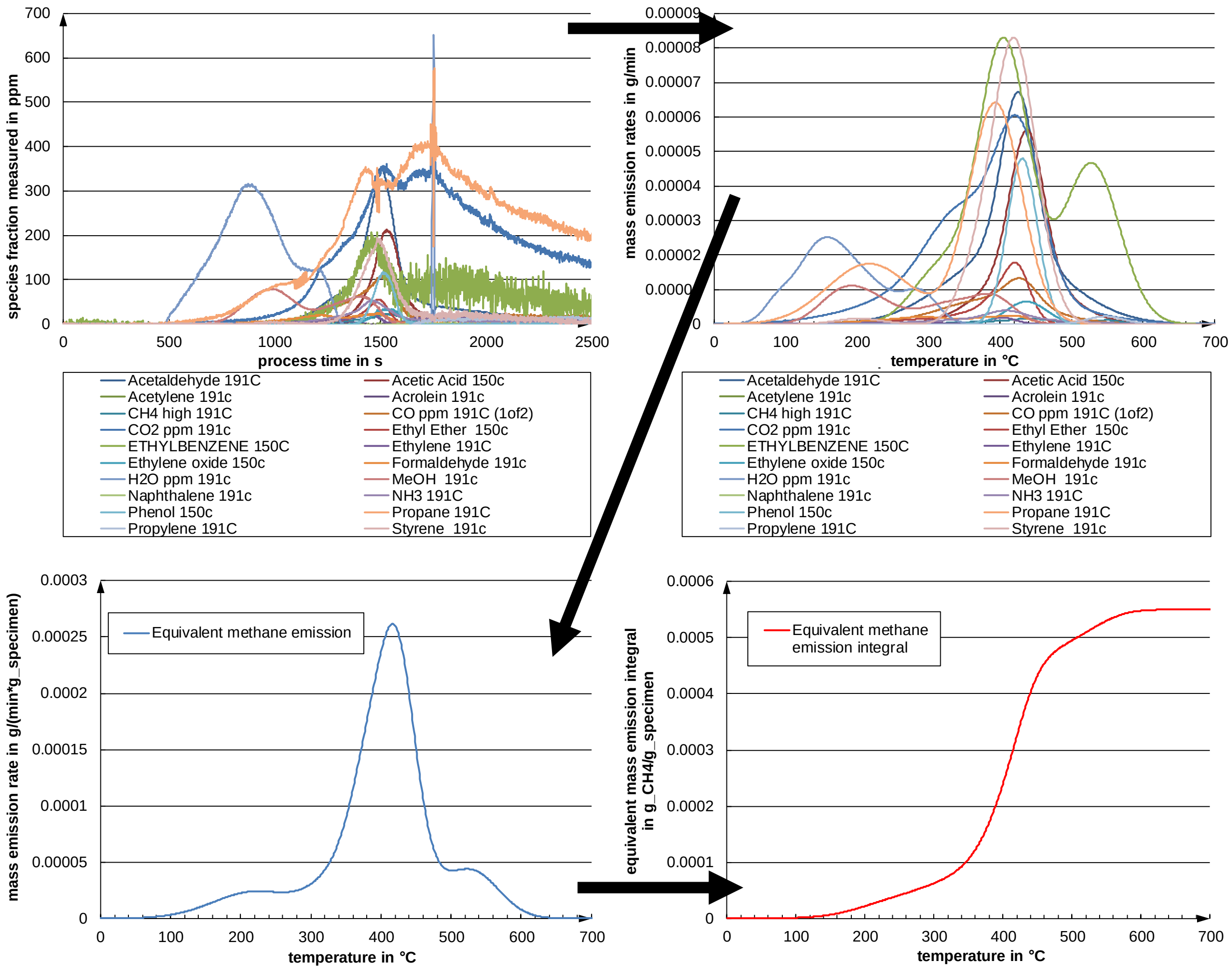


3. Data processing and simulation integration

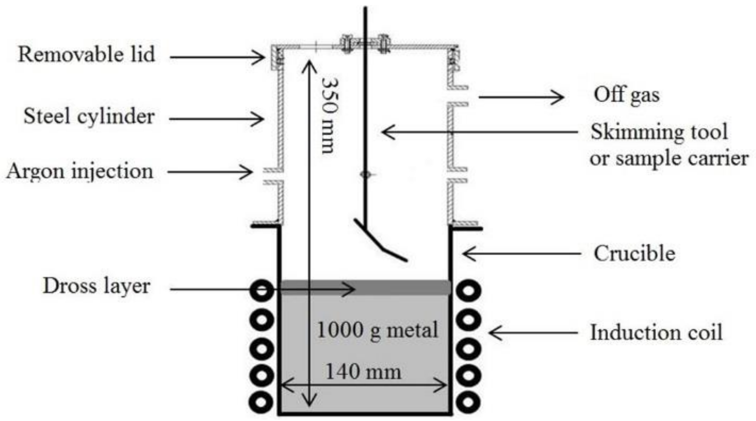
- Development of method, MATLAB algorithm and user-defined function to:
  - convert the measured species' vol. fractions into absolute mass emissions (methane equivalent)
  - transform them into computable datasets for simulation integration
  - calculate time dependent properties (H_{inf} etc.) of the gas mixture



Bruns, H.; Rückert, A.; Pfeifer, H.: Approach for Pyrolysis Gas Release Modelling and its Potential for Enhanced Energy Efficiency of Aluminium Remelting Furnaces.
Energy Materials 2017 – Conference Proceedings. Editors: Liu, X. et al. pp: 87-95, Springer 2017

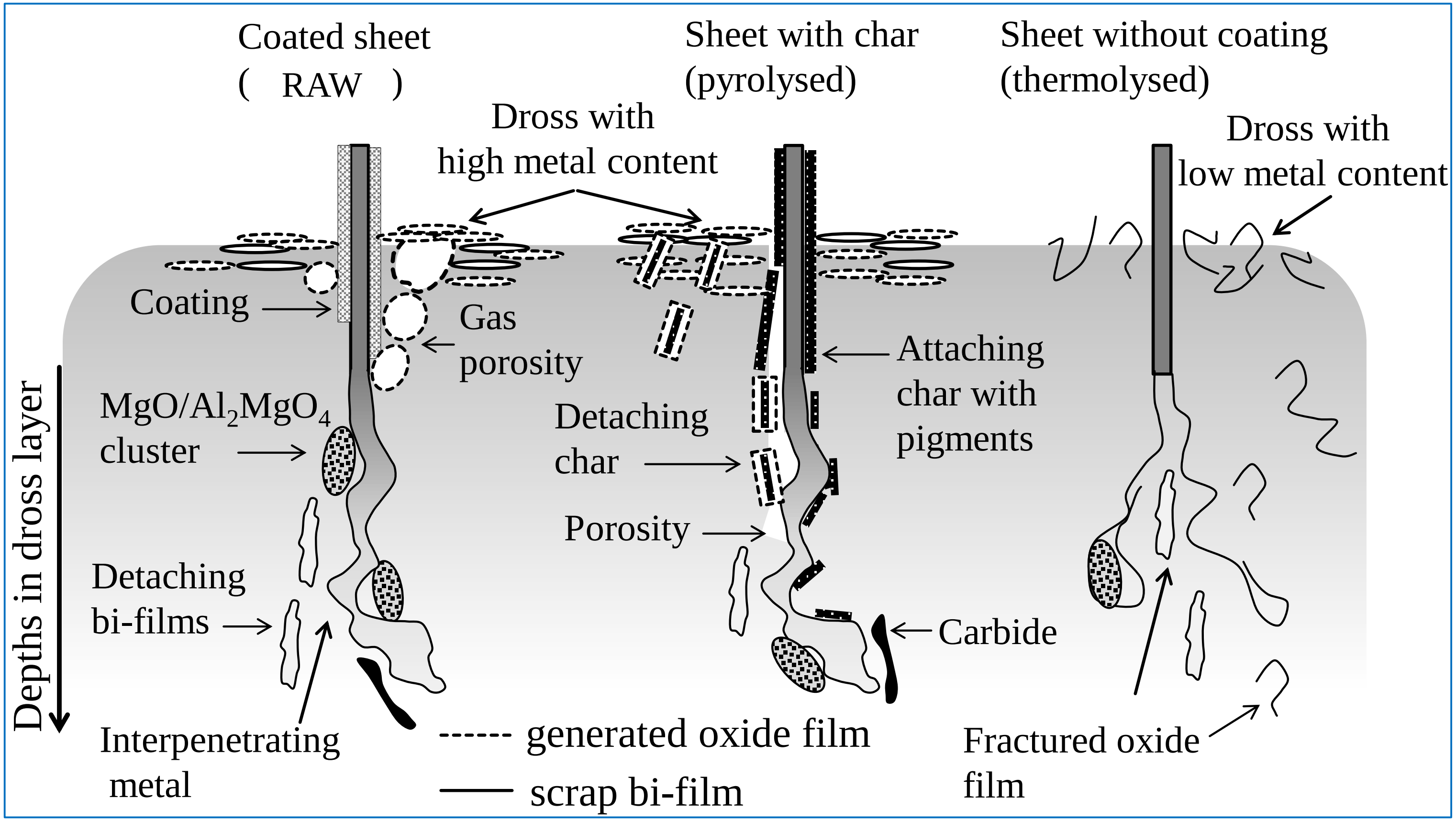
Dross formation related to scrap input by solid-liquid interactions

1. Development of methods
   - Lab scale investigation of thermal pre-treatment, level of contamination and density of baled UBC scrap of dross formation and metal loss
   - Measurement of heat transfer through dross layer into melt as CFD furnace model input
2. Investigated parameters
   - Qualitative and quantitative impact of carbon reactions at dross metal interface
   - Impact of pyrolysis/thermolysis on physical and chemical dross formation reactions
   - Effect of scrap porosity and density on dross formation
   - Radiative and conductive heat transfer through dross layer



J. Steglich, R. Dittrich, G. Rombach, M. Rosefort, B. Friedrich, A. Pichat: Dross formation mechanisms of thermally pre-treated used beverage can scrap bales with different density. Light Metals 2017, ed. by. A. P. Radvik, TMS, February 27, 2017, San Diego, California, USA

Dross formation mechanisms of coated can sheet with and without thermal pre-treatment based on microscopic- and SEM EDX-results.



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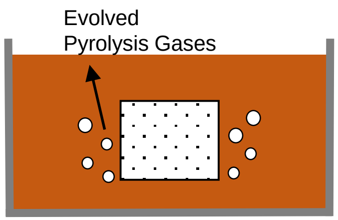
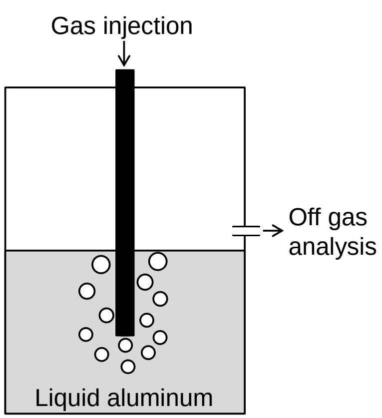


Phenomena of submerged UBC bales



Simulation of gas-liquid reactions in exp. setup

Selection of pyrolysis gases for gas/liquid test

- Aromatic compounds are not stable over 750°C: thermal decomposition into C_5H_6 cyclopentadiene and CO
  - C_4H_{10} (butane): representative for long-chain hydrocarbons
- CH_4, CO_2 and CO as typical pyrolysis gases
- O_2: enclosed air due to scrap packaged structure

Example: Reactions of liquid Al - CO_2

$$(1)\ Al_{(l)} + \frac{3}{2} CO_{2(g)} = \frac{\mathbf{1}}{\mathbf{2}} \boldsymbol{Al_2O_3}_{(s)} + \frac{3}{2} CO_{(g)}$$

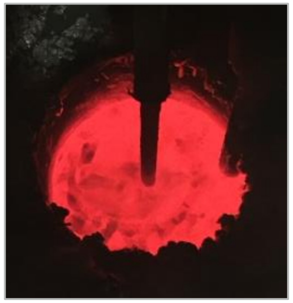
ΔG(1023 K) = -379 kJ/mol

$$(2)\ Al_{(l)} + \frac{3}{2} CO_{(g)} = \frac{\mathbf{1}}{\mathbf{2}} \boldsymbol{Al_2O_3}_{(s)} + \frac{3}{2} C_{(s)}$$

ΔG(1023 K) = -367 kJ/mol

R. Dittrich, B. Friedrich, G. Rombach, J. Steglich, A. Pichat: Understanding of interactions between pyrolysis gases and liquid aluminum and their impact on dross formation. Light Metals 2017, ed. by. A. P. Radvik, TMS, February 27, 2017, San Diego, California, USA

WP6: Experimental Investigation

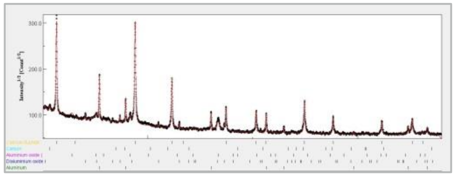


- Injection of gas mixture (95% Ar + 5% $O_2/CO_2/CO/CH_4/C_4H_{10}$)
- Total amount of test trials: 15
- Off-gas analysis (FT-IR)

- Dross skimming and cooling process under Ar
- Metal casting

- Dross remelting under flux (70:30 NaCl:KCl, CaF_2) to separate metallic and non-metallic part

- Analysis of dross structure



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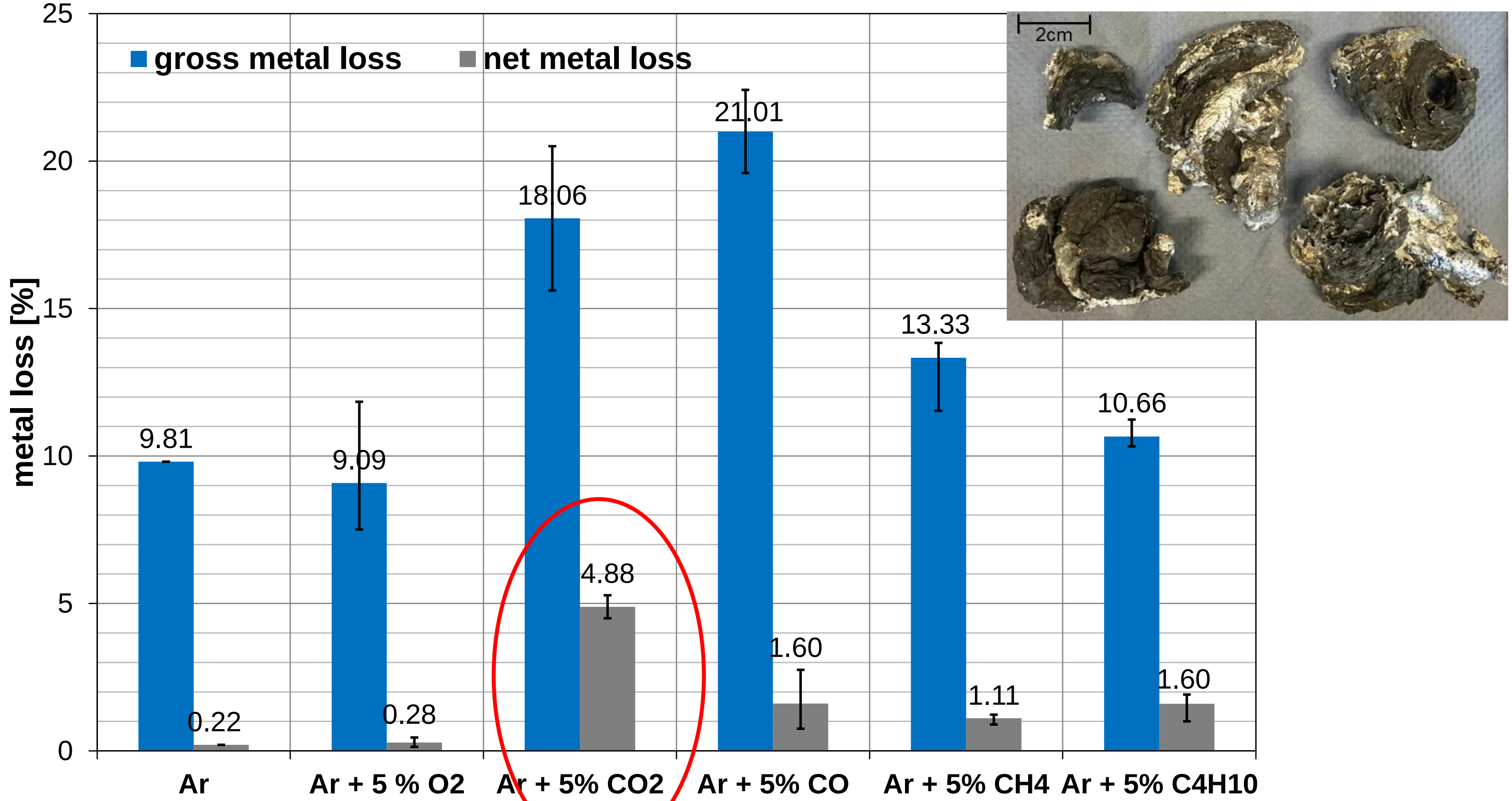
Metal Loss

$$\textit{gross metal loss}\ \% = \frac{m_{cast}}{m_{initial}} \qquad \textit{net metal loss}\ \% = \frac{m_{cast} + m_{metal\ recovery\ from\ dross}}{m_{initial}}$$



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CO_2

- High impact on dross formation
- 2-stage reaction mechanism
- No carbide formation in the presence of CO_2 → assumption of re-oxidation by excess CO_2

CO

- Formation of γ-Al_2O_3 and graphite
- Moderate influence on dross formation

O_2

- Less influence on dross formation
- Formed γ-Al_2O_3 film on gas bubble surface inhibits further oxidation

CH_4 and C_4H_{10}

- Aluminum acts as catalyst for the thermal decomposition of hydrocarbons
- Butane decomposes into methane (CH_4) and propene (C_3H_6)
- Moderate influence on dross formation

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- Combustion
  - variation of conventional and flameless combustion
- Gas emissions during de-coating
  - hydrocarbons and moisture evaporation from bales
- Melting Process
  - Generic model of phase changes – transformation from solid ingot model to bale model (porous medium)

- <u>Possibilities of model application</u>
  - Experimental determination of parameters for different scrap input
  - Construction of twin chamber furnace model and transfer of generated knowledge
  - Validation of the furnace model’s general behavior (combi pyrolysis gas emission, water evaporation, combustion etc.,