CCU Technology Development at RIST

November 5, 2013

Research Institute of Industrial Science & Technology
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☑ RIST Overview

- R&D System of POSCO
- Organization
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☑ CCU R&D Activities

- Motivation
- CO$_2$ capture and utilization technology in iron and steel industry
- CO$_2$ Capture Using Aqueous Ammonia
- CO$_2$ Conversion using COG Reforming
- Heat Recovery from Molten Steelmaking Slag
R&D System of POSCO

<table>
<thead>
<tr>
<th>INSTITUTE</th>
<th>RIST</th>
<th>POSLAB</th>
<th>POSTECH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Established Date</td>
<td>March, 1987</td>
<td>July, 1994</td>
<td>November, 1986</td>
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</tbody>
</table>
| Research Area | • Energy & Environment  
• Material & Processing  
• Steel structure & Architecture | • Product Development  
• Product Application  
• Process Development | • Education & Training  
• Basic & Advanced Research |
| Researchers | 257 (Ph. D 227) | 665 | 268 |

* Total 482

* POSLAB : POSCO Technical Research Laboratories  
* POSTECH : Pohang University of Science and Technology  
* GIFT : Graduate Institute of Ferrous Technology
RIST Location

[Songdo Global R&D Center]

[Gangwon Industrial Research]

[Gwangyang Envi. Research]

[Ulsan Plant Research]
Contents

RIST Overview
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Iron & Steel Making Processes

- One of the largest CO₂-emitting sectors in industry
- 70 million ton-CO₂/year (~10% of CO₂ emission in Korea)

Iron making (CO₂ 91%)
- Coke ovens
- Sinter plants
- Lime kilns

Steel making (1%)
- Converter

Hot rolling (4%)
- Hot rolling mills

Cold rolling (3%)
- Cold rolling mills

Majority of CO₂ emissions are originated from coal - reducing agent of iron ore

$$Fe_2O_3, Fe_3O_4 + Carbon(Coal) \rightarrow Fe + CO_2$$

Main reaction in Blast Furnace
South Korea has approved a national emissions trading program to reduce the global warming pollution from its largest sectors by 2015.

The ETS (emissions trading scheme) which comes into force from 2015, is designed to help the country reduce emissions by 30% by 2020, compared to business-as-usual levels.

Steel industry is allocated 6.5% reduction target by 2020.
**Motivation**

Need for iron industry-specific CO₂ reduction strategy

- **CO₂ Conversion to useful chemicals**
  
  \[ \text{CO}_2 + \text{Reducing agent} \rightarrow \text{Useful chemicals} \]

  - Intensive CO₂
  - By-product/carbon (H₂, CH₄, Carbon)
  - Thermal E at high T (>500~1,000°C)

- **CO₂ Capture & Utilization in Iron Industry**

  - Massive CO₂ emissions
  - Substantial by-product gases (COG, LDG)
  - Abundant waste heats

  → CO₂ capture & utilization (conversion) can be realized within the industry boundary.
CO₂ capture and utilization technology in iron and steel industry

A concept of CCU within the steel industry boundary

- CO₂ capture using aqueous ammonia, its conversion into reducing gases and injection of them into blast furnace

**CO₂ Capture**
- Aqueous ammonia CO₂ capture process
  - CO₂ source: BFG (Blast Furnace Gas)
  - Low-cost chemical (NH₃)
  - Low regeneration Temp. (~80°C)

**Research Strategy**

- CO₂ Capture - Aqueous ammonia CO₂ capture process
- CO₂ Conversion and Utilization - CO₂ conversion via COG reforming
- CO₂ Reduction - Inject the product gas into BF as a reducing gas
- Waste Heat Recovery
  - Waste heat from boiler stacks: utilized as regeneration energy
  - Waste heat from molten slag: utilized as CO₂ conversion energy

**Regeneration Energy**

- Captured CO₂

**Conversion Energy**
CO₂ capture and utilization technology in iron and steel industry

- Project Name: Technology Development for CO₂ capture and utilization in iron and steel industry
- Project Due: ‘09.6 ~ ‘14.5 [Phase I: ‘09.6 ~ ‘12.5, Phase II: ‘12.6 ~ ‘14.5]
- Participating Organizations: RIST, POSCO, POSCO E&C, KIER, POSTECH, SKK Univ.
CO₂ Capture Using Aqueous Ammonia (I): Concept/Feature

- **Ammonia-Based CO₂ Capture Process developed at RIST**

- **Technology Feature**
  - Feed gas: BFG
  - Absorbent solution: low concentration aqueous ammonia solution (< 10 wt %)
  - Waste heat recovered from stack gas and used as the regeneration energy

Steam from waste heat (120 °C, 1kg/cm²)
CO₂ Capture Using Aqueous Ammonia (II): Milestones

☐ R&D history

- Lab-scale research (2006~2007)
- 1ˢᵗ stage pilot plant research (2008-2010): 50 Nm³-BFG/hr (Dec. 2008)
- 2ⁿᵈ stage pilot plant research (2010-2014): 1,000 Nm³-BFG/hr
  - One-site pilot tests are on-going (May 2011-), Purification/Liquefaction facilities integrated (Apr. 2012-)

☐ 2ⁿᵈ Pilot Plant Spec.

<table>
<thead>
<tr>
<th>Item</th>
<th>Spec.</th>
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</thead>
<tbody>
<tr>
<td>Feed Gas</td>
<td>BFG (Blast Furnace Gas, CO₂ ~ 22%)</td>
</tr>
<tr>
<td>Feed Gas Flow rate</td>
<td>1,000Nm³/h</td>
</tr>
<tr>
<td>Absorbent Sol.</td>
<td>&lt;10% NH₃</td>
</tr>
<tr>
<td>Product CO₂</td>
<td>10 t-CO₂/d, 0.5MW power plant</td>
</tr>
<tr>
<td>Purity of product CO₂</td>
<td>&gt;95% (Gas)</td>
</tr>
<tr>
<td></td>
<td>&gt;99.8% (Liquid)</td>
</tr>
</tbody>
</table>

☐ Test Results

- CO₂ recovery > 90%, L-CO₂ purity > 99.5%

☐ Further Plan

- Long-term continuous operation
- Additional pump around and higher NH₃ concentration in absorbent solution
- Basic engineering design for commercial scale
CO₂ Conversion using COG Reforming (I) : Concept/Feature

□ Background
- Need for the conversion of capture CO₂ and the utilization in steel industry

□ Steel-industry-specific CO₂ conversion and utilization

- Mass production of the H₂ and/or CO rich gases by using COG reforming with steam and CO₂
  - Require highly coking-resistant catalyst for the COG reforming
  - Require optimization of reaction condition, heat integration, and scale-up by using reactor modeling
CO₂ Conversion using COG Reforming (II): Milestones

☐ R&D History/Plan

• Lab-scale research (2009~2011): Development of RIST catalysts with high activity over COG reforming with CO₂
  → Higher CH₄ conversion compared with commercial catalysts by 15%

• Pilot plant research (2012 - 2014): 50 Nm³-(H₂+CO)/hr
  - The conceptual design has been carried out ( - 2012)
  - The pilot plant construction is on-going (Feb. 2013-)

• CFD model development and case study to inject the reducing gas into blast furnace (not included in this PT)

☐ Pilot Plant Spec.

<table>
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<tr>
<th>Item</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Feed Gas</td>
<td>Simulated COG (Coke Oven Gas)</td>
</tr>
<tr>
<td></td>
<td>- CO₂ &amp; Steam</td>
</tr>
<tr>
<td>Reforming Catalyst</td>
<td>Ni-based catalyst</td>
</tr>
<tr>
<td>Product</td>
<td>~ 50 Nm³-(H₂+CO)/hr</td>
</tr>
<tr>
<td>Conc. H₂ + CO</td>
<td>&gt; 85 %</td>
</tr>
</tbody>
</table>

☐ Further Improvements

• Development of enhanced catalysts with high coking resistance
• Optimization and scale-up
Heat Recovery from Molten Steelmaking Slag (I)

Overview
Development of heat recovery technology for the high temperature molten slag
- key issues: dry granulation and fast cooling of molten slag

Design Basic

<table>
<thead>
<tr>
<th>Heat recovery ratio</th>
<th>&gt; 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target of recovery temperature</td>
<td>&gt; 500 ℃</td>
</tr>
<tr>
<td>Final process scale</td>
<td>180 t-slag/h,unit</td>
</tr>
</tbody>
</table>

Heat recovery ratio (%) = Recovered heat by air / Molten slag heat capacity X 100

Conceptual Design

Granulation

Application
Generation of power or steam by rapid cooling of slag particles
Heat Recovery from Molten Steelmaking Slag (II)

R&D Activities & Schedule

(2009~2011)

- Designed and installed a system for dry granulation and heat recovery
- Performance test of the equipment
- Recovery ~ 50%

(2012-2013)

- On-site pilot test at POSCO
- Target: Basic data for commercial scale-up

(2014 - )

- Commercial recovery system and its integration with CO₂ conversion unit

< Demo facility, 30 t-slag/h >
CCU R&D topics at RIST

Major R&D Topics related to CCU technology and carbon emission reduction

• CO₂ capture and utilization technology in iron and steel industry
  - CO₂ Capture
  - Waste Heat Recovery from flue gas and molten steelmaking slag
  - CO₂ Utilization

• Power generation from waste heat
• Restoration of coastal environments by steel-making slag
• Development of novel process for the synthesis of DMC
• Biodiesel production from sewage sludge & microalgae
In Korea, CO\textsubscript{2} utilization rather than storage is a “must” considering the geological and industrial environments.

POSCO desperately needs to reduce CO\textsubscript{2} emissions.
- National emissions trading program will begin at 2015.
- Steel industry-specific CO\textsubscript{2} reduction routes are being investigated.

A concept of CO\textsubscript{2} capture and utilization within the steel industry boundary.
- The integrated concept of capturing CO\textsubscript{2} (using AA), its conversion into reducing gases (by COG reforming), and injection into BF is being studied.
- The pilot plants are operating at the lab or on-site separately.
Thank you