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Carbon Capture and Compression Research

World-changing research from The University of Nottingham

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Solid Sorbents for Carbon Capture and Multi-pollutant Control:

- Step Change Adsorbents for CO₂ Capture (2009 – 2013) EPSRC (EP/G061785/1).
- Innovative Adsorbent Materials and Processes for Integrated Carbon Capture and Multi-pollutant Control for Fossil Fuel Power Generation (2009 – 2013) EPSRC (EP/G063176/1)

CO₂ Compression:

- CO₂ Optimised Compression: COZOC (2008-10). Technology Strategy Board. TS/G001693/1.

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Developing Sorbent Based Capture Technologies

Source: Figueroa et al. 2008 - Int. J. Greenhouse Gas Control 2:9-20.

ADVANTAGES:

- Potential "on paper" to reduce energy loading by 30-50%
- Reduce overall cost of CCS and increase uptake

DEVELOPMENTS NEEDED:

- Materials - working capacity (>3 mmol g⁻¹)
- Stable + Durable
- Economic
- Process design / bed / solid handling

Regeneration Energy (Heat) vs. Sorbent Loading

Source: Gray et al (2008) Int. J. Greenhouse Gas Control, 2:3-8

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- Step Change Adsorbents for CO₂ Capture - **£1.6 million**. E.ON-EPSRC strategic call on CCS. **2009-2013**.

Investigators:

- Dr Trevor Drage (PI), Prof Colin Snape University of Nottingham
- Dr Joe Wood, University of Birmingham
- Prof Andy Cooper, University of Liverpool
- Prof Xiao Guo, UCL

UNIVERSITY OF BIRMINGHAM | UCL | The University of Nottingham | UNIVERSITY OF LIVERPOOL

e-on UK | EPSRC

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Research Strategy

Integrated approach is vital for success

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Functionalised Mesoporous Nanostructures for Carbon Capture

(Prof. Z. Xiao Guo, UCL Chemistry; z.x.guo@ucl.ac.uk)

- Design**
 - Carbon Zeolites Carbides - with Organic Linkers (-NH₂, -COOH)
 - Atomic / Molecular Modelling
- Synthesis**
 - Nano-catalysis
 - Meso-hybrid
 - Macro-support
- Characterisation**
 - TGA / DTA / DSC / P-C-I / MS / GC; SEM/TEM/APM

University of Birmingham – Inorganic Materials Preparation of Modified Hydrotalcite Adsorbents

Joe Wood and Jiawei Wang

Example preparation Procedures

- Mg(NO₃)₂·6H₂O + Al(NO₃)₃·9H₂O (3:1) 90 cm³ distilled water
- NaOH + Na-dodecylsulfonate 50 cm³ distilled water
- APTS in 50 cm³ ethanol

100 cm³ water Vigorous stirring
Aging water bath 80°C, 12 hours
Filtration
Washing, drying
Product

Park, A-Y, Kwon, H., Woo, A.J. and Kim, S.J., 2005. Layered double hydroxide surface modified with (3-aminopropyl)triethoxysilane by covalent bonding. Adv. Mater. 17, 106 – 109.

Tao et al., 2009, Applied Surface Science 255, 4334 – 4340.

Characterization and Simulated Adsorption Tests In Birmingham

EPSRC-China Project

Innovative Adsorbent Materials and Processes for Integrated Carbon Capture and Multi-pollutant Control for Fossil Fuel Power Generation

项目名称: 适用于化石燃料电站的新型吸附剂材料以及碳捕捉和多污染物控制集成技术的开发

UK > Prof. Colin E. Snape, Dr Cheng-gong Sun, Dr Trevor Drage & Dr Hao Liu (Energy Technologies Research Institute, University of Nottingham)
> Prof. Z Xiao Guo, (University College of London)

CHINA > Prof. Yuhuan Sun, Prof. Jianguo Wang and Prof. Wei Wei, Institute of Coal Chemistry, Chinese Academy of Sciences
> Prof. Haiying Qi, Institute of Thermal Engineering, Tsinghua University
> Prof. Baosheng Jin, Thermal Engineering Research Institute, Southeast University

EP/G063176/1 Value of award: £983,000

Aims of the research

- Conduct the underpinning research to accelerate the development and demonstration of novel integrated carbon capture & simultaneous multi-pollutant control technologies.
- The ultimate goal of reducing the cost of near zero emission coal plant considerably so that the new technologies can impact of the implementation of the next generation of carbon capture plants in the 2020s.
- The technologies are based on a range of novel regenerable adsorbent materials being developed by the partners, which are capable of achieving the simultaneous removal of SO_x, NO_x, HCl, HF, and toxic metals, particularly mercury.

ULTRA HIGH CAPACITY CO-PRECIPIATED MANGANESE OXIDE SORBENTS FOR MERCURY CAPTURE

Patent: PCT/GB2008/050056

- zirconia is the most effective support
- promotional affect observed with CeO₂
- will now be tested for As

Sorbent test conditions:
Hg evaporation chamber: 30°C;
Test chamber: 35°C;
N₂ flow: 80 ml/min;
Sorbent bed: 5 cm x 0.5 cm i.d.;
dilution factor: 3 (sand/sorbent by volume)

- Capacity achieved for bed packed solely with sorbent at a temperature of 50°C and a N₂ flow of 130 ml/min.

Collaboration map showing activities and partner interactions based around the project themes

UCL (Z. Xiao Guo)
Chemistry/Chemical Engineering
High capacity carbon/metal oxides hybrid materials, performance-enhanced fibrous carbon materials for multi-pollutant removal and gas separation. Grafted nano-porous materials, metal-complex oxides and carbon composite materials for CO₂ capture. Test rigs & analytical: Circulating fluidised bed absorber/regenerator, well established gas analytical systems, and bench- to pilot-scale materials production facilities

UoN (C. Snape, C. Sun, T. Drage, H. Liu)
Lead Partner
Sorbent materials for CO₂ capture (polyethyleneimine) and for multi-pollutants control (multi-functional carbon-based composites, supported/precipitated manganese metal oxides-based materials for SO_x, NO_x, HCl and H₂ removal). Sorbents performance testing, cross effect of other gas components/pollutants and their impact on following CO₂ capturing processes. Component process developments, system integration, conceptual design & modelling. Test rigs & analytical: lab-scale fixed bed and bubbling fluidised bed reactors, high pressure CO₂ adsorption analysis, multiple pollutants detection systems (SO_x, NO_x, HCl, Hg etc.), SEM, particle loading and size distribution, WGD etc.

Tsinghua Univ. (H. Qi)
Thermal Engineering
Simultaneous multi-pollutant cost-effective iron-based in situ/external catalytic absorption materials, dry absorber process engineering. Sorbent materials and process engineering for CO₂ capture. Conceptual design of reactor for multi-pollutant removal by use of solid sorbents of a 600 MW, PF-fired power generation unit

Southeast Univ. (B. Jin, China)
Thermal Engineering
Pilot-scale testing of CO₂ capture and regeneration of sorbents by use of existing pilot-scale bubbling fluid bed reactors. Pilot-scale testing of multi-pollutant control sorbents by use of the existing pilot-scale Dry FG testing rig. Conceptual design of reactor for CO₂ capture by use of solid sorbents of a 600 MW, PF-fired power generation unit. System integration and conceptual design

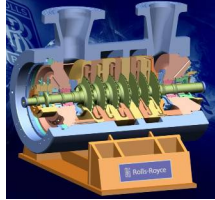
**CO₂ Optimised Compression: COZOC (2008-10).
Technology Strategy Board. TS/G001693/1.**

Aims:

Develop concept designs for low-power systems to compress CO₂ for efficient pipeline transport and underground storage.

Partners

- Rolls-Royce (lead):** Advanced novel compressor concept design
- E.ON Engineering:** Ensure the advanced designs fulfil customer requirements and plant integrated with existing and new power plants.
- University of Nottingham:** Determining the physical properties of CO₂ and relevant mixtures.



Preliminary results revealed that these innovative concepts could:

- Significantly reduce the power consumption of CCS systems
- Save power plant operators billions of pounds in avoided loss of revenue.
- Provide more choice, increase competition and potentially help to drive down capital costs.



http://www.innovation.gov.uk/assets/pdf/Casestudies/2010/TS/G001693/1/TS/G001693/1_Spec_RollsRoyce_web_22%20Bank%20Board.pdf

'At a recent US Department of Energy workshop on CO₂ compression, it was clear that COZOC is leading the industry, tackling the right technical issues.'

Jonathan Bygrave, Chief Engineer, Industrial Compressors, Rolls-Royce