



Evaluating Materials for Carbon Capture: Unveiling the Power of DVS Carbon

Paris, Avril 2024 - **The imperative to combat climate change has intensified the quest for sustainable solutions, leading researchers to explore innovative methods for carbon capture, utilization, and storage (CCUS). Among the diverse array of materials under scrutiny, solid sorbents have emerged as promising candidates, offering unique mechanisms for capturing and storing carbon dioxide (CO₂). In this blog post, we unravel the transformative capabilities of the DVS Carbon, a high-resolution gravimetric absorption analyzer, and its pivotal role in meticulously evaluating materials for CCUS applications.**

The Landscape of Solid Sorbents in CCUS

As the urgency to decarbonize our society accelerates, the scientific community is navigating a complex landscape of materials aimed at addressing the challenges of carbon capture. From metal-organic frameworks (MOFs) to zeolites and activated carbons, researchers are exploring diverse avenues to find materials that can efficiently and sustainably capture CO₂. The efficacy of these materials, however, hinges not only on their capacity to absorb CO₂ but also on their performance under realistic and dynamic process conditions.

Challenges in Material Evaluation

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Effectively evaluating materials for CCUS demands a multifaceted approach. Beyond assessing the quantity of CO₂ a material can absorb, researchers must consider a spectrum of factors such as working capacity, kinetics, selectivity, stability, thermal properties, and cost considerations. A recent collaboration between researchers at Imperial College in London and industry experts resulted in the formulation of best practices, emphasizing the need for complete characterization metrics and in-process relevant conditions.

The Crucial Role of DVS Carbon in Material Evaluation

In this landscape of intricate challenges and evolving best practices, the DVS Carbon stands as a beacon of innovation. Developed with the express purpose of enabling precise and realistic testing of materials for CCUS, the DVS Carbon is a gravimetric sorption analyzer that transcends traditional measurement tools. Let's explore the key features that make the DVS Carbon an indispensable instrument in the pursuit of sustainable carbon capture solutions.

Gravimetric Precision and Real-Time Monitoring

At the heart of the DVS Carbon lies its gravimetric basis, leveraging a highly sensitive symmetric microbalance. This microbalance, a testament to cutting-edge engineering, facilitates direct measurements of changes in sample mass with unparalleled precision, reaching down to the microgram level. This real-time monitoring capability is foundational in understanding the dynamic nature of material interactions with CO₂ under varying conditions.

Dynamic Flow System for Realistic Simulations

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The DVS Carbon's dynamic flow system is a cornerstone of its capability to simulate realistic process conditions. By precisely controlling concentrations, flow rates, and time, researchers can mimic diverse scenarios, from direct air capture with low CO₂ concentrations to post-combustion conditions with high flue gas concentrations. This flexibility is instrumental in obtaining insights into material performance that align with real-world applications.

Innovation in Sensor Technology

To enhance its performance, the DVS Carbon incorporates patented speed-of-sound sensors. This sensor technology, meticulously redesigned, enables the high-accuracy measurement of carbon dioxide concentrations in the gas phase. Operating within a range of up to 100 percent CO₂ by volume, these sensors contribute to the instrument's ability to capture nuanced changes during absorption and desorption processes.

In the following sections, we will delve into case studies that exemplify the DVS Carbon's capabilities in evaluating materials under realistic conditions, offering a glimpse into its potential impact on advancing carbon capture technologies.

The Breakthrough Analyzer (BTA) Frontier: Illuminating Competitive Adsorption

In tandem with the DVS Carbon, the Breakthrough Analyzer (BTA) Frontier stands as a pivotal instrument in the arsenal for comprehensively understanding the adsorption dynamics of materials, especially in scenarios involving competitive adsorption of multiple gases.

Multi-Component Breakthrough Experiments:

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- **Simultaneous Gas Introduction:** The BTA Frontier allows the introduction of multiple gases simultaneously, mimicking real-world conditions where various gases compete for adsorption sites.
- **Dynamic Breakthrough Curves:** By continuously monitoring breakthrough curves, researchers gain insights into how different gases interact with the material over time.

Quantitative Uptake Analysis:

- **Integration of Breakthrough Curves:** The breakthrough curves obtained can be integrated to quantitatively determine the total and individual uptakes of each gas.
- **Realistic Industrial Conditions:** The instrument enables experiments under conditions representative of industrial settings, providing actionable data for material evaluation.

Versatility and Adaptability:

- **Customizable Experimental Parameters:** Researchers can tailor experiments to specific industrial scenarios by adjusting parameters such as gas concentrations, flow rates, and temperature.
- **Complementary to Gravimetric Analysis:** When coupled with gravimetric instruments like the DVS Carbon, the BTA Frontier offers a holistic approach to understanding material behavior.

Illuminating Material Performance:

In the context of competitive adsorption, the BTA Frontier shines a light on how gases interact with a material in real-world scenarios. Its ability to simulate and quantify

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competitive adsorption provides invaluable insights for researchers and engineers aiming to deploy materials in practical applications, where multiple gases coexist and vie for adsorption.

Whether it's elucidating the interplay between CO₂ and water vapor in post-combustion flue gas or exploring the dynamics of other gas mixtures, the BTA Frontier adds a layer of depth to the understanding of material performance under complex industrial conditions.

Case Study 1: Evaluating Calcium Oxide for Carbon Capture

Experimental Procedure:

- 1. Introduction and Humidification:** Calcium oxide (CaO) samples were loaded into the DVS Carbon and subjected to carrier gas flow at 25°C. Humidity was introduced at various levels (25%, 50%, 70%, 85%) to assess its impact on the hydration of CaO.
- 2. Carbonation Process:** After hydration, the samples were subjected to CO₂ introduction at 400 ppm while maintaining humidity at 85%. This step aimed to evaluate the carbonation kinetics of CaO under conditions representative of post-combustion flue gas.
- 3. Water Isotherm:** Following carbonation, water isotherms were recorded to understand the uptake of water on the material.
- 4. Thermal Regeneration:** The final step involved a thermal regeneration process to drive away all moisture and obtain pure CaO.

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Results and Insights:

Hydration and Carbonation Kinetics:

The experiments revealed that the hydration and carbonation kinetics of CaO are highly influenced by the level of humidity. The higher the humidity, the faster the reactions, showcasing the material's sensitivity to water content. This insight is critical for assessing the material's performance in realistic flue gas conditions where varying humidity levels are encountered.

Water Uptake and Thermal Regeneration:

The recorded water isotherms provided valuable data on the material's affinity for water. The subsequent thermal regeneration step demonstrated the feasibility of completely transforming CaO to calcium hydroxide, confirming the reversibility of the process.

Real-World Implications:

Understanding the kinetics and dependencies on humidity allows researchers to tailor the use of CaO in post-combustion carbon capture scenarios. The ability to control and optimize the regeneration process is crucial for the material's practical application in industrial settings.

Case Study 2: ZLI 13x Zeolite for Post-Combustion CO₂ Capture

Experimental Procedure:

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1. **Single-Component Isotherms:** The DVS Carbon recorded single-component isotherms for both CO₂ and water on ZLI 13x to understand their individual uptakes.
2. **Multi-Component Uptakes:** Breakthrough experiments in the BTA Frontier were conducted to quantify total and individual uptakes when CO₂ and water were introduced simultaneously.

Results and Insights:

Competitive Adsorption of CO₂ and Water:

Single-Component Isotherms:

The isotherms revealed that ZLI 13x exhibits a high uptake for both CO₂ and water. However, even at low concentrations, water seems to saturate the material more rapidly than CO₂. This highlights the competitive nature of water and its potential to impact the material's performance in post-combustion scenarios.

Multi-Component Breakthrough Experiments:

The breakthrough experiments provided a dynamic perspective, showing that water and CO₂ compete for adsorption sites. The total uptake of CO₂ was significantly reduced when introduced simultaneously with water, emphasizing the need to consider water's impact in practical flue gas conditions.

Real-World Implications:

These findings underscore the importance of understanding the water-CO₂ competition when evaluating materials like ZLI 13x for post-combustion CO₂ capture.

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The DVS Carbon and BTA Frontier tandem offers a holistic view, enabling researchers to gauge the material's performance in complex industrial settings.

Conclusion

The DVS Carbon emerges as a transformative instrument in the landscape of material evaluation for CCUS. Its ability to provide real-time, high-resolution data under diverse conditions empowers researchers to make informed decisions in selecting materials for carbon capture. As we navigate the complexities of decarbonization, tools like the DVS Carbon play a pivotal role in accelerating the development of sustainable solutions.

For a more in-depth understanding of the DVS Carbon and its applications, download the full instrument information at <https://surfacemeasurementsystems.com/product/dvs-carbon/>.

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