**RESEARCH NEWS STORY**

**July 16, 2024**
**Chiba University**

# Capturing Carbon with Energy-Efficient Sodium Carbonate−Nanocarbon Hybrid Material

*Scientists have developed a nanocomposite material with sodium carbonate and nanocarbon to capture carbon dioxide from industrial emissions.*

**Carbon capture is a promising approach for mitigating carbon dioxide ($CO_2$) emissions. Different materials have been used to capture $CO_2$ from industrial exhaust gases. Scientists developed hybrid $CO_2$ capture materials containing sodium carbonate and nanocarbon prepared at different temperatures, tested their performance, and identified the optimal calcination temperature condition. They found that the hybrid material exhibits and maintains high $CO_2$ capture capacity for multiple regeneration cycles at a lower temperature, making it cost- and energy-effective.**

**Image title**: A nanocomposite material of sodium carbonate and nanocarbon to capture carbon dioxide from industrial exhaust gas
**Image caption**: Scientists have created a new hybrid material containing sodium carbonate and nanocarbon to capture carbon dioxide from industrial emissions. They found that it demonstrates a high $CO_2$ capture capacity that lasts for 10 regeneration cycles at a low temperature of about 80 °C.
**Image credit**: thewritingzone from Openverse https://openverse.org/image/25f2d614-9398-4492-9dfe-58ff0fc59b7c
**Image license**: CC BY-SA 2.0
**Usage restrictions**: Credit must be given to the creator. Adaptations must be shared under the same terms.

Industrial emissions are one of the main sources of climate change-inducing carbon dioxide ($CO_2$). While adopting renewable and clean energy alternatives is one option for mitigating these carbon emissions, carbon capture technology is another solution to control $CO_2$ emissions. In big $CO_2$-emitting industries, such as cement, oil refineries, and thermal power plants, carbon capture technology can be easily applied to remove $CO_2$ emissions directly at the source at a feasible cost and with low energy consumption. Different materials have been explored for $CO_2$ capture in factories, including zeolites, metal−organic frameworks, natural minerals, alkalis, and alkali metal salts. Among them, alkali metal carbonates, such as sodium carbonate ($Na_2CO_3$), are considered effective and inexpensive materials with stable properties and easy procurement.

Theoretically, $Na_2CO_3$ has a decent $CO_2$ capture capacity and can be easily regenerated for successive uses. However, directly applying $Na_2CO_3$ to capture $CO_2$ causes crystal agglomeration, leading to poor efficiency and shorter longevity. This issue can be eliminated by using a carbon skeleton for $Na_2CO_3$. Porous carbon materials with good pore connectivity provide low density, structural stability, hydrophobicity, and a large surface area that can stabilize $Na_2CO_3$. Previous studies report that $Na_2CO_3$−carbon nanocomposites have a $CO_2$ capture capacity of 5.2 mmol/g. However, these studies do not inspect the effect of the carbonization temperatures on the overall performance of the material.

Therefore, in a new study published in *Energy & Fuels* on June 12, 2024, Professor Hirofumi Kanoh and Bo Zhang from the Graduate School of Science, Chiba University, synthesized a hybrid $CO_2$ capture material consisting of $Na_2CO_3$ wrapped with porous nanocarbon. They further evaluated its $CO_2$ capture and regeneration efficiencies at different carbonization temperatures. The $Na_2CO_3$−carbon hybrids (NaCH) were derived by carbonization of disodium terephthalate at temperatures ranging from 873K to 973 K in the presence of nitrogen as a protective gas. "*Reducing $CO_2$ emissions is an urgent issue, but research on the methods and material systems for $CO_2$ capture are still lacking. This $Na_2CO_3$−carbon hybrid system proved promising in our initial investigations, prompting us to explore it further*," states Prof. Kanoh.

The team measured the hybrid materials' $CO_2$ capture capacity under humid conditions to mimic the conditions of factory waste exhaust gases. They found that the NaCH hybrids prepared at carbonization temperatures near 913–943 K demonstrated higher $CO_2$ capture capacities. Among them, NaCH-923 had the highest $CO_2$ capture capacity of 6.25 mmol/g and a high carbon content of over 40%, which resulted in a larger surface area, enabling a more uniform distribution of $Na_2CO_3$ on the nanocarbon surface. This reduced the rate of $Na_2CO_3$ crystal agglomeration and led to faster reaction rates.

After NaCH-923 effectively captured $CO_2$, the scientists again heated the resultant NaCH-923-$CO_2$ in the presence of nitrogen to test its regeneration performance. They found that NaCH-923 could be regenerated and used for $CO_2$ capture for 10 cycles, while retaining over 95% of its initial $CO_2$ capture capacity. These results indicate that NaCH-923 exhibits good structural strength, durability, and regeneration, which makes it an excellent material for $CO_2$ capture under humid conditions.

Further experiments on the NaCH-923-$CO_2$ showed that the sample underwent a steep mass change at 326−373 K (around 80 °C on average). Since the temperature of the exhaust gas from thermal power plants is also typically in that range, the waste heat from factories and power plants can easily be used as a heat source for regenerating NaCH-923, thereby effectively reducing energy consumption.

These findings show that the carbonization temperature significantly influences the $CO_2$ capture performance and carbon content of NaCH hybrids, with NaCH-923 exhibiting the best characteristics. NaCH-923, being a solid adsorbent, can efficiently capture $CO_2$ at ambient temperature and pressure with high selectivity for $CO_2$ and without the problem of equipment corrosion that exists with liquid adsorbents currently used in industries. Moreover, these characteristics allow for its widespread application in various configurations, environments, and diverse industrial settings.

"*By transforming $Na_2CO_3$, which already has a good $CO_2$ capture capacity, into a nanocomposite, it became possible to improve the reaction rate and reduce the decomposition and regeneration temperature. This enables the use of factory waste heat for regeneration at around 80 °C, giving us an energy-cost efficient $CO_2$ capture system,*" concludes Prof. Kanoh.

**About Professor Hirofumi Kanoh**

Hirofumi Kanoh is a Professor at the Graduate School of Science, Chiba University, Japan. He heads the 'Kanoh Lab' or the Molecular Chemistry Lab at the Department of Chemistry. His core research specialization is in physical chemistry with a focus on the creation and characterization of novel nanoporous solids. His research aims to develop new molecular science that can help protect the earth's environment by utilizing nanospace in solids, and to create basic science aimed at understanding and applying new functions of nanospace and nanostructured materials. He has over 300 publications and over 45 patents in the field of nanochemistry.

**Funding:**
This study was partially supported by JSPS KAKENHI Grant Number 22K05186.

**Reference:**
**Title of original paper:** Sodium Carbonate−Carbon Hybrid Material for Low-Energy-Consuming $CO_2$ Capture
**Authors:** Bo Zhang[1] and Hirofumi Kanoh[1]
**Affiliations:** [1]Graduate School of Science, Chiba University, Japan
**Journal:** *Energy & Fuels*
**DOI:** 10.1021/acs.energyfuels.4c01232

**Contact:** Hirofumi Kanoh
Graduate School of Science, Chiba University, Japan
**Email:** kanoh@faculty.chiba-u.jp

**Public Relations Office, Chiba University**

**Address:** 1-33 Yayoi, Inage, Chiba 263-8522 JAPAN
**Email:** koho-press@chiba-u.jp
**Tel:** +81-43-290-2018