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RESEARCH NEWS STORY

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Chiba University

Viciazites: Efficient Carbon Capture Designer Materials That Could Desorb Below 60 °C

Study shows how precisely controlling nitrogen-containing functional groups in carbon-based materials can enable low-temperature operation (≤ 60 °C)

Solid materials for carbon capture can help reduce greenhouse gas emissions, but many existing systems remain energy-intensive and costly, because releasing captured carbon dioxide (CO_2) typically requires high temperatures. Recently, researchers from Japan developed three kinds of 'viciazites', a new type of carbon-based material with precisely positioned nitrogen-containing functional groups. Through tight molecular control, these materials can release captured CO_2 at temperatures as low as 60 °C, paving the way for efficient carbon capture.

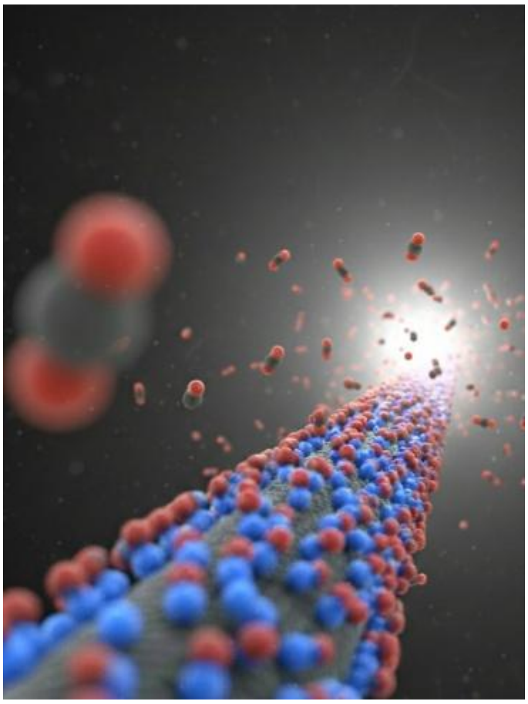

Image title: Towards cost-effective carbon dioxide capture using amine-functionalized carbon materials
Image caption: This image created using Gemini Pro, depicts an activated carbon fiber functionalized with amine groups (–NH_2) at adjacent positions. This arrangement improves the energy efficacy of key interactions, enabling the desorption of captured carbon dioxide at lower temperatures.
Image credit: Associate Professor Yasuhiro Yamada from Chiba University, Japan
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Capturing carbon dioxide (CO_2) before it reaches the atmosphere is a key strategy for reducing greenhouse gas emissions. Even though carbon capture technologies have existed for decades, their widespread adoption has been slow for a straightforward reason: most of them are expensive and inefficient. For example, aqueous amine scrubbing, which is the most common industrial method, requires heating large volumes of liquid above 100 °C to release captured CO_2 and reset the system for reuse. These energy demands translate directly into operating costs, making large-scale deployment challenging.

Carbon-based solid adsorbents have emerged as a promising alternative. These solid, inexpensive materials with large surface area can bind CO_2 and then release it with less heat under low temperature, especially when featuring nitrogen-containing functional groups. Unfortunately, while the performance benefits of these functional groups are apparent, standard synthesis methods can only deposit them randomly and in mixed configurations, making it difficult to know which specific arrangement actually drives efficient performance and why.

Against this backdrop, a research team led by Associate Professor Yasuhiro Yamada from the Graduate School of Engineering and Associate Professor Tomonori Ohba from the Graduate School of Science at Chiba University, Japan, tackled this problem. Their work reports the synthesis and thorough characterization of a new class of carbon materials called 'viciazites,' which contain a carefully controlled configuration of nitrogen groups in adjacent positions. The paper, published online in the journal *Carbon* on February 27, 2026, was co-authored by Mr. Kota Kondo, also from Chiba University.

The team synthesized three distinct viciazites, each carrying a different type of adjacent nitrogen pairing. To introduce adjacent primary amine groups (–NH_2 groups), they carbonized a compound called coronene at high temperature, then treated the material with bromine and finally with ammonia gas. This three-step process produced adjacent –NH_2 groups with 76% selectivity, meaning that the vast majority of introduced nitrogen ended up in the target configuration. The other two materials were made using different precursors: one carrying adjacent pyrrolic nitrogen was synthesized at 82% selectivity, and the other with adjacent pyridinic nitrogen was synthesized at 60% selectivity.

All three materials were coated onto activated carbon fibers to create practical adsorbent samples. The researchers used several techniques, including nuclear magnetic resonance spectroscopy, X-ray photoelectron spectroscopy, and computational modeling to confirm that the introduced nitrogen groups were indeed positioned next to each other in an adjacent manner and not scattered randomly.

Performance tests showed clear differences between the three configurations. The materials with adjacent –NH_2 groups and adjacent pyrrolic nitrogen both outperformed untreated carbon fibers in CO_2 uptake, while adjacent pyridinic nitrogen groups showed little benefit. The most striking result was observed with desorption, which is the process of releasing the captured CO_2 to regenerate the material. "*Performance evaluation revealed that in carbon materials where NH_2 groups are introduced adjacently, most of the adsorbed CO_2 desorbs at temperatures below 60 °C. By combining this property with industrial waste heat, it may be possible to achieve efficient CO_2 capture processes with substantially reduced operating* *costs*," highlights Dr. Yamada. Additionally, the pyrrolic nitrogen-containing material, though releasing CO_2 at a higher temperature, may prove more durable in the long run owing to the superior chemical stability of that functional group.

Overall, by showing that adjacent nitrogen configurations can be built deliberately and reproducibly, this study establishes a promising design framework for the next generation of carbon capture materials. "*Our motivation is to contribute to the future society and to utilize our recently developed carbon materials with controlled structures. This work provides validated pathways to synthesize designer nitrogen-doped carbon materials, offering the molecular-level control essential for developing next-generation, cost-effective, and advanced* CO_2 *capture technologies*," concludes Dr. Yamada. The researchers also note that viciazite materials may find uses beyond CO_2 capture, such as adsorbents for metal ions and catalysts, given the precise and tunable nature of their surface chemistry.

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About Associate Professor Yasuhiro Yamada from Chiba University
Dr. Yasuhiro Yamada obtained his PhD in February 2008 from The State University of New York at Buffalo. He currently serves at the Graduate School of Engineering, Chiba University. He conducts research on structurally controlled carbon materials, focusing on developing techniques for structural control and analysis and unraveling the mysteries of high-performance carbon materials. He has published more than 150 papers to his name.

About Associate Professor Tomonori Ohba from Chiba University
Dr. Tomonori Ohba obtained his PhD in March 2002 from Chiba University. He currently serves at the Graduate School of Science, Chiba University. He conducts research on the molecular systems at the interfaces of nanoscale materials and nanoscale material chemistry. He has published more than 214 articles to his name.

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