Ceramic technologies that **prevent pollution and capture carbon**

In 1970, the US federal government passed the Clean Air Act, which established air quality standards regulating pollution from industry and transport. This landmark law has been emulated by governments worldwide ever since, contributing to better air quality for billions of people.

Significantly, the legislation also spurred technical innovations designed to meet environmental goals without sacrificing growth. One of these innovations is the catalytic converter, fitted onto automotives with internal combustion engines to reduce harmful emissions. As a result, tailpipe emissions from new passenger vehicles are 99 per cent cleaner for most pollutants compared to the 1960s.

One of the largest global manufacturers of substrates used in such catalytic converters today is NGK Insulators Ltd., the Japanese technology company.

NGK's president Shigeru Kobayashi likes to talk about Senator Edmund Muskie of Maine, who authored the Clean Air Act and became a leading voice of modern American environmentalism. Kobayashi sees similarities between the developments in the 1970s in air pollution regulation and the current pivot to carbon neutrality. He says the new global commitment to cutting GHG emissions and its regulatory frameworks is transforming his company. And, he believes, the commitment will continue to spur new innovations, including many in ceramics.

"Reducing and regulating the emissions of CO_2 is now the key issue and clearly where the business opportunities are," says Kobayashi. "I believe we have many ceramic-based technologies that can effectively contribute to decarbonisation and efforts to capture, store and utilise carbon sustainably."

Ceramic solutions for CCUS

Indeed, NGK has a surprisingly broad portfolio of potential solutions across the carbon, capture, utilisation and storage (CCUS) cycle.

The company is working on ceramic membranes capable of separating substances at a molecular level, including carbon dioxide, with unique sub-nanometre-sized pore control technology. It is already field-testing one of these membranes separate CO_2 during enhanced oil recovery processes. In addition, it hopes to develop others that can capture CO_2 directly from factory and energy plant flues. And for the vast amounts of CO_2 already released into our atmosphere, the company is developing a honeycomb-structured ceramic contactor for use in direct air capture (DAC, see sidebar).

Captured carbon in these processes can be fed into a solid-oxide electrolysis cell to generate hydrogen or ceramic reactors to generate various synthetic fuels such as methane, methanol and e-fuels, both solutions that NGK is hard at work to realise.

Shigeru Kobayashi, President, NGK Insulators, Ltd.

Finally, to power various steps of this cycle, the company is offering grid-scale ceramic-based NAS® storage batteries that have been successfully deployed for over 20 years. It is also developing a new zinc rechargeable ZNB battery optimised for safe indoor use.

"All of these key technologies — from membranes, reactors, to honeycombs — have evolved out of producing catalytic converters for the automotive industry," says Kobayashi. "So we already have the know-how, factories, people and capital needed for massive scaling of these solutions."

New value from ceramics

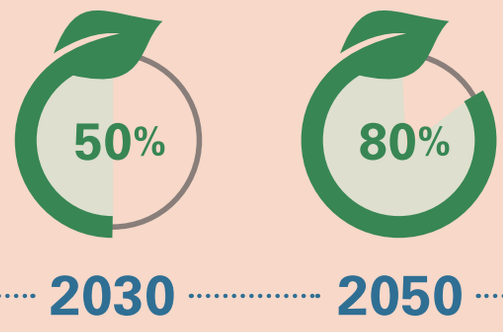
It makes sense for a company to be eager to refashion its production lines, which annually supply tens of millions of components to internal combustion engine automobiles, towards products aimed at a carbon-neutral future.

But even from a purely technical perspective, ceramics offer advantages.

"Ceramic membranes and filters can be used efficiently under high temperature, high pressure and corrosive environments while also providing efficient and highly accurate separation of particles, including for CO_2," explains Kobayashi.

Compared to other organic materials currently being tested for DAC and various CCUS processes, such as pellets and fibres, ceramics can improve energy efficiency and structural durability.

Another consideration is that these ceramic products can be made from a material that is abundant and commonly available. For example, NGK's ceramic-based NAS® batteries, which do not use rare metals, will become increasingly attractive as global lithium supplies come under strain from surging demand.



Percentage of total sales NGK is aiming to generate from products related to carbon-neutral and digital technologies

To work towards its new vision as a leader of carbon-neutral and digital technologies, NGK will spend ¥300bn over the ten-year period to 2030 on R&D for solutions related to these two fields. The goal is to generate half of its total sales from products from these areas by 2030 and to then raise it to 80 per cent by 2050 from its current 30 per cent[1].

The company also expects steady demand for automotive catalysts as exhaust regulations across developing world markets become more stringent, and the shift to EVs has yet to materialise. Elsewhere, sales from semiconductor manufacturing equipment materials and various electronic components are robust, in line with the ongoing digital transformation of the global economy.

Bringing a hard-to-abate sector to zero emissions

One key challenge in achieving net zero emissions is ensuring the technology used to capture carbon does not generate more carbon than it captures. This challenge is particularly relevant for 'hard-to-abate' sectors like steel, cement and chemicals, which are energy-intensive and have hefty emissions.

Ceramic manufacturing is an energy-hungry industry, with high-tech industrial ceramics often fired at over 1,300 degrees Celsius inside furnaces primarily fuelled by burning natural gas. Today, industrial ceramics accounts for some 1 per cent of Europe's carbon emissions.

NGK figures show the company emitted, at its peak level, 870,000 tonnes of CO_2 in 2019 (of which 70 per cent came from electricity and 30 per cent from fossil fuels used for kilns). The firm says it is working to reduce emissions to 370,000 tonnes of CO_2 by 2030 and to reach net zero by 2050[2].

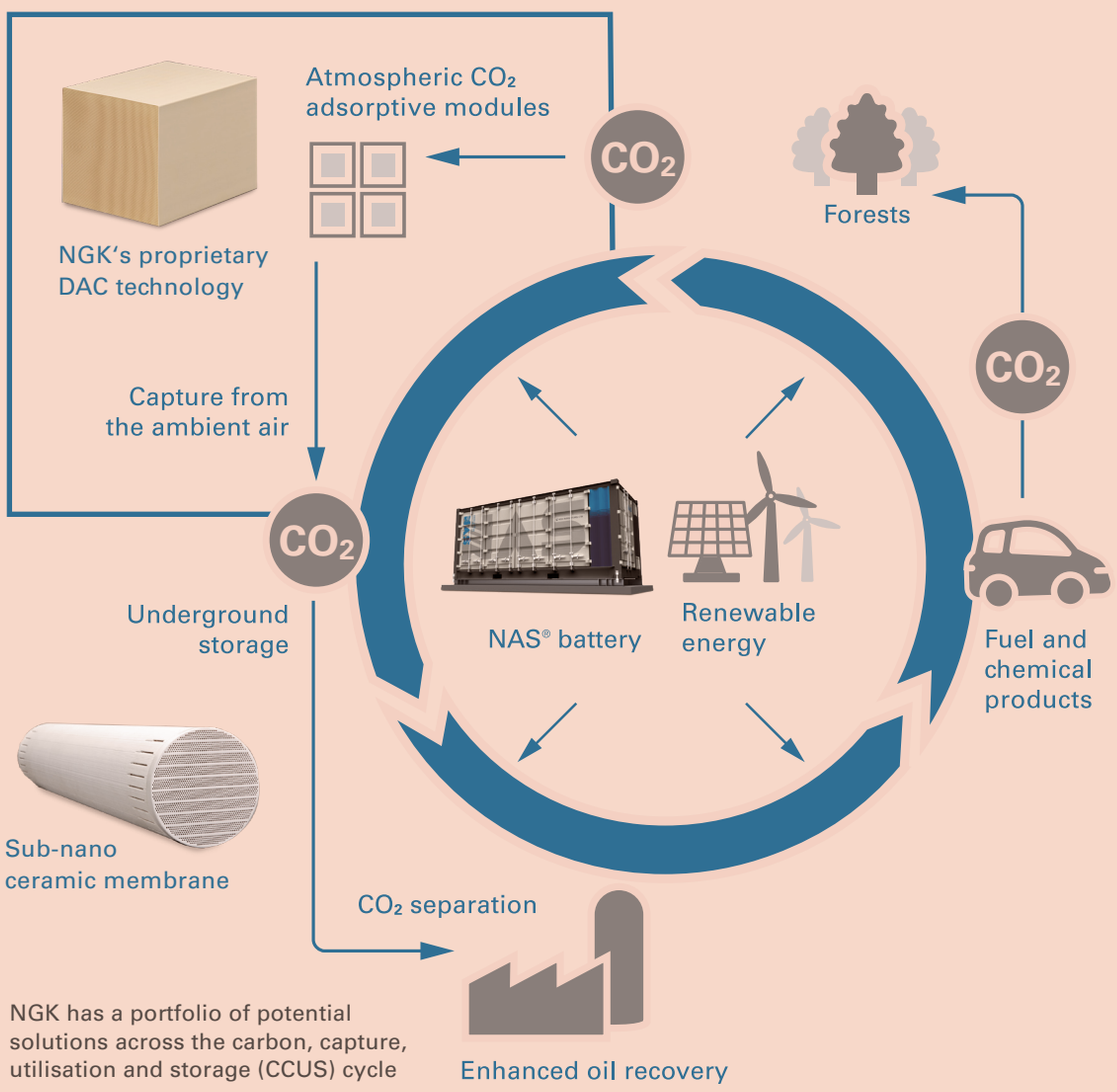
"We have been experimenting with hydrogen to fire our kilns and find that it is more or less possible," explains Kobayashi. "But for this fuel transition to be feasible, there needs to be a supply chain of cheap and clean hydrogen."

In the meantime, NGK is making existing plants more efficient and experimenting with other processes, such as methanation and electric kilns.

Last year, NGK joined the RE100, a global initiative which aims for 100 per cent of the electricity used in business operations to come from renewable energy sources. As a result, the company has committed to sourcing all electricity in its overseas operations from renewables by 2025[3] and globally by 2040[4]. To accelerate this process, NGK is deploying large-scale NAS® storage batteries in combination with photovoltaic cells across its factories globally, with a target of generating some 40MW (amounting to a cut of 22,000 tonnes of CO_2 emissions) from its solar panels by 2025[5].

Much remains to be done, but the tempo for the century-old ceramics specialist is accelerating.

"There are few companies like us which have been patiently, almost boringly, researching ceramic technologies for decades," says Kobayashi. "Now, we are combining this with a focus on agility to bring these solutions to market quickly."



NGK has a portfolio of potential solutions across the carbon, capture, utilisation and storage (CCUS) cycle

How ceramics can contribute to scaling up DAC

The science is clear. Meeting Paris Agreement goals will require gigatonnes of carbon already emitted to be effectively scrubbed out of the air.

One promising solution is direct air capture (or DAC), a technology that removes carbon directly from the ambient air through a chemical process. To make a material impact, DAC must be scaled up fast. The International Energy Agency estimates that an average of 32 large-scale DAC plants, each capable of capturing 1 megatonne of CO_2 per year, need to be built annually between now and 2050.

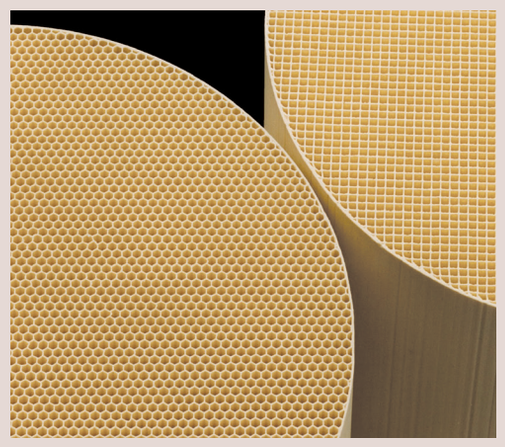
NGK believes that its ceramic substrate — supplied for decades in use for catalytic converters to purify exhaust gases from combustion engines in cars — is suitable for this task.

The ultra-thin walls of the substrate's honeycomb structure create a very large surface area to be coated with chemicals that bind to CO_2 and remove them from ambient air. Its structural strengths also generate reduced pressure loss and heat capacity than other approaches. This means less electricity is needed to push the air through the contactor and less heat is required to release the captured CO_2, making the process more efficient. Ceramics are also highly durable, resulting in longer lifespans and lower capital costs, compared to other materials.

By deploying these ceramic components in modular and easy-to-scale solid-DAC plants, carbon removal operations can be scaled up rapidly and more efficiently.

The company expects that 30 litres of honeycomb ceramics will be needed to extract one tonne of CO_2 annually. NGK aims to modify its existing plants to be able to supply 300 million litres of honeycomb for DAC by 2040[6]. That represents a fifth of the capacity of DAC that the IEA estimates will be required to reach climate targets.

Currently the company is supplying samples of its ceramic components to DAC companies and aims to achieve demonstration tests by 2025.



The company believes the honeycomb structure of its ceramic substrates could help scale carbon removal operations

1, 2 NGK Report 2022
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