Technology Scan

Focus: Air Pollution Control Technologies

ASIA-PACIFIC

AUSTRALIA

Solar-powered carbon capture systems

A technology has been developed by a carbon dioxide capture company called AspiraDAC, with its first customer, global financial infrastructure company Stripe. The first generation product was developed in collaboration with the University of Sydney. It will be followed by a second generation unit made by utilizing additive manufacturing processes.

When it comes to the engineering of the machine, it is built around a sponge-like substance produced at the University of Sydney that traps CO_2 molecules when air travels through it. Fans suck air into the sponge-filled canisters, and heat is used to extract pure CO_2, which **may be piped and stored underground**. The best feature of this technology is that the solar panels that cover the units like an A-frame tent provide all of the power.

https://interestingengineering.com

CHINA

Low-temperature ignition for diesel soot elimination

Using conductive metal oxides as catalysts, researchers have developed an electrification strategy aimed at decreasing the ignition temperature of soot. Relevant results were published in *Nature Catalysis*. This research was conducted by Prof. Zhang Jian's group at the Ningbo Institute of Materials Technology and Engineering (NIMTE) of the Chinese Academy of Sciences (CAS) and Prof. Zhang Zhaoliang's group of the Jinan University.

Catalytic soot combustion is the most efficient after-treatment technology for reducing diesel soot particulate emissions, which can trigger severe health and environmental problems. However, urban diesel vehicles idle frequently in traffic with exhaust temperatures reaching from 100°C to 200°C only, which is too low for catalytic soot combustion to occur. Aiming at realizing soot ignition at low temperatures, researches at NIMTE and Jinan University designed an electrification strategy for soot combustion. Typical conductive metal oxides with excellent oxidation resistance and conductivity were employed as catalysts.

According to the researchers, 53 per cent of the soot in the mixtures was combusted within only a few minutes at <75°C. The performance achieved was far superior to that achieved from a conventional thermal catalytic soot combustion, generally with T_{50} (the temperature at which 50 per cent of soot is converted) >300°C. Thus, the dependence of electrification on contact conditions is much weaker than that of a conventional thermal process.

In regard to energy demand, an electrification process consumes considerably less energy than a thermal process, with an energy-saving rate of one to two orders of magnitude. In addition, two key mechanisms for the performance were illuminated, electrically driven release of lattice oxygen from catalysts accounts for the rapid soot ignition at low temperatures, while the opposite electrostatic fluidization between the conductive catalyst and soot particles is responsible for the catalyst-soot contact efficiency improvement.

The electrification process has achieved a breakthrough in the ignition temperature for soot combustion, presenting a prospective strategy to solve the common issue of all automotive after-treatment at low exhaust temperatures. Promisingly, this strategy could be integrated into vehicle design, especially that of hybrid electric vehicles, by virtue of onboard electric power systems.

https://phys.org

INDIA

Environment-friendly fuel engine technology for vehicles

Researchers from the Indian Institute of Technology (IIT) Delhi's Department of Energy Science and Engineering (DESE), Indian Oil Corporation (IOC R&D), and Ashok Leyland Ltd. have developed a technology that enables a diesel-powered automotive vehicle to run in flex fuel mode, that is, either 100 per cent diesel or Dimethyl Ether (DME) plus Diesel mode. The project was funded by the Department of Science and Technology (DST). Using this technology, the researchers converted a diesel-powered automotive vehicle into a flex fuel vehicle on a pilot basis. This flex fuel technology-based vehicle DOST was jointly flagged off on 8 April 2022 at IIT Delhi by the officials. While the flex fuel engine technology that uses DME was developed by the IIT Delhi, the IOC R&D undertook the endurance and field trials tests and developed the dedicated engine oil with the technical support of Ashok Leyland.

The major highlights of the technology developed by the IIT Delhi, IOC R&D, and Ashok Leyland are:

- Flex Fuel Vehicle Technology (Vehicle can run both modes: either 100 per cent diesel or DME-Diesel mode)
- The transition of diesel trucks from conventional diesel to DME as an alternative fuel (First phase as Flex Fuel Vehicle; Second Phase as dedicated 100 per cent DME/alternative fuelled vehicle)
- Less or negligible smoke, soot, Particulate Matter (PM) emission
- Lower noise with smoother engine or vehicle operation
- Improvement in transient engine performance
- Enhancement of energy security
- Sustainable environment as there is a substantial reduction in Greenhouse Gas Emission

https://news.careers360.com

Material that can absorb greenhouse gas

Researchers at the Indian Institute of Chemical Technology (IICT), Hyderabad have computationally designed a hybrid material that can capture methane and also act as a catalyst to convert it to high purity hydrogen. The team has succeeded in computationally designing this hybrid material that can also simulate a process of capturing carbon dioxide in situ and convert it to high purity hydrogen from non-fuel grade bioethanol. The team has developed a facility, where they can test this material and push for innovative technology in carbon capture.

The new facility developed by the researchers is a dual operational fixed cum fluidized bed reactor system (FBR) that can carry out enhanced steam methane reforming (SESMR) for high purity H2 production based on the modeling and preliminary experimental studies.

https://www.indiatoday.in

Converting CO_2 into eco-friendly methane

Indian scientists have developed an affordable metal-free catalyst that can convert carbon dioxide to methane by simply absorbing visible light. The research that's currently ongoing would help reduce CO_2 into value-added products like methane, where it can be used for clean fuel as well as applications in fuel cells as a hydrogen carrier.

CO_2 reduction can be done in a variety of ways such as photochemical, electrochemical, photoelectrochemical, photothermal etc. A photochemical process makes use of the solar energy as a renewable source. However, for a photo-catalyst to convert CO_2 into other applications, you need light-harvesting properties, charge carrier, separation proficiency, and the presence of a proper electronically aligned conduction band, so the endeavour to turn carbon dioxide into methane selectively and effectively is a challenging endeavour. Only some specific catalysts are able to do so and most of them contain metal counterparts that are toxic and expensive.

To overcome this, researchers from the Jawaharlal Nehru Centre for Advanced Scientific Research –an autonomous institute of the Department of Science and Technology, Government of India – have created a metal-free porous organic polymer that absorbs visible light to catalyze the CO_2 reduction reaction, turning it into methane.

They've developed a donor-acceptor assembly using a C-C coupling to form a stable conjugated microporous organic polymer, which was used as a heterogeneous catalyst. The keto group present in the phenanthraquinone moiety acted as a catalytic site in contrast with other conventional metal-based catalysts, where the metal counterpart carries out the CO_2 reduction reaction.

During a catalysis process, the first chemical dubbed conjugated microporous polymer could update carbon dioxide on its surface due to its high CO_2 intake capability at a room temperature and turn it into methane. The push-pull effect between the electron-rich donor and the electron-deficient acceptor caused efficient electron-hole separation, enhancing electron transfer kinetics and assisting in efficient catalysis.

https://www. indiatimes.com

CO_2 capture from power plants

The Indian Institute of Technology (IIT) Guwahati has partnered with National Thermal Power Corporation (NTPC) Limited to design and develop a highly energy-efficient plant for carbon dioxide capture from power plants. In a communiqué, the IIT Guwahati has stated that this technology, which works on flue gas using a newly activated amine solvent (IITGS), consumes up to 11 per cent less energy as compared to the commercial activated MDEA (Monoethanolamine) solvent, and up to 31 per cent less energy compared to the benchmark MEA (Monoethanolamine) solvent.

This indigenous technology was developed by a research team led by Bishnupada Mandal, from the Department of Chemical Engineering, IIT Guwahati. It has the potential to save a lot of foreign exchange for the nation. Bishnupada Mandal, Department of Chemical Engineering, IIT Guwahati, said, "The increase in anthropogenic CO_2 emissions is one of the reasons attributed to global warming. Extensive research efforts are being made by the scientific community to overcome this global challenge that includes modifications to existing technologies through efficiency improvement for CO_2 capture."

According to the IIT Guwahati, the outcomes of this project will benefit oil, natural gas, biogas industries, and petroleum refineries. This project, through its research and education, will support and strengthen the UNs Sustainable Development Goals (SDGs) as well. After the successful completion of test studies, the pilot plant has been shifted to NTPC's NTPC Energy Technology Research Alliance(NETRA) facility. The IIT Guwahati Team and the NTPC Limited are in the process of patenting the technology. This development has the potential to impact and combat global climate change. The next phase of the study will involve the testing of the pilot-pant using industrial flue gas.

The MEA and other proprietary solvent-based technologies are available for CO_2 capture in the chemical industry. This technology is utilized in coal and gas-fired power plants, mainly to produce food-grade CO_2 in small quantities (compared to CO_2 capture in power plants). However, the IIT Guwahati claims the process is energy-intensive, if adopted for large-scale CO_2 capture in power plants. It has developed an energy-efficient amine-based process for CO_2 capture from flue gas.

https://www.telegraphindia.com

JAPAN

Converting CO_2 to formic acid

The photoreduction of CO_2 into a transportable fuel like formic acid (HCOOH) is a great way of dealing with CO_2's rising levels in the atmosphere. To aid in this mission, a research team from Tokyo Tech chose an easily available iron-based mineral and loaded it onto an alumina support to develop a catalyst that can efficiently convert CO_2 into HCOOH with 90 per cent selectivity!

The scientists developed the photocatalytic systems that could reduce CO_2 with the aid of sunlight. Such a system consists of a light-absorbing substrate (i.e., a photosensitizer) and a catalyst that can enable the multi-electron transfers required to reduce CO_2 into HCOOH.

In a recent study published in *Angewandte Chemie*, the team adopted a simple impregnation method to synthesize their catalyst. They then used the iron-loaded Al_2O_3 material for photocatalytic reduction of CO_2 at room temperature in the presence of a ruthenium-based (Ru) photosensitizer, an electron donor, and a visible light of wavelength over 400 nanometer. The results were quite encouraging; their system showed 80-90 per cent selectivity towards the main product, HCOOH, and a quantum yield of 4.3 per cent (which indicates the system's efficiency).

This study presents a first-of-its-kind, iron-based solid catalyst that can generate HCOOH when accompanied by an effective photosensitizer. It also explores the importance of a proper support material (Al_2O_3) and its effect on the photochemical reduction reaction.

https://www.eurekalert.org

Carbon capture system claims 99 per cent efficiency in ambient air

Researchers from the Tokyo Metropolitan University have developed a new compound that can reportedly remove carbon dioxide from ambient air with 99 per cent efficiency and at least twice as fast as the existing systems.

The Direct air capture (DAC) technologies usually remove carbon dioxide by piping air or exhaust through some kind of filter or catalyst, including magnetic sponges, zeolite foam or materials made of clay or coffee grounds. Other carbon capture technologies bubble the air through a liquid, which can either absorb the CO_2 or cause it to separate out into solid crystals or flakes.

The new compound falls into the last category, which is known as liquid-solid phase separation systems. While studying a series of liquid amine compounds, the Tokyo Metro team discovered a compound called isophorone diamine (IPDA), which was particularly effective at capturing carbon dioxide.

In tests, the team found that the IPDA was able to remove more than 99 percent of CO_2 from the air with a concentration of 400 parts per million (ppm) – about the level currently in the atmosphere. This process also happened much faster than other carbon capture techniques, removing 201 millimoles of CO_2 per hour, per mole of the compound. That is at least twice as fast as the other DAC lab systems, and far faster than the leading artificial leaf device.

The pollutant separated out into flakes of a solid carbamic acid material, which could be removed from the liquid relatively easily. If need be, it can be converted back into gaseous CO_2 by heating it to 60 °C (140 °F), which also releases the original liquid IPDA ready for reuse. Whether the carbon is kept as a solid or a gas, it can still be stored or reused in industrial or chemical processes.

The new system shows promise but, of course, there is always the question of scale. Humanity belches about 30 billion tons of carbon dioxide into the atmosphere every year, and the world's largest direct air capture plant currently removes about 4,000 tons a year. It feels a little like bailing water out of a sinking ship with a shot glass. The researchers on the new study are now working on improving the system and investigating how the captured carbon could best be used.

https://newatlas.com

Recycling of CO_2 and drug development

Researchers at the Institute for Chemical Reaction Design and Discovery (ICReDD) at Hokkaido University have formulated a technique that has the potential to assist in the recycling of waste carbon dioxide (CO_2) while also creating molecules beneficial for drug development. The team guided by Professor Tsuyoshi Mita applied an electrochemical technique wherein an electron was incorporated into either the CO_2 molecule or to the other molecule in the solution, rendering it much easier for them to react with each other. This study marks a particularly huge breakthrough since CO_2 is used to conduct a traditionally challenging type of transformation with unparalleled efficiency. When the specific conditions are met, electrons can be shared between numbers of atoms in a molecule by what is known as an aromatic system.

These systems are particularly stable and hard to break, but the new technique formulated at ICReDD can dearomatize, or break these stable aromatic systems by incorporating CO_2 into the molecule using electricity. This method has the potential to recycle CO_2 as well as produce high value-added dicarboxylic acids from basic starting materials, solving two issues simultaneously.

Before the actual experiments, the researchers from the ICReDD screened numerous heteroaromatic compounds by assessing their reduction potentials, which is a measure of how a compound will react when exposed to an electric environment. The results allowed the scientists to detect potentially reactive compounds and perform targeted electrochemical experiments. They show that a wide range of substrates that display highly negative reduction potentials can very efficiently experience this extraordinary dearomative incorporation of two CO_2 molecules.

https://www. azocleantech.com

REPUBLIC OF KOREA

Low-temperature DeNOx catalyst for reducing emission

At the Extreme Materials Research Center, which is a part of the Korea Institute of Science and Technology(KIST), a research team of Dr. Kwon, Dong Wook, and Dr. Ha, Heon Phil announced the development of a high-durability low-temperature catalyst material for selective catalytic reduction (SCR); it can reduce NOx into water and nitrogen, which are harmless to the environment and the human body.

The team successfully developed a composite vanadium oxide-based catalyst material that significantly limited the formation of poisonous ammonium sulfate by suppressing the adsorption reaction between the active sites and sulfur dioxide. A catalyst interface engineering technique was used in which molybdenum and antimony oxides were added to the vanadium-based catalyst.

The developed vanadium oxide-based composite catalyst material has significantly increased catalytic life when exposed to sulfur dioxide at 220°C, with the time to reach 85 per cent of the initial performance delayed by about seven times as compared to that in a conventional catalyst. The developed catalyst is also energetically efficient due to increased low-temperature activity, which significantly lowers the burden of NOx treatment without reheating the exhaust gas. As a result, it is possible to reduce air pollutant treatment costs if the developed catalyst is applied to industrial sites in the future.

After completing the laboratory-scale reactor experiment, the team installed a pilot demonstration facility at the Kumho Petrochemical's Yeosu 2nd Energy Cogeneration Power Plant to test using actual flue gas. The KIST-Kumho Petrochemical team aims to establish plant facilities by 2022 after deriving an optimal operation plan by evaluating and verifying the driving variables of the demonstration facility for about ten months.

https://phys.org

SINGAPORE

Storing CO_2 below ocean floor sediments

Scientists from the National University of Singapore (NUS) Department of Chemical and Biomolecular Engineering have shown the first-ever experimental proof of the steadiness of CO_2 hydrates in oceanic sediments — a vital step in rendering this carbon storage technology a practical reality. The team's results — part of a project financially supported through the Singapore Energy Centre — were first reported in the scientific journal *Chemical Engineering Journal*.

Using a specially engineered laboratory reactor, the NUS researchers demonstrated that CO_2 hydrates can stay stable in oceanic sediments for up to 30 days. Soon, the team says, the same technique can be used to verify the stability of CO_2 hydrates for longer periods of time. At low-temperature and under high-pressure environments formed by the ocean, CO_2 can be stored within water molecules, creating an ice-like substance. These CO_2 hydrates develop at a temperature just above the freezing point of water and can store nearly 184 m^3 of CO_2 in 1 m^3 of hydrates. The presence of massive volumes of methane hydrates in similar sites globally and their safe existence offers a natural analogy to support the theory that CO_2 hydrates will stay stable and safe if deposited under deep-oceanic sediments. The researchers state that this technology could ultimately be transformed into a commercial-scale process, allowing nations like Singapore to efficiently sequester over two million tons of CO_2 per annum as hydrates to comply with the emission reduction targets.

Working with specially engineered equipment, Prof Linga and his team recreated the environments of the deep ocean floor, where temperatures range between 2 °C to 6 °C, and the pressures are 100 times greater than what is encountered at sea level. Developing a macro-scale reactor that could sustain such conditions was difficult and is one of the reasons why experiments to verify the stability of CO_2 hydrates were not formerly possible.

The NUS researchers surpassed this challenge using an in-house developed pressurized vessel, fitted with a silica sand bed, which mimicked ocean sediments. The researchers were able to create solid hydrates on top and within the silica sand bed, and modified the pressurized vessel to imitate the oceanic environment to view the stability of the formed solid CO_2 hydrates in sediments. Under pressurized settings, the hydrates were monitored for 14 to 30 days, and were found to exhibit a high level of stability.

This hydrate technology would enable nations to sequester large quantities of carbon emissions in deep-ocean geological formations on top of how it is presently stored in saline aquifer formations and depleted oil and gas reserves.

https:// www.azocleantech.com

EUROPE

AUSTRIA

Molybdenum, sulphur key to converting CO_2 into methanol

RResearchers at the Vienna University of Technology (TU Wien) have developed a solution that allows for the production of liquid methanol from carbon dioxide using a catalyst material made of sulphur and molybdenum. The new technology is already patented and in the process of being brought to an industrial scale, is meant to sequester CO_2 from the exhaust gas stream of large industrial plants.

"To convert carbon dioxide, catalysts based on copper have often been used so far," Karin Föttinger, one of the scientists involved in the project, said in a media statement. "However, they have the disadvantage that they are not robust. If there are certain other substances in the exhaust gas stream besides carbon dioxide, for example, sulphur, the catalyst quickly loses its activity. It is said that the catalyst is poisoned." Given this situation, Föttinger and her team set out to find a better material.

The group was able to show that catalysts based on sulphur and molybdenum fulfills these requirements. Special additional elements, such as manganese, ensure that carbon dioxide, which is actually very unreactive, is activated and converted. By choosing such additional elements, the properties of the catalysts can be precisely adapted to the desired area of application. In this way, methanol can now be produced from waste gases containing CO_2.

https://www.mining.com

DENMARK

Decarbonization technology for waste-to-energy plant

Danish researchers have demonstrated that it is possible to remove most of the carbon dioxide (CO_2) from the emissions of a waste incinerator, and by demonstrating the viability of the process, the researchers believe that they have developed a key technology in the fight against climate change. A pilot plant has been operational in Copenhagen for several months and a novel gas monitoring technology has enabled the optimization of plant efficiency.

Researchers from the Technical University of Denmark (DTU) are, therefore, working with a highly innovative waste incineration plant in Copenhagen to develop a process, which will be able to capture carbon dioxide (CO_2) from its emissions. The project is utilizing advanced gas analyzers from the measurement product manufacturer Vaisala to measure the carbon capture efficiency and, therefore, carbon capture utilization and storage (CCUS) viability.

The researchers have developed a pilot plant to remove CO_2 from the emissions of the incinerator at the Amager Bakke Waste-to-Energy Plant, which is one of the largest combined heat and power (CHP) plants in the northern Europe, with the capacity to treat 560,000 tonnes of waste annually. Developed by the Copenhagen-based waste management company ARC (Amager Ressourcecenter), which is jointly owned by five Copenhagen-area municipalities, the CHP plant features a number of innovations including a rooftop artificial ski slope, which is a part of an outdoor activity centre known as CopenHill.

The pilot plant was developed to capture CO_2 from the emissions of processes such as wastewater treatment, biogas production, anaerobic digestion, and waste incineration. However, the researchers are also investigating the ways in which CO_2 can be both captured and utilized. Prior to its installation at the Amager Bakke, the pilot carbon capture plant was operated at a wastewater treatment plant. "The technology itself is not new," explained Jens Jørsboe, a researcher from the DTU, "However, the focus of our work has been to lower the cost of carbon capture, so that it can become economically feasible."

Exhaust gas from the Amager Bakke incinerator is passed through an electrostatic precipitator (ESP) to remove particulates, nitrous oxide (NOx) compounds are removed by selective catalytic reduction (SCR), and a scrubber removes oxides of sulfur. High levels of CO_2 remain in the flue gas and the main purpose of the pilot carbon capture plant is to investigate the feasibility of its capture. To achieve this, the gas is passed upwards through a column packed with beads and a monoethanolamine (MEA) solvent which scrubs the CO_2 from the gas. The solvent is then passed to a desorber, which removes the CO_2, which is now almost pure, and regenerates the MEA for re-use. As a research project the produced CO_2 is currently still vented to the air; but on a commercial basis, there are many different industrial applications, in which CO_2 can be utilized. For example, CO_2 can be reacted with hydrogen in the Sabatier process to produce methane (a gas fuel) and water, at an elevated temperature and pressure, in the presence of a nickel catalyst. This can be a green method for manufacturing fuel if the hydrogen is generated by electrolysis using renewable energy – from solar, biogas, or wind power for example.

https://www.gasworld.com

NETHERLANDS

Prototype EV scrubs CO_2 from air

A student team from the Eindhoven University of Technology has built a prototype electric passenger car that removes and stores carbon dioxide from the air as it rolls down the roads, with the aim of capturing more CO_2 than is emitted during a full lifecycle of a vehicle. The project is the seventh for the TU/ecomotive students, following 2018's Noah concept and the Luca from 2020. The challenge for the Zem (EM-07) team was to build a carbon net-zero electric vehicle.

The team created a monocoque and body panels using additive manufacturing techniques to reduce material waste and produce "as little CO_2 emissions as possible," while also making use of recycled plastics, which can be shredded and re-used for other projects. The use of recycled plastics continues inside, along with sustainable materials like pineapple leather. Polycarbonate is the material of choice for the windows instead of glass, which the team says is better for the environment. And a modular infotainment system, modular electronics, and modular lighting were installed as well, which can all be reused in other products.

The fact that the Zem is an electric vehicle means that zero carbon dioxide is emitted while it's being driven around. As the focus of this project was the car's carbon footprint and recyclability, the details on the drivetrain are scant but the students have mentioned that there are nine 2.3-kWh modular battery packs installed, there's a 22-kW motor, and there's "an old Audi differential with a relatively high gear ratio to increase the torque.

What looks like a fairly standard grille to the front actually flows to the direct air capture technology – for which the students are seeking a patent – that scrubs the air as the vehicle moves along. The team claims that up to two kg of CO_2 could be removed for every 20,600 km (12,800 miles) traveled per year at around 60 km/h (37 mph). Though this isn't a great deal on its own, if the technology were to be rolled out to the millions of cars on the road around the world, then it has the potential to make a real contribution to the decarbonization efforts.

The Zem's filter currently fills to capacity after 320 km (200 miles), and the thinking is that such filters could be cleaned using green energy and the captured CO_2 stored in a tank as an EV is topped up at charging stations, and then reused to capture the next batch. What happens to the captured CO_2 after drop-off isn't clear – though we have seen some interesting projects recently that show potentials in dealing with such things, including using captured CO_2 to make more eco-friendly concrete, creating synthetic fuels and plastics from simple chemical building blocks and even putting the fizz in bubbly water.

https://newatlas.com

UK

Supercapacitor device helps reduce CO_2 emissions

Scientists have built a low-cost device capable of selectively capturing carbon dioxide gas while charging. When it ejects, the CO_2 can be distributed in a controlled manner and accumulated to be reused or disposed of. A supercapacitor device is the size of a two-pence coin and is created in part from sustainable materials such as coconut shells and seawater.

The supercapacitor, developed by scientists at the University of Cambridge, could help fuel carbon capture and storage innovations at a much cheaper price. Every year, approximately 35 billion tons of CO_2 are discharged into the air, and the alternatives to avoid these emissions and resolve the climate crisis are desperately needed. The most sophisticated carbon capture technologies are currently energy-intensive and costly.

A supercapacitor is made up of two electrodes, one positive and one negative in charge. The group tried interchanging from a negative to a positive voltage to broaden the charging time from previous trials in works led by Trevor Binford. This increased the ability of a supercapacitor to capture carbon.

The results are reported in the journal *Nanoscale*.

https://www.azom.com

NORTH AMERICA

USA

Technology to reduce heavy-duty diesel emissions

The Southwest Research Institute (SwRI®) demonstrated the effectiveness of its patented and award-winning Catalyzed Diesel Exhaust Fluid (CAT-DEF™) technology during the WCX™ World Congress Experience in Detroit, which took place from 5 to 7 April. The internally funded advancement successfully reduced the heavy-duty diesel engines' nitrogen oxide (NOx) emissions to meet the California Air Resources Board (CARB) 2027 standards.

CAT-DEF, which stands for Catalyzed Diesel Exhaust Fluid, is an SwRI-developed catalyst- and surfactant-modified diesel exhaust fluid (DEF) solution. Today's diesel engines use selective catalytic reduction (SCR), an advanced emissions control system, to abate NOx emissions. The DEF is injected into the exhaust stream and ideally decomposes to form ammonia, which reacts with NOx on the SCR catalyst to form N_2 and H_2O.

Although the current process is relatively efficient at temperatures greater than 250°C, at temperatures below 250°C, the urea-derived deposits form within the after-treatment system. These deposits severely limit low-temperature NOx conversion and increases fuel consumption as high-temperature engine operations are required to remove the deposits. The SwRI's novel technology decreases the NOx and carbon dioxide emissions for diesel engines by significantly reducing the undesirable deposit formations in exhaust systems.

"Although DEF technology has been utilized for more than a decade, the highest emissions control efficiencies could never be realized due to DEF's tendency to create potentially harmful deposits in the exhaust system, particularly when the engine is operated at low loads and temperatures," said Dr. Charles E. Roberts Jr., the director of SwRI's Commercial Vehicle Systems Department. "A combination of surface-active agents and heterogenous catalysts blended into CAT-DEF reduces deposits by 90% with potential reductions up to 98%."

Using internal fundings, the SwRI engineers studied the technology's effectiveness for reducing NOx emissions at the new standards set by CARB – known for enacting stricter standards than the Environmental Protection Agency – through a head-to-head comparison of diesel engines operated with and without the CAT-DEF.

https://www.eurekalert.org

Carbon capture technology to remove 99 per cent of CO_2 from air

The University of Delaware engineers have demonstrated a way to effectively capture 99 per cent of carbon dioxide from air using a novel electrochemical system powered by hydrogen. It is a significant advance for carbon dioxide capture and could bring more environmentally friendly fuel cells closer to the market. The research team, led by UD Professor Yushan Yan, reported their method in *Nature Energy*.

Fuel cells work by converting fuel chemical energy directly into electricity. They can be used in transportation for things like hybrid or zero-emission vehicles. Yushan Yan, the Henry Belin du Pont Chair in Chemical and Biomolecular Engineering, has been working for some time to improve hydroxide exchange membrane (HEM) fuel cells, an economical and environmentally friendly alternative to traditional acid-based fuel cells used today. But HEM fuel cells have a shortcoming that has kept them off the road – they are extremely sensitive to carbon dioxide in the air. Essentially, the carbon dioxide makes it hard for an HEM fuel cell to breathe. This defect quickly reduces a fuel cell's performance and efficiency by up to 20 per cent, rendering the fuel cell no better than a gasoline engine. Yan's research group has been searching for a workaround for this carbon dioxide conundrum for over 15 years.

The research team's results showed that an electrochemical cell measuring two inches by two inches could continuously remove about 99 per cent of the carbon dioxide found in air flowing at a rate of approximately two liters per minute. An early prototype spiral device about the size of a 12-ounce soda can is capable of filtering 10 liters of air per minute and scrubbing out 98 per cent of the carbon dioxide, the researchers said.

Scaled for an automotive application, the device would be roughly the size of a gallon of milk, Setzer said, but the device could be used to remove carbon dioxide elsewhere, too. For example, the UD-patented technology could enable lighter, more efficient carbon dioxide removal devices in spacecraft or submarines, where ongoing filtration is critical.

https://scitechdaily.com

New Catalyst Could Clean Natural Gas Engine Emissions

A newly developed catalyst with a unique, atomic-sized "rafts" does a better job than the current technologies for cleaning up emissions from natural gas engines. Natural gas-powered technologies might become cleaner and more practical for trucks, off-road vehicles, and equipment powertrains as a result of the research, which was published in *Nature Catalysis*. Researchers created palladium (Pd) oxide catalyst "rafts" that are bound together by single platinum atoms. Their catalyst cleans up natural gas and makes the catalytic process more tolerant of water vapor, lowering the quantity of unburned methane released.

While natural gas engines produce roughly 25 per cent less carbon dioxide and particle pollution than gasoline or diesel engines, they still emit unburned methane because their exhaust emission's catalytic converters are inefficient at low temperatures. This new technology was shown to operate at ahigher reaction rates than the existing technologies.

"The improvements in energy efficiency have to go hand in hand with the after-treatment technologies," said Yong Wang, the Voiland Distinguished Professor at the Washington State University's (WSU) Gene and Linda Voiland School of Chemical Engineering and Bioengineering. He is also one of the paper's corresponding authors. "Currently, combustion from methane to generate power is not able to use the most efficient combustion technology. So it works, but there is room for further improvement in that efficiency."

The researchers from the WSU and the University of New Mexico (UNM) headed the team, which included partners from the United States, the European Union, and China. While not as widely used in the U.S., natural gas engines are commonly used in vehicles worldwide, especially in China, Iran, and India. Because they're less polluting than diesel engines, they are often used in trucks and buses in urban areas. Natural gas-powered engines are also used in the gas industry to run thousands of compressors that pump natural gas to people's homes.

However, these natural gas-powered vehicles emit unburnt methane because their exhaust emission's catalytic converters are not efficient at low temperatures. The more efficiently the engines work and the cleaner they burn, the lower the exhaust temperatures become, and the poorer the catalysts perform at cleaning up pollutants. Unburnt methane from an engine, in particular, is a potent greenhouse gas that is about 25 times worse than carbon dioxide, contributing to climate change.

Furthermore, one of the byproducts of methane combustion is water, and the conventional catalysts are "notoriously bad" when it comes to working in the presence of water, said Wang. The cleaner-burning fuel ends up working against itself in removing pollutants. Compared to the typically used catalysts made of Pd oxide nanoparticles, the rafts that the researchers developed provided better tolerance to water vapor with improved reactivity.

"The strongly bound platinum (Pt) can serve as a nucleation site for added metal atoms," said Abhaya K. Datye, a professor in the UNM's Department of Chemical and Biological Engineering and one of the corresponding authors of this study. "Using trapped Pt atoms, we were able to demonstrate the formation of Pt as well as Pd oxide two-dimensional rafts which modify the oxidation state and reactivity of the active phase."

"Our theory calculations suggested that the raft does not readily dissociate water, thus inhibiting the adverse effects of water poisoning in the catalysis of methane oxidation," said Hua Guo, a professor in the UNM Department of Chemistry and Chemical Biology.

https://scitechdaily.com

Catalyst that can turn carbon dioxide into gasoline

A new catalyst, invented by Matteo Cargnello, a chemical engineer at Stanford University and his colleagues, moves toward this goal by increasing the production of long-chain hydrocarbons in chemical reactions. It produced 1,000 times more butane – the longest hydrocarbon it could produce under its maximum pressure – than the standard catalysts given the same amounts of carbon dioxide, hydrogen, catalyst, pressure, heat and time. The new catalyst is composed of the element ruthenium – a rare transition metal belonging to the platinum group – coated in a thin layer of plastic. Like any catalyst, this invention speeds up chemical reactions without getting used up in the process. Ruthenium also has the advantage of being less expensive than other high-quality catalysts, like palladium and platinum.

Cargnello and his team describe the catalyst and the results of their experiments in their latest paper, published in the journal *Proceedings of the National Academy of Sciences*. Cargnello and his team took seven years to discover and perfect the new catalyst. The hitch: The longer the hydrocarbon chain is, the more difficult it is to produce. The bonding of carbon to carbon requires heat and great pressure, making the process expensive and energy intensive.

In this regard, the ability of the new catalyst to produce gasoline from the reaction is a breakthrough, said Cargnello. The reactors in his lab would need only greater pressure to produce all the long-chain hydrocarbons for gasoline, and they are in the process of building a higher pressure reactor.

https://news.stanford.edu

Scrubbing carbon dioxide from factory emissions

Carbon dioxide can be harvested from smokestacks and used to create commercially valuable chemicals thanks to a novel compound developed by a scientific collaboration led by an Oregon State University (OSU) researcher. Published in the *Journal of Materials Chemistry A*, the study shows that the new metal organic framework, loaded with a common industrial chemical, propylene oxide, can catalyze the production of cyclic carbonates while scrubbing CO_2 from factory flue gases. The new, three-dimensional, lanthanide-based metal organic framework, or MOF, can also be used to catalyze cyclic carbonate production from biogas, a mix of carbon dioxide, methane and other gases arising from the decomposition of organic matter.

"We've taken a big step toward solving a crucial challenge associated with the hoped-for circular carbon economy by developing an effective catalyst," said chemistry researcher Kyriakos Stylianou of the the OSU College of Science, who led the study. "A key to that is understanding the molecular interactions between the active sites in MOFs with potentially reactive molecules."

An MOF is an inorganic-organic hybrid, a crystalline porous material made up of positively charged metal ions surrounded by organic "linker" molecules, in this case lanthanide metals and tetracarboxylate linkers. The metal ions make nodes that bind the linkers' arms to form a repeating structure that looks something like a cage; the structure has nanosized pores that adsorb gases, similar to a sponge. The MOFs can be designed with a variety of components, which determine an MOF's properties.

Lanthanide-based materials are generally stable because of the relatively large size of lanthanide ions, Stylianou said, and this is true with lanthanide MOFs as well, where the acidic metals form strong bonds with the linkers, keeping the MOFs stable in water and at high temperatures. This is important because the flue gases and biogas are hot as well as moisture rich. The lanthanide MOFs are also selective for carbon dioxide, meaning they're not bothered by the presence of the other gases contained by industrial emissions and biogas.

"We observed that within the pores, propylene oxide can directly bind to the cerium centers and activate interactions for the cycloaddition of carbon dioxide," Stylianou said. "Using our MOFs, stable after multiple cycles of carbon dioxide capture and conversion, we describe the fixation of carbon dioxide into the propylene oxide's epoxy ring for the production of cyclic carbonates." Cyclic carbonates have a broad range of industrial applications, including polar solvents, precursors for polycarbonate materials such as eyeglass lenses and digital discs, electrolytes in lithium batteries, and precursors for pharmaceuticals.

https://www.google.com/phys.org

Polymer membrane improves efficiency of carbon dioxide capture

Researchers have developed a new membrane technology that allows for more efficient removal of carbon dioxide (CO_2) from mixed gases, such as emissions from power plants. "To demonstrate the capability of our new membranes, we looked at mixtures of CO_2 and nitrogen, because CO_2/nitrogen dioxide mixtures are particularly relevant in the context of reducing greenhouse gas emissions from power plants," says Rich Spontak, co-corresponding author of a paper on the work. "And we've demonstrated that we can vastly improve the selectivity of membranes to remove CO_2 while retaining relatively high CO_2 permeability."

"We also looked at mixtures of CO_2 and methane, which is important to the natural gas industry," says Spontak, who is a Distinguished Professor of Chemical and Biomolecular Engineering and a Professor of Materials Science & Engineering at the North Carolina State University. "In addition, these CO_2-filtering membranes can be used in any situation in which one needs to remove CO_2 from mixed gases – whether it's a biomedical application or scrubbing CO_2 from the air in a submarine."

The research team, from the U.S. and Norway, addressed this problem by growing chemically active polymer chains that are both hydrophilic and CO_2-philic on the surface of existing membranes. This increases the CO_2 selectivity and causes relatively little reduction in permeability.

"In short, with little change in permeability, we've demonstrated that we can increase selectivity by as much as about 150 times," says Marius Sandru, co-corresponding author of the paper and senior research scientist at SINTEF Industry, an independent research organization in Norway. "So we're capturing much more CO_2, relative to the other species in gas mixtures."

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