A new initiative to Carbon-Capture-Storage – how can a new battery be used to reduce carbon dioxide from our air?

Engineers at MIT have developed a solid-state electrochemical cell that selectively removes CO2 from the air at a greater efficiency than existing carbon-capture technologies. This can be effective on gases at almost any concentration: from exhaust fumes to those found in open-air, presenting huge potential to tackle climate change.

By Adam Suttle, in partnership with SciWorthy and The Blue Marble Space Institute of Science

Carbon capture will become integral to a green economy. Image Source: 'Pixy - Rawpixel Ltd. ' Creative Commons License. [1]

Carbon capture initiatives (CCI) are technologies which filter out CO2 from gases before, and in some new cases after, they reach the atmosphere. There is substantial scientific consensus that anthropogenic greenhouse gases - of which the largest contributor is CO2 - are causing the unusually wild fluctuations in global climate patterns over the last century [2]. For this reason, carbon capture is receiving greater attention from governments and investors around the world.

There are several existing carbon capture methods that rely on processes of varying pressures/temperatures, membranes to filter out CO2 or a chemical reaction known as solvent scrubbing. They are difficult to scale, required lots of energy to manufacture and have little geometric flexibility making them hard to build into existing devices where space limitations are problematic. Furthermore, most are aimed for large-scale combustion and other industrial fumes, with concentrations of CO2 above 10% [2].

Researchers, Sahag Voskian and T. Alan Hatton, at MIT, have engineered a revolutionary new 'electro-swing-absorption' (ESA) carbon capture technique, which overcomes many of these existing issues. They created a specialized electrochemical cell (or battery) that absorbs CO2 from air as it passes through the device. In addition, to their study on this device, they are commercializing the process through their start-up company, Verdox.

The battery uses some newly engineered materials which make up a cathode (negative electrode) and an anode (positive electrode) of the cell. The researchers built these up from tiny structures known as carbon nanotubes (CNT). They coated the anode with an iron-based chemical called Ferrocene and the cathode with a polymer-based chemical called Polyanthraquinone [2]. They sandwiched these together into layers with channels for gas to flow between, acting as an electrolyte to the cell. The researchers analysed the pressure of a gas stream of

air that they passed through the device during charging and discharging to test the capability for absorbing CO2. Experiments were repeated for a variety of CO2 concentrations to mimic the performance in high concentration environments, such as those found in exhaust gas, and low concentration environments, such ambient air and confined indoor conditions.

On charging, they found CO2 molecules actively bound to the cathode surfaces through a chemical process known as reduction, where the CO2 molecule gained two extra electrons and to attach to the chain of the polymer, Polyanthraquinone [2]. On discharging, they reported the reverse, oxidation, reaction taking place to release the bound CO2 molecules. This is essential so the device can capture new CO2 on the next charge-discharge cycle. During discharge, the cell could provide some of the power required for the complete operation as it gave some energy required to charge it back.

CO2 can be captured and used for fizzy drink production.
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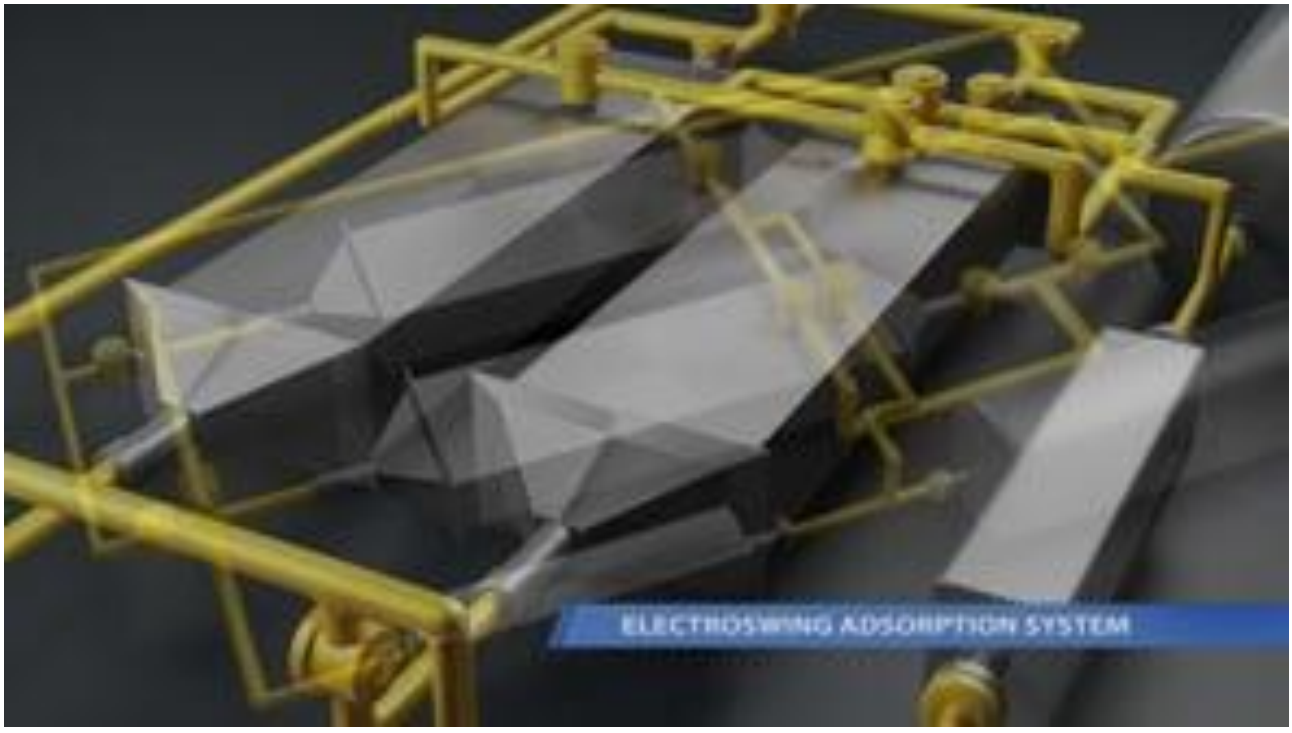
When two of these cells were linked together to operate in opposite modes simultaneously, this would remove the wait-time required between cycles. As one cell discharges, and regenerates its ability to capture CO2, the exhaust stream can be diverted into the opposite cell for CO2 adsorption [4]. The pure CO2 released on discharge can be used to supply a source for carbonating drinks for fizziness or to farmers who require air concentrated with CO2 to maximise crop growth within greenhouses. Alternatively, the CO2 can be stored using existing schemes such as compression into tanks or burial underground, preventing the CO2 from ever reaching the atmosphere.

The device can uniquely switch between absorbing or releasing, CO2, unlike alternative carbon capture methods, which require significant amounts of time, chemical processing or energy, to regenerate before they can absorb CO2 again. The device is highly scalable and can be designed in many shapes and sizes, only requiring a power supply to function. The researchers found that this technology was very durable, with their prototype lasting over 7000 cycles with less than 30% loss in capacity for absorbing CO2 [2]. It is expected this lifetime can be vastly improved through new cell design and improved composite processing. The device proved effective at absorbing CO2 from low concentrations, down to 0.8%, which mimics the expected conditions for ventilation of confined living spaces, such as space modules, submarines and buildings, setting it apart from existing technologies.

The researchers conducted a preliminary financial analysis for their technology and concluded the device could be economically feasible for industries; costs ranged from $50–$100 per ton CO2 [2] depending on the feed concentrations of CO2 and the applications under consideration.

Direct emission of carbon dioxide to the atmosphere still occurs in the 21st century
Image Source: 'Pixy - Rawpixel Ltd. ' Creative Commons License. [5]

While there is a global drive to reduce fossil fuel combustion, the reality is that they will continue to be combusted long into the future, whether that be by through chemical manufacturing for our materials and resources, pharmaceuticals to provide us with cosmetics and medicines or our heavy goods transport industry, where the density of batteries proves too low for feasibility in planes and ships. The 2015 Paris Agreement, therefore, heavily emphasizes the need for CO2 negative technology [2]. The efficiency in design and scalability of the ESA carbon capture that this study shows brings significant potential for use amongst sustainable economies.



Video demonstrating a duel electrochemical ESA carbon capture system. This video was submitted by the researcher Sahag Voskian. [6]

Want to learn more about this study?

Check out the paper yourself!

This can seem a little daunting at first, even for those who are well-grounded in scientific thinking. Go through it at your own pace – the key takeaways in scientific papers can be found in the introduction and conclusion sections! The language here tends to be a little more familiar.

I have tried my best efforts to communicate a summary of this study in under 700 words here, without delving into too much of the science. It is just as important in today's society for scientists to communicate their research in everyday language, so it is accessible to the public.

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