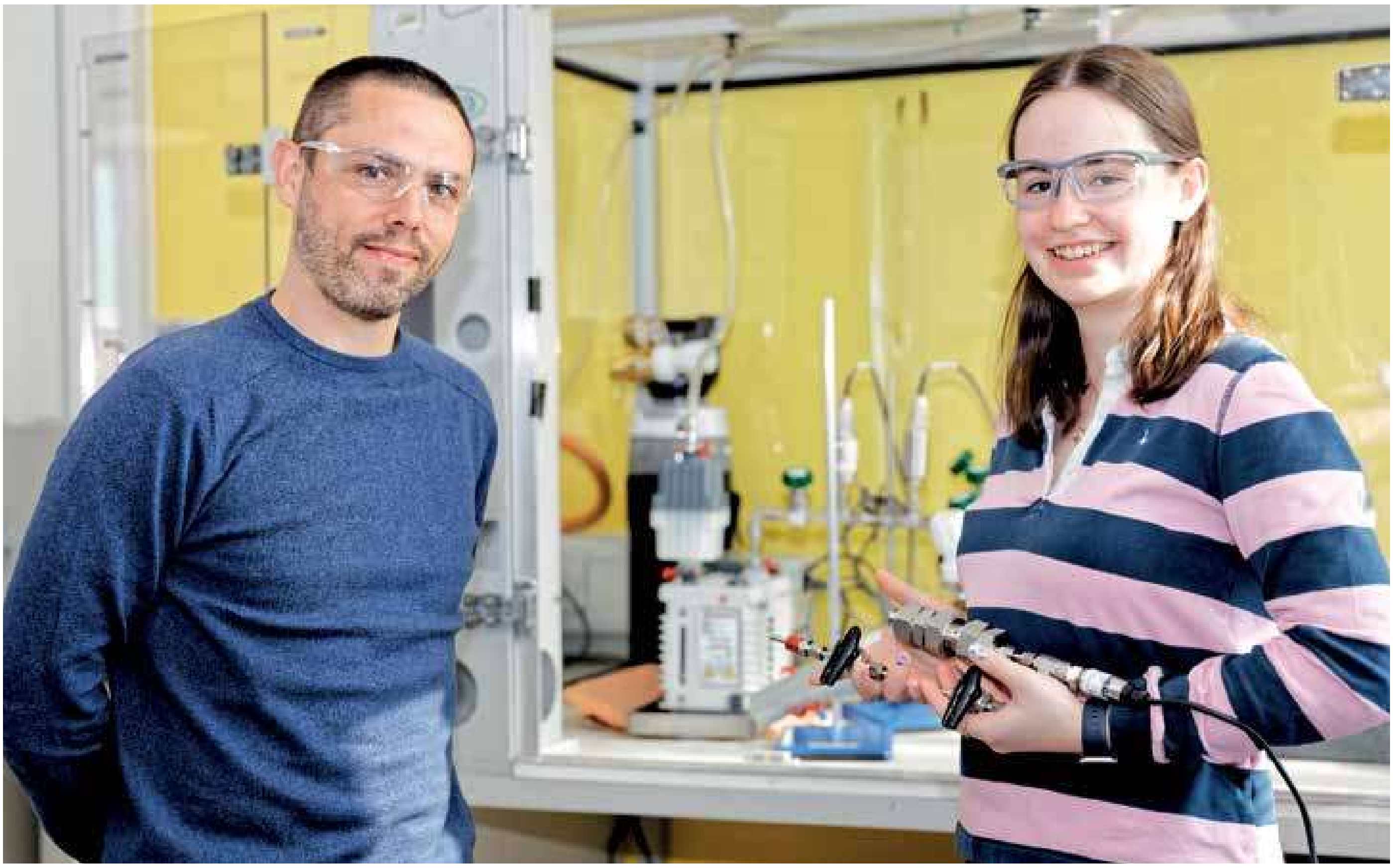
A super supercapacitor

The Forse group's goal is to find, understand, and optimise materials that reduce greenhouse gas emissions. One technology they are exploring is supercapacitors that can absorb can absorb carbon dioxide gas; a two-pence-sized device that the Forse lab is banking on to help tackle climate change.



Dr Israel Temprano Farina and Grace Mapstone with the supercapacitor.

The Forse laboratory is fine-tuning a supercapacitor that can selectively capture the greenhouse gas carbon dioxide while it's charging. Then, when it discharges, the CO_2 is released and can be collected.

"Around 35 billion tonnes of CO2 are released into the atmosphere each year and we urgently need solutions to eliminate these emissions," says Dr Alexander Forse, who leads the group.

A supercapacitor is very similar to a rechargeable battery but instead of using chemical reactions in order to store charge, it simply separates charges at the two electrodes. The advantage is that there is less degradation over time because there are no chemical reactions so it can tolerate many more charge-discharge cycles.

"The trade-off is that supercapacitors can't store as much as batteries charge, but for something like carbon capture we would prioritise durability," comments Grace Mapstone, a PhD student in the Forse group who is building and optimising these supercapacitors.

Low-cost materials

"The best part is that the materials used to make The best part is that the materials used to make supercapacitors are quite cheap and abundant. are quite cheap and abundant. We want to use materials that are inert, that don't harm environments, and that we need to dispose of less frequently. For example, the CO_2 dissolves into a water-based electrolyte which is basically seawater and it's not going to harm the environment.

"The electrodes are made of carbon. We have plenty of carbon, in fact, the carbons we use are made out of waste coconut shells."

The two-pence sized supercapacitor, shown here attached to a structural support.

Drawing in CO_2

The supercapacitor consists of two electrodes of positive and negative charge. In work pioneered by Trevor Binford while completing his Master's degree with the Forse group, the team tried alternating from a negative to a positive voltage to extend the window of voltage. "Our new insight is that by slowly alternating the current between the plates we can capture more CO_2," comments Dr Alexander Forse.

However, this supercapacitor does not absorb CO_2 spontaneously: it must be charging to draw in CO_2. When the electrodes become charged the negative plate draws in the CO_2 gas. The goal is for the supercapacitor to selectively draw in CO_2 gas and ignore other emissions, such as oxygen, nitrogen and water, which don't contribute to climate change. This method means that the carbon can be captured alongside the secondary function of storing energy in a capacitor.

Currently, the most advanced carbon capture method employed in industry involves bubbling emissions through a solution of amines. The second step involves collecting the carbon and boiling the amines to refresh them. However, this process involves energy input and is expensive.

"The charging-discharging process of our supercapacitor potentially uses less energy than the amine heating process used in industry now," explains Forse.

"Our next questions will involve investigating the precise mechanisms of CO_2 capture and improving them. Then, it will be a question of scaling up!"

The research was funded by a Future Leaders Fellowship awarded to Forse, a UK Research and Innovation scheme developing the next wave of world-class research and innovation. It documents the improvements made in the carbon capture capacity of this device.

Working together

Dr Israel Temprano, part of the Grey group, contributed to the project by developing an analysis technique.

Temprano had developed a gas analysis technique to probe electrochemical devices in general and, in the Grey group, used this technique to study the mechanisms of batteries.

He comments, "Alex got me involved in this project because he needed to develop this technique to study electrochemical absorption of CO_2. I joined the team to adapt the techniques that I have previously developed to this new supercapacitor."

The technique uses a pressure sensor that responds to changes in gas adsorption in the electrochemical device. For lithium-air batteries, the pressure sensor responds when the battery is absorbing oxygen as it charges or releasing oxygen as it discharges.

This way, you can tell how much oxygen is required for the battery to function. In turn, this indicates which mechanisms are at play inside the device.

"Alex and I started talking and wanted to adapt the system that I had designed for the supercapacitor for CO_2 absorption," explains Temprano. "This field of research is very new so the precise mechanism working inside the supercapacitor still isn't known."

The results from Temprano's contribution help narrow down the precise mechanism at play inside the supercapacitor when CO_2 is absorbed and released. Understanding these mechanisms, the possible losses, and the routes of degradation are all essential before the supercapacitor can be scaled up.

These sorts of bold visions for a carbon-free future require intelligence, tenacity and collaboration.

"That's one of the good things about the chemistry department," comments Temprano, "is that it promotes really good inter-team collaborations."

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Dr Alexander Forse.