Power brokers

Finding new ways to maintain systemic energy, improve battery technology and speed up reaction times has drawn attention to these innovative chemists.

From AI-powered approaches to light-based experimentation, these researchers are bringing fresh perspectives to long-standing challenges in chemistry. With a focus on sustainability and efficiency, their ideas show how small tweaks to a system can have profound impacts.

Xiaona Li's team aims to boost the conductivity of solid electrolytes.

In full flow
Xiaona Li

Solid-state batteries offer many advantages over lithium-ion batteries: they're lighter, they can store more energy, and because they use a stable solid material instead of a flammable liquid electrolyte, they're safer. But for the technology to become more widespread, "there are many issues we need to solve", says Xiaona Li, an inorganic chemist at the Eastern Institute of Technology in Ningbo, China.

In a battery, electrons flow from an anode to a cathode through an external circuit to deliver power, while charged ions move through the electrolyte between two electrodes to maintain charge balance. In lithium-ion batteries, ions move relatively easily through a liquid electrolyte; in solid-state designs, the ions move through a solid electrolyte, which is typically slower and can constrain performance.

The materials used in a solid electrolyte can make all the difference. One option that Li is investigating is halides — compounds made by combining a halogen element, such as fluorine or iodine, with another element, often a metal. "The conductivity of halides can be very high," she says.

One type of halide, lithium indium chloride, is a promising candidate, but it's difficult to produce. The process usually involves grinding lithium chloride and indium chloride — crystalline salts made of metal and chlorine atoms — into a fine powder before rapidly heating and then slowly cooling the material to alter its structure and properties. "It's a method that's hard to scale up," says Li.

During her postdoctoral studies at the University of Western Ontario in London, Canada, Li and her colleagues pioneered an alternative water-based method[1] to synthesize lithium indium chloride. They found that dissolving the precursor components in water resulted in an electrolyte with high ionic conductivity, meaning the ions could pass through it more efficiently. "The method is cheaper, requires less energy, and is highly suitable for large-scale batch production," says Li.

Her team in China is now working to improve solid electrolyte conductivity. Scientists typically rely on doping — adding small amounts of other elements to the mixture — but it can be hard to find the right combination. Li's team took a different approach, designing a halide-based set-up in which parts of the battery temporarily dissolve and release their ions. A 2025 study[2] in *Nature Energy* by Li and her colleagues identifies 73 halide materials that could be used to achieve this state.

"The result is a glass-like solid that can still conduct electricity really well, because the ions are free to move inside it," she says. "We found that this approach can be universally applied to many different materials."

Sandy Ong

Reactive research
Ananth Govind Rajan

Ananth Govind Rajan is fascinated by how the smallest components of a system contribute to the whole. Growing up in Delhi, he loved taking apart the family radio to study its components before reassembling it from memory. "I've always been interested in tinkering with things and figuring out why they work," he says.

A chemical engineer at the Indian Institute

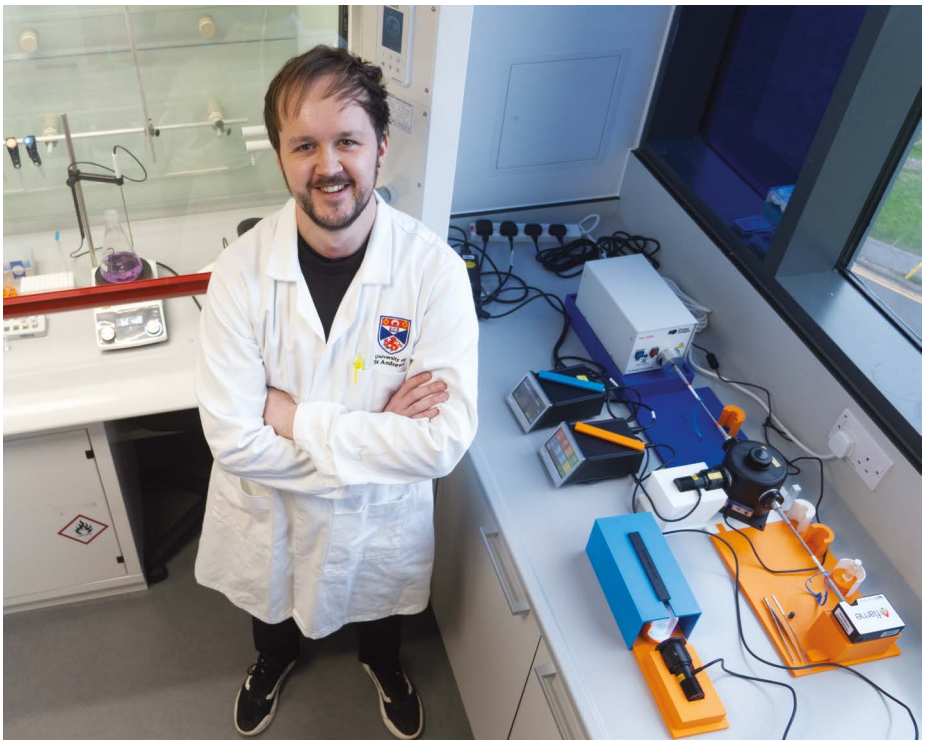
of Science in Bengaluru, Govind Rajan wants to find the most effective materials to use as catalysts. Nanomaterials are a promising option because their unusually high surface-area-to-volume ratio exposes more atoms at the surface, which increases active reaction sites and enables faster, more efficient chemistry.

During his postdoctoral research at Princeton University in New Jersey, Govind Rajan and his colleagues used nanomaterial catalysts to speed up electrolysis – a process that uses electricity to split water into hydrogen and oxygen. Using models to vary factors such as temperature, pressure and acidity, they identified the optimal conditions to speed up reactions on a nickel oxyhydroxide nanoparticle catalyst in an electrolysis system.[3]

Since returning to India and setting up his own lab in 2020, Govind Rajan has switched part of his focus to water filtration systems. Last year, he and his colleagues described[4] how weaving graphene oxide – a nanomaterial made from a sheet of graphene with oxygen atoms attached – into a filtration membrane could make it more chemically reactive and easily dispersible in water. He says the modification improved both the membrane's filtration rates and its resilience, which could help it work more effectively for longer.

Govind Rajan is also using artificial intelligence to design membranes[5] that take advantage of nanopores – tiny holes or channels in a material that molecules or ions can flow through. There are "countless possible nanopore shapes and arrangements" to consider when designing a new material, he says, and using AI to speed up the screening and testing processes could be a game-changer. "We came up with a machine-learnable language that turns complex nanopore structures into strings of text that computers can easily understand."

Finding ways to support communities in their shift towards more sustainable living is a key motivation for Govind Rajan. "Some of the most pressing problems in clean water and clean energy" will be solved with the help of nanomaterials, he says. **Sandy Ong**



JAKE GREENFIELD/IMINESWITCH.COM

Jake Greenfield uses custom experimental set-ups to study light-sensitive molecules.

Switching gears
Jake Greenfield

As an organic chemist at the University of St Andrews, UK, Jake Greenfield studies photoswitches: photosensitive molecules that can change form and function when exposed to light. Photoswitches exist in nature – the rod cells in our retinas have specialized proteins that detect light and trigger the chemical signals that allow us to see, for example. They can also be synthesized for use in areas such as smart materials and medicine.

A perennial challenge in chemistry is to create photoswitches using imines – molecules with one carbon atom double-bonded to a nitrogen atom. Imines lack stability, which limits how useful they'd be as photoswitches in the real world, but they're interesting candidates for exploring photosensitivity in the lab, says Greenfield. "Imines are attractive because they're easy to make and, importantly, reversible: the imine bond can break and reform."

"I think sometimes returning to a seemingly well-trodden area with a fresh perspective can unlock new behaviour."

Imine photoswitches could theoretically form one arrangement when exposed to light and then come apart and form a different structure in the dark. Researchers have been looking for the right type of imine for the task. In one experiment, Greenfield and his colleagues tracked how the colours of various imine photoswitches changed under light and discovered that some performed far better than expected[6]. "To our surprise, several imines were already strong photoswitch candidates," he says.

Greenfield is now investigating whether imine photoswitches can mimic the way biological systems operate. The challenge, he says, is to keep energy moving through the system. In a 2024 study[7], he and Jiarong Wu, a PhD student at the Institute of Organic Chemistry in Würzburg, Germany, used light to push an imine photoswitch into a higher energy state. They then discovered that light could drive a sequence of chemical reactions involving imines, in which the products of one reaction served as the reactant molecules for the next[8]. The set-up, which mirrors how reactions inside living cells are organized into interconnected pathways, could inform the design of chemical networks that respond predictably to light, says Greenfield, which could feed into new models of cell-like behaviour.

Coming at old problems from new angles is what drives Greenfield's interest in chemistry. "I think sometimes returning to a seemingly well-trodden area with a fresh perspective can unlock new behaviour, showing that even very familiar, accessible chemistry can still surprise you." **Felicity Nelson**

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