What type of batteries explode

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Today, lithium ion batteries are something we are all familiar with, they power our phones, our laptops, our cameras and even our electric cars. With their comparative low weight, low self-discharge and very high energy density it''s clear these batteries are here to stay, at least for now.

But with such a high energy density comes a price, when these batteries fail, they can do so quite catastrophically, leading to fire and even explosions. In a process known as thermal runaway, a series of exothermic reactions can take place within the cell leading to overheating, boiling of the pyrophoric liquid electrolyte and eventually cell rupture. Cases like this have been reported in the media recently with recalls of many faulty consumer electronic devices exploding and, in some cases, causing injury.

With an ever-increasing number of lithium ion batteries around us, it is paramount that we develop an understanding of how and why these batteries fail in order to inform safer design and predictability of operation.

Prof. Paul Shearing is a Royal Academy of Engineering Chair in Emerging Technologies at the University College London, leads the STFC Global Challenge Network in Batteries and Electrochemical Energy Devices and is a founding investigator of The Faraday Institution. His research covers a broad range of electrochemical engineering topics, with a focus on the relationship between the performance and microstructure of energy storage devices, an area in which he has published more than 160 papers in the past 5 years.

Shearing makes it clear to us from the start that although battery failure can be spectacular catastrophic, it is important to remember that battery failure is extremely rare and that failures in the field are estimated to be between 1 in 10 - 40 million.

"That''s a really, really low chance of failure" Shearing expands "but of course we''re all using lithium ion batteries every day, and with the rise of electric vehicles, there''s more and more lithium ion batteries than ever before. So we really need to understand, even in these very isolated events, what goes wrong, why it goes wrong and how we can prevent it."

4D X-ray tomography is a non-destructive technique which enables the in-situ cross sectional imaging of samples over time. The use of high energy X-rays allows the user to create a 3D model of the sample at submicron resolution and observe how it changes over time.

"It's all part of a wider picture of understanding that is trying to prevent failure from happening in the first place, predict the rare occurrences when they do happen, mitigate their danger and keep them localized." Shearing explains

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In order to visualize how the failure propagates through the device at very high speeds, Shearing and his collaborators utilize the X-ray imaging capabilities only made possible from a synchrotron source. As such, they have run battery safety projects in both the European Synchrotron Research Facility (ESRF) and the UK"s national synchrotron facility, the Diamond Light Source.

Using the very high X-ray flux generated from the synchrotrons, multiple battery chemistries and geometries can be analyzed under a range of extreme conditions including extremes of temperature, current, voltage and mechanical pressure. In tandem to this, Shearing"s team captures thermal and electro-chemical data simultaneously to build up a correlative picture of the failure event.

"It's quite a broad matrix of how all these conditions ultimately influence the failure, and we can characterize, for example, how likely that failure is to propagate from one cell to a neighbouring cell, what the maximum temperature a cell failure might experience. You know, it's really a whole new platform capability for understanding these failure scenarios." Shearing reveals.

In particular, Shearing and his collaborators utilized the large field of view of the I12 JEEP beamline at the UK Diamond Light Source to investigate the 18650-lithium ion battery, one of the most common formats on the market, powering everything from laptops to electric vehicles. Here, 18650 represents the size of the battery (18mm diameter 65mm tall), differentiating it from conventional sized AA or AAA batteries such that a normal consumer does not accidently swap in a lithium ion battery with a different battery chemistry.