

Manufacturing Excellence

Unbreakable: The smart screen of the future

The University of Queensland is conducting research that could enable the manufacture of unbreakable smart screens.



Dr Jingwei Hou, an ARC Future Fellow and senior lecturer at the School of Chemical Engineering, the University of Queensland speaks with Alexandra Cooper about the invention of a new process that could inform the manufacture of unbreakable device screens.

WHEN a consumer lifts a brand-new smart phone from its packaging for the first time, there is often a moment of appreciation for the technology that lies in the palm of their hand which possibly displays the most care they will show the device throughout its life span. In that moment, the device seems perfect in its manufacture.

But how perfect is the screen, really?

According to a 2017 study by the comparison website Finder, more than 1,300 smart phones are lost or destroyed per day in Australia. Cracked and shattered screens

are the most common method of damage, costing over \$755 million to repair or replace.

“Liquid-phase sintering of lead halide perovskites and metal-organic framework glasses,” a report published in *Science* in October 2021, has potentially signalled the end of cracked device screens through a new discovery in perovskite nanocrystal technology.

Perovskite is a mineral that takes the form of a calcium titanium oxide crystal. The nanocrystals, lead-halide perovskites, are able to harvest sunlight and convert it into renewable electricity.

The report was authored by a global team of researchers led by the University of Queensland. *Manufacturers' Monthly* found out how it all began from an ARC Future Fellow and senior lecturer from the School of Chemical Engineering, Dr Jingwei Hou. Hou's main research focuses on the physical properties of microporous materials and then translating them into useful devices for membrane separation, optics, energy storage and catalysis.

“When I first came to the University of Queensland, the research centre had just published the world record for the perovskite

solar panels,” Hou said. “I asked the chief investigator why they wouldn't bring the new technology to the market; they said the material is really good, but there are some problems with stability.”

These stability issues manifested as a sensitivity to temperature, water, oxygen, air, and light. Even water vapour in the air would kill the devices in a matter of minutes. This was how Hou realised that his previous post-doctoral research at the University of Cambridge on hybrid glass translated to perovskite technology.

“It was quite a happy accident that

when I was at Cambridge, we actually developed a new generation of glass material called a hybrid glass that has a lot of interesting properties,” he said. “I tried to put them together to see whether the perovskite could be stabilised – and the result was really, really good.

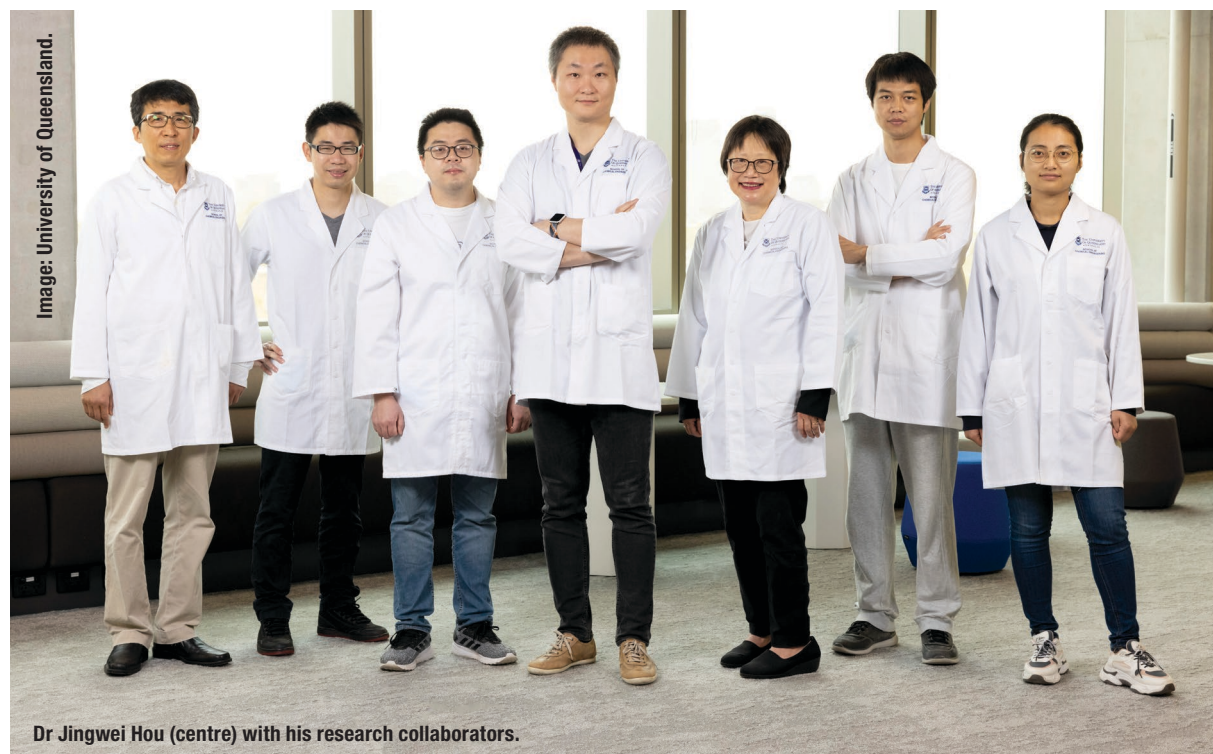
“It not only stabilised the perovskite, but also made the perovskite somewhere between 100 to 1,000 times more efficient. We also discovered that putting the perovskite with metal-organic frameworks (MOFs) glass actually made the glass stronger and more durable. This advanced us further towards the unbreakable glass domain.”

For around 20 years, MOFs have been defined by materials scientists as porous, crystalline materials that can trap compounds in their molecular cavities. However, in 2015 Hou’s collaborators at Cambridge also found non-crystalline MOFs in liquid and glass states. The researchers uncovered what occurs at the molecular level when some metal-organic frameworks are heated to a melting point and then cooled to produce a glass-like state. They later reported around 10 MOFs that can be melted into a liquid and turned into this state.

According to these research, on heating this kind of metal-organic framework its metal ions and organic ligands begin wobbling within the crystals as the material melts. This disrupts the normally ordered structure of the MOF’s crystalline form, breaking the connections between bonds while some portions of the extended structure remain in place to create a glass state. Further molecular fragmentation occurs once a MOF reaches a liquid state, however some of its internal structure keeps an element of connectivity.

As the University of Queensland team discovered, adding chemicals to the material to create glass altered its physical properties – hence the development of a stronger and more durable glass once the MOFs were melded with the perovskite crystals.

The report, “A New Dimension for Coordination Polymers and Metal–Organic Frameworks: Towards Functional Glasses and Liquids,” was published in *Angewandte*



Dr Jingwei Hou (centre) with his research collaborators.

Chemie International Edition by a Kyoto University materials scientist, Professor Satoshi Horike, and colleagues.

The report stated: “Liquid and glass MOFs could provide a new state of material that demonstrates porosity, ion conductivity and optical properties such as luminescence. They also show promise for heat storage, in energy devices and for gas permeation. Hybrid materials incorporating glass or liquid MOFs with other materials, such as organic polymers, metal particles or metal ions could be used as strong adhesives in energy devices or in catalytic reactions.

“Scientists should revisit the huge library available for crystalline MOFs from the viewpoint of phase change to liquid and/or glass. Doing so could lead to the design of new functional materials.”

Indeed, this has led to the design of new materials such as the University of Queensland’s composite glass. In turn, this will not only enable the manufacture of glass screens with superior durability, but also deliver crystal clear image quality.

“At present, QLED or quantum dot light-emitting diode screens are considered the top performer for image display and performance,” Hou

said. “This research will enable us to improve on the nanocrystal technology by offering stunning picture quality and strength.”

The perovskite process

The University of Queensland team of chemical engineers and material scientists developed a process to wrap or bind the nanocrystals in a porous glass. The glass was responsible for stabilising the materials, enhancing their efficiency, and inhibiting the toxic lead ions from leaching out of the materials.

Hou likens the process of producing the composite glass to that of baking chocolate chip cookies in a remarkably simple and fast method.

“Basically, we have the perovskite nanocrystals which are the chocolate chips, and then we blend it with the MOFs glass which is the cookie dough,” he said. “After we forge them into certain shapes – small cookie shapes – we heat them at over 270°C for 30 minutes and we’ve got the product. Very simple and very quick.”

This chocolate chip cookie structure is part of the reason why the composite glass is so effective and durable, when compared to the structure within a current smart phone. Conversely, this is a

sandwich structure, Hou said.

“Our current mobile phones display a sandwich structure – it has a bottom layer, which is a blue light emitter, and a red phosphor and green phosphor layered structure on top of that,” he said. “If you have multiple layers, that causes a lot of problems in the interface. But if we transform that into something more like the chocolate chip cookie type of structure, that means it is both easier to make and much more durable.”

The composite glass is produced using an anti-synthetic family of material, including minerals ores such as zinc and lead. This will create a multitude of opportunities for the process to be used in the local manufacture of relevant smart devices, as Australia has one of the largest reserves in the world of those two minerals.

“That’s a great opportunity to use our own mineral ores, rather than selling them at a very low price, if we can process them locally into a really high-end, cutting-edge technology,” Hou said. “We now have a patent registered in Australia through the University of Queensland, and we are looking for some local as well as international collaborators to bring this technology to the next step.”



The high-strength composite glasses are made using MOFs glass and perovskite nanocrystals.

Image: University of Queensland.

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A scalable technology

The whole perovskite nanocrystal technology is scalable and uses materials that are mostly in a solid state, which means an excessive amount of solvent is not required. Using less solvent reduces production costs and minimises the impact on the external environment. It also minimises waste, according to Hou.

“All of our materials are made from raw material, then directly transformed into the real product without generating any extra waste, as you don’t need additional material for reaction. So, it’s really good from a manufacturing perspective,” he said.

As mentioned earlier, the

University of Queensland team had to overcome some stability problems to create the new, more efficient perovskite material. Previously, the technology was produced under delicate conditions which would not have been suitable for large scale manufacturing.

“The solar panel our centre made for the world record had to be fabricated within a totally bone-dry environment, without any humidity and preferably without any oxygen or water as well,” Hou said. “That made scaling up really difficult, because you can’t really have a workshop or manufacturing site without oxygen.”

The solution was a final treatment that was applied at the end of the process.

“Because we have the final open treatment step, that step will get rid of all the moisture and all the oxygen and all the defects that the solar panels have,” Hou said. “That will make the technology really easy to scale up, as it just needs a final treatment in nitrogen or argon.”

Future applications

Other than smart mobile phone displays, there is potential for the perovskite nanocrystal technology to be commercialised for applications such as solar panels, wearable devices, computer screens, lighting, televisions, x-rays, and digital cameras.

“We can transfer the technology very easily to solar panels. We could also make solar panels more flexible, potentially becoming a kind of wearable solar panel device that you can put on your T-shirt,” Hou said. “They can be used for LED materials for lighting, the films for digital cameras or even x-rays; so, when you do a bone scan, you will need a much lower dose of the x-ray beam

to create a very large picture. This would both increase the resolution and reduce the exposure to the x-ray’s radiation levels as well.”

Hou said that these are only a few of the different applications his research team at the University of Queensland have envisioned for the new perovskite process – the technology could cover a range of sectors within the Australian manufacturing industry.

“We are looking at mining companies, from where we’re trying to directly convert the raw materials from the mining site to really high value products,” he said. “We are also actively working with a medical professional to further develop more detailed medical imaging; I think there is a lot of potential there.”

The only question that remains is what the future could look like with unbreakable screens adorning consumers’ smart devices and appliances?

“The whole process we have made – from the raw materials all the way to the final product – is 100 per cent compatible with the manufacturing industry,” Hou said. “It’s a huge opportunity.” **M**

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