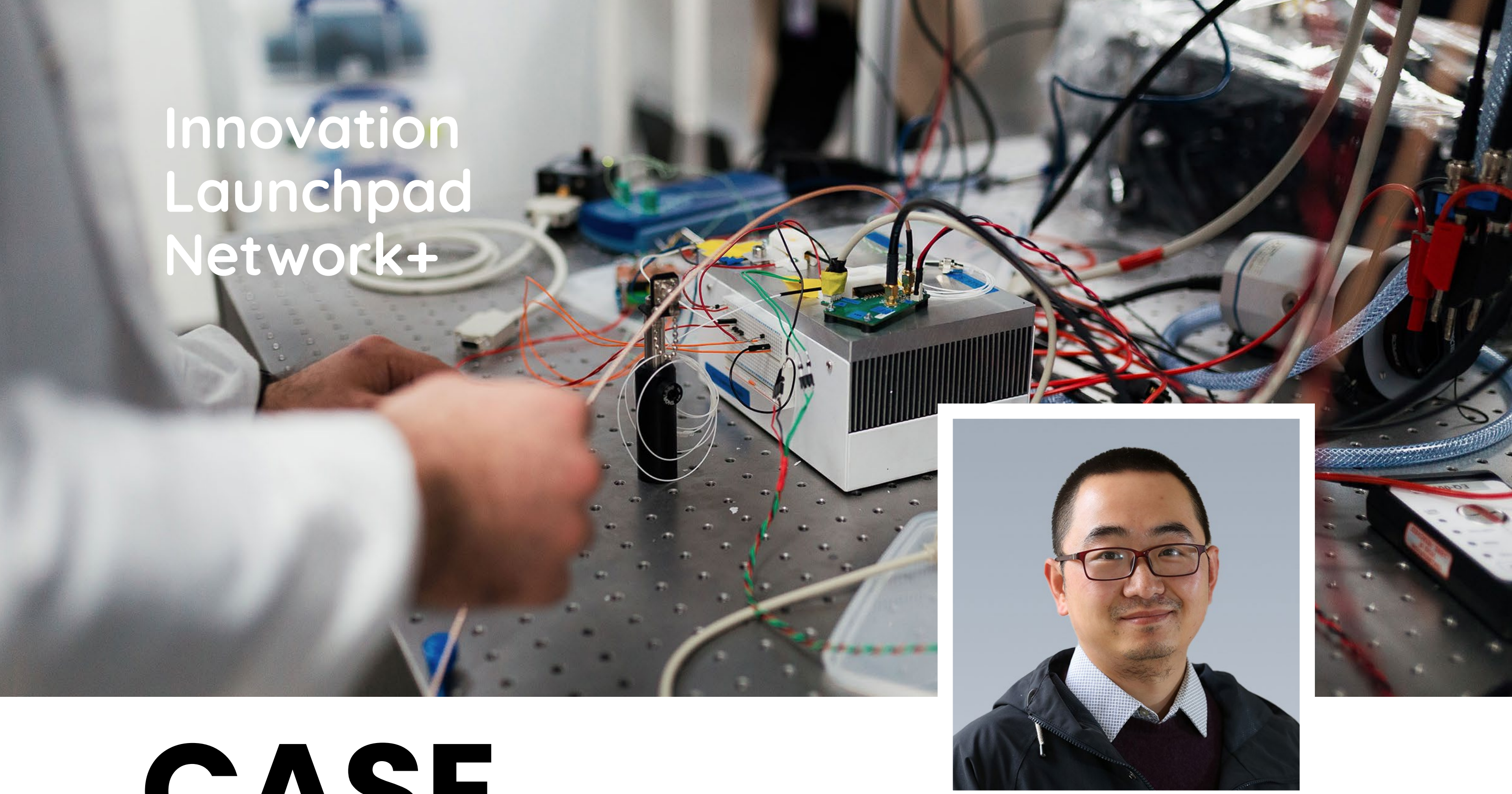

CASE STUDY

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The Challenge

The transition to Net Zero and electrification is placing unprecedented demands on power electronics, particularly in energy storage components such as capacitors. Conventional capacitor technologies rely heavily on vacuum-deposited oxide dielectrics, which are energy-intensive to manufacture, difficult to scale, and increasingly incompatible with emerging low-cost, high-throughput production methods.

At the same time, next-generation applications - including electric vehicles, renewable energy systems, and advanced power conversion - require capacitors with higher power density, improved frequency response, and enhanced thermal stability. Existing materials and fabrication approaches are struggling to meet these combined performance and sustainability requirements.

The key challenge addressed in this project was whether solution-processed compound semiconductor nanomaterials could provide a viable alternative to traditional dielectric materials. Specifically, we sought to determine whether these materials could deliver competitive electrical performance while enabling low-carbon, scalable manufacturing routes aligned with industrial needs.

Bridging this gap required not only materials innovation, but also validation within realistic device architectures and alignment with end-user requirements - something that cannot be achieved within academia alone.

Innovation
Launchpad
Network+

Innovation

To address this challenge, we developed a new materials and device platform based on solution-processed colloidal semiconductor nanocrystals, targeting their use as dielectric layers in power capacitors.
Using a scalable liquid-phase laser synthesis approach, we produced semiconductor nanocrystals with controlled composition and properties, enabling integration into printable thin films. These materials were then incorporated into prototype capacitor structures, fabricated and tested in collaboration with the Compound Semiconductor Applications Catapult.
A key innovation of this work lies in replacing conventional oxide dielectrics with semiconductor-based, solution-processable materials (AlN, Al_2O_3, SiC, GaN), opening a pathway towards low-energy, high-throughput manufacturing. The project also integrated materials design with device-level validation, leveraging Catapult facilities to ensure that performance metrics were aligned with real-world application requirements.
This collaborative approach enabled rapid iteration between materials development and device testing, ensuring that the research remained focused on industrial relevance. It also established a new framework for translating nanomaterials research into functional electronic components.

Result

During the project, we demonstrated the feasibility of using solution-processed semiconductor nanocrystals as functional dielectric materials and established a clear materials-to-device integration pathway. We also identified critical factors such as interface engineering and film uniformity as key to performance.
Key outcomes:
-Successful synthesis of AlN, Al_2O_3, SiC and GaN using laser ablation methods
-Fabrication of working capacitor prototypes
-Validation of dielectric behaviour relevant to power electronics applications
-Functional device operation confirmed through electrical characterisation
-Compatibility with solution-based processing routes demonstrated
-Strong alignment with industrial fabrication workflows through Catapult validation

These results provide the first step towards a new class of capacitor technologies that combine performance, scalability, and sustainability, significantly advancing the readiness level of the concept.

Impact

This project establishes a fundamentally new approach to capacitor design, replacing energy-intensive fabrication processes with scalable, low-carbon alternatives. It directly supports the UK's ambitions in Net Zero manufacturing and advanced power electronics.

Sector transformation
-Enables printable, low-cost capacitor manufacturing
-Reduces reliance on vacuum processing
-Supports integration with next-generation semiconductor platforms (e.g. SiC, GaN)

Potential
The technology has strong potential for adoption across:
-Electric vehicles
-Renewable energy systems
-Power conversion and grid technologies

Beyond immediate applications, this work opens a broader opportunity to rethink how electronic materials are manufactured - shifting towards solution-based, sustainable semiconductor processing.

The collaboration has also laid the foundation for:
-Follow-on funding (EPSRC, Innovate UK)
-Industrial partnerships
-IP generation and commercialisation pathways

Overall, the project demonstrates how academic innovation, when combined with Catapult infrastructure and expertise, can rapidly translate into technologies with real industrial and societal impact.

CSA Catapult

"This project demonstrates the strength of collaboration between academia and the Catapult network. By combining novel solution-processed compound semiconductors with application-driven engineering, we are unlocking new opportunities for sustainable next-generation power electronics technologies." **- Professor Ingo Ludtke, Head of Power Electronics at CSA Catapult.**

Bo Hou

"This collaboration has transformed how we approach compound semiconductor research - taking us beyond discovery to real device validation. Working with the Catapult has enabled us to align fundamental science with industrial needs and significantly accelerate the pathway to impact."

CATAPULT Compound Semiconductor Applications

UK Research and Innovation