



Innovate
UK

The background of the top half of the poster is a photograph of a semiconductor laboratory. A person in a white cleanroom suit and mask is in the foreground, holding a large, circular, multi-colored wafer. In the background, another person is working at a microscope. The scene is lit with a cool blue light, and several computer monitors displaying data are visible.

Semiconductors

Global Business
Innovation Programme
Semiconductors, Taiwan
4-9 September 2023

全球商業創新計畫
台灣國際半導體展
(SEMICON Taiwan)
2023年9月4至9日



Foreword

Innovate UK, the UK's national innovation agency, is pleased to be in Taiwan this week with a strong delegation of exciting UK semiconductor businesses and the state-of-the art Compound Semiconductor Applications Catapult.

As part of Innovate UK's Global Business Innovation Programme, delivered by Innovate UK EDGE, the agency's resource which helps ambitious UK businesses to grow and scale, the businesses are looking to explore the opportunities of working with Taiwan and to build innovation and R&D focused partnerships and collaborations. By bringing together and harnessing the complementary strengths in semiconductors in the UK and Taiwan it will enable us to better compete in the global market and drive economic growth.

The visit this week is part of a growing relationship between Innovate UK and Taiwan following a Memorandum of Understanding (MoU) signed with The Department of Industrial Technology,

Ministry of Economic Affairs of Taiwan in November 2022.

The objective of the MoU is to establish a solid basis for cooperation, especially in cutting edge applied research, experimental development and innovation and to support and promote R&D and innovation activities between us. The MoU led to the first bilateral R&D competition launched in April 2023 funded by Innovate UK and the Department of Industrial Technology, working closely with ITRI.

On behalf of Innovate UK and the delegation visiting Taiwan this week, we look forward to meeting with you and building and strengthening relationships.



David Golding
Deputy Director,
Global, Innovate UK

前言

英國國家創新機構——英國創新局 (Innovate UK) 很高興和陣容堅強的英國半導體產業代表團，以及最先進的化合物半導體應用创新中心 (Compound Semiconductor Applications Catapult)。

在本週一起造訪台灣。這是英國創新局旗下「全球商業創新計畫 (Global Business Innovation Programme)」的一部分，由英國創新優勢處 (Innovate UK EDGE) 負責執行；該處提供資源協助胸懷大志的英國企業成長與擴張。本次訪問團的各家企業希望探索與台灣合作的機會，並建立聚焦於創新和研發的夥伴關係與合作。藉由匯集並善用英國和台灣在半導體領域的互補優勢，我們在全球市場將更具競爭力，且可驅動經濟成長。

本週的訪問計畫，是英國創新局和台灣經濟部技術處在2022年11月簽署合作備忘

錄後，雙方關係持續成長的一環。該備忘錄的目標是建立堅實的合作基礎，尤其是在尖端應用研究、實驗開發和創新方面，以支持並促進英、台之間的研發和創新活動。前述備忘錄促成英國創新局和台灣經濟部技術處於2023年4月贊助經費，並和工業技術研究院密切合作，推出首次英、台雙邊研發競賽。

我們謹代表英國創新局和本週訪台的代表團，期待和各位會面，並建立與強化彼此關係。



David Golding
英國創新局 (Innovate UK)
全球事務部副總監

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UK Semiconductor Sector

Semiconductors are one of the five technologies of the future, along with quantum, AI, engineering biology and future telecoms. It plays a critical role in the UK's economic and national security, positioning the country as a science and technology superpower on the global stage.

Globally, the semiconductor industry is the fourth largest, with revenue reaching \$601.7 billion in 2022, reflecting a substantial increase of 100.6% since 2012. The sector is projected to achieve annual growth rates of 6% to 8% until 2030. The demand for semiconductors is expected to rise significantly due to their applications in various fields, including communications infrastructure, artificial intelligence, smart devices, quantum and cloud computing, electric and autonomous vehicles, power electronics, and renewable energy.

The UK has a long-standing tradition of leadership in science and technology, playing a crucial role in the development of technological innovations from the steam engine to the World Wide Web. The country's expertise has also been instrumental in advancing semiconductor technologies.

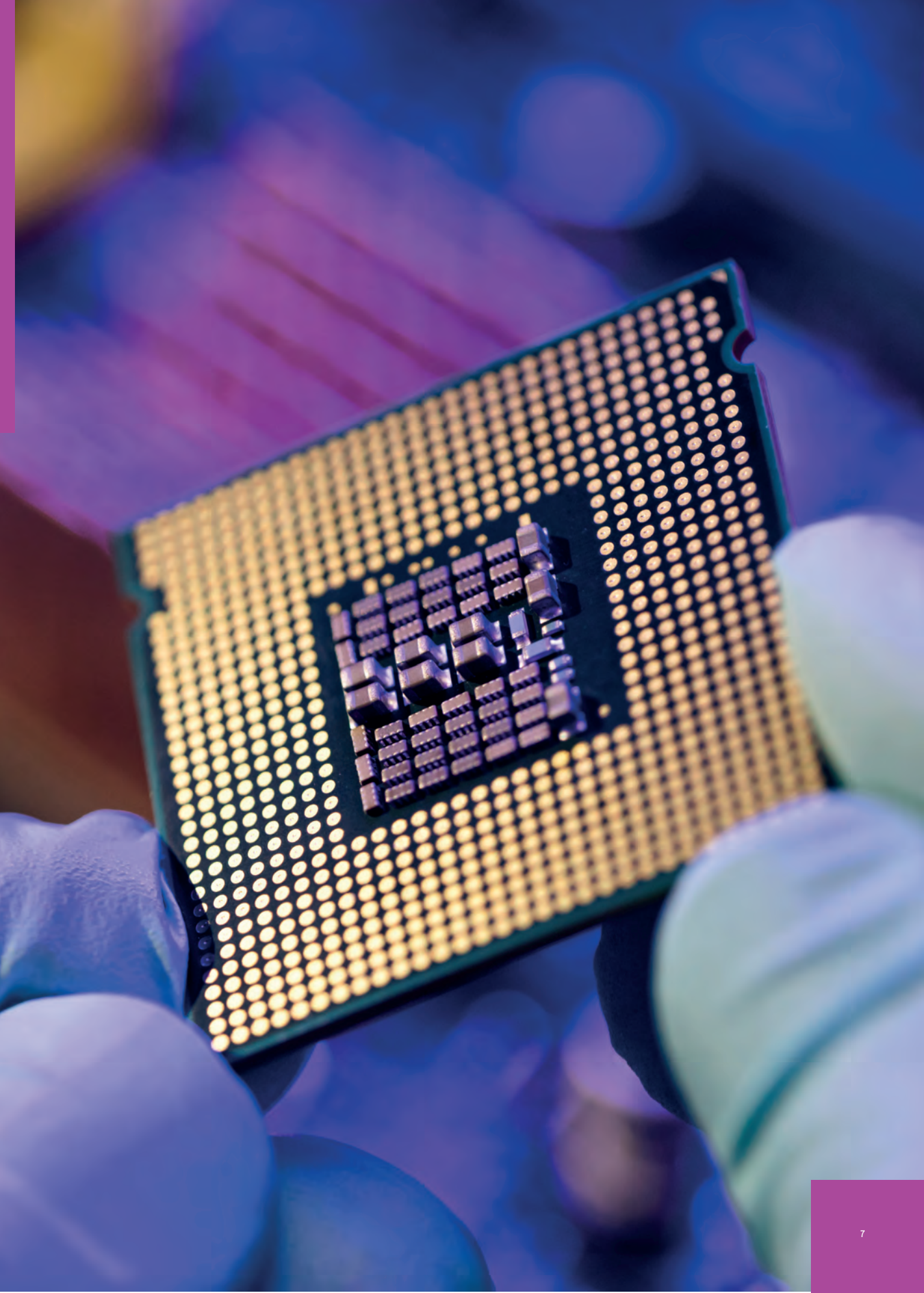
Through initiatives like the UK Science and Technology Framework and National Semiconductor Strategy, the UK aims to maintain its world-leading position in the semiconductor technologies of the future by leveraging its fundamental strengths, fostering new discoveries and innovation, and creating opportunities for growth and higher-paid jobs, thereby contributing to the prosperity of the UK economy.

UK Research & Development Strengths

The UK possesses strengths across the semiconductor value chain, with three significant areas of strategic advantage: semiconductor design and IP, compound semiconductors, and world-leading semiconductor research capabilities, supported by a robust academic network. These strengths are spread across different regions of the UK, including Cambridge for electronics, Bristol for photonics, South Wales for compound semiconductors, Scotland for photonics, heavy power and satellite applications, and the North East for gallium nitride and gallium arsenide RF chips.

Research and Innovation

In terms of research and innovation, the UK ranks third in Europe and eighth globally for semiconductor International Patent Families. It also boasts four of the world's top 10 universities and has areas of research expertise in design, advanced materials, compound semiconductors, power electronics, photonics, quantum technologies, and heterogeneous integration. The UK's research proficiency has already led to the establishment of innovative companies such as Pragmatic Semiconductor and Paragraf.



Design and IP

The UK's strength in semiconductor design and IP is enhanced by companies like Arm and Imagination Technologies, dedicated design houses, and over 110 companies, as well as exceptional R&D clusters in Bristol and Cambridge. The presence of internationally leading semiconductor design companies like Apple, Intel, and Infineon further reinforces the UK's leadership in emerging technologies critical to both prosperity and security.

Compound Semiconductors

The UK has developed a significant presence in the compound semiconductor supply chain, leveraging its strong foundation in physical sciences and engineering research. The country is a global player in the compound semiconductor market, with companies like IQE driving its growth by supplying compound semiconductor wafer products and advanced material solutions to the industry. The UK also excels in compound semiconductor fabrication, including Siverts (Indium Phosphide), ClasSiC (Silicon Carbide), and Lumentum (Indium Phosphide).

Over the last 10 years the Engineering and Physical Sciences Research Council (EPSRC) has supported semiconductor research through 498 grants, totalling £539 million. Innovate UK, the UK's innovation agency has distributed £214 million of grants directly to SMEs in the semiconductor space and established the Compound Semiconductor Applications Catapult (CSAC), which through working with academia and industry helps UK companies to commercialise new technologies. Investment has also seen the emergence of hotspots of expertise, such as CSconnected, the world's first compound semiconductor cluster.

UK Government Commitment

The UK government has shown its commitment to the semiconductor sector through the recently published UK semiconductor strategy. With a vision for the next 20 years, the government aims to secure world-leading strengths in semiconductor technologies by focusing on the UK's strengths in R&D, design and IP, and compound semiconductors. This will facilitate technological innovation, boost growth and job creation, bolster our international position in order to improve supply chain resilience and protect and improve national security. To support this strategy, the government plans to invest up to £1 billion over the next decade and launch a UK Semiconductor Infrastructure Initiative to bring the sector together and develop an enabling infrastructure for start-ups and SMEs. The UK also seeks to strengthen bilateral relationships with like-minded governments and foster a framework that stimulates international collaboration.

Taiwan's Commitment and Strengths

Taiwan manufactures over 60% of the world's semiconductors and 92% of those that are most advanced. Taiwan's semiconductor industry contributes 15% to its GDP.

The total output value of Taiwan's IC industry reached US\$145.7 billion in 2021. Taiwan's IC design output value reached US\$43.2 billion in 2021, which accounted for 22.0% of the total worldwide and ranked second globally, just behind the United States. Taiwan has long held the top global market share position in foundry services, with a market share of 79.7%, and IC packaging and testing, with a market share of 59.0%.

Taiwan's semiconductor ecosystem is supported by organisations like the Industrial Technology Research Institute (ITRI), which plays a crucial role in the growth of Taiwan's high-tech industry, including semiconductors. Taiwan's capabilities include cutting-edge technology, exemplified by the Taiwan Semiconductor Manufacturing Company, one of the world's leading semiconductor manufacturers with clients like Apple, Qualcomm, and Nvidia. ITRI offers various services to industries, including technology development, consultation, testing, and analysis.

Opportunities for collaboration

The UK is a world leader in new and emerging semiconductor materials, design and IP, device research and design automation.

Taiwan has a comprehensive semiconductor ecosystem comprising design, foundry, assembly, and testing facilities, as well as a vast network of suppliers and vendors and benefits from a manufacturing infrastructure that is needed to support a resilient supply chain.

Whilst Taiwan is well placed to maintain and further its silicon fabrication dominance, it is also targeting increased development of compound semiconductors, emerging materials and advance packaging which align well with the UK's areas of expertise in IC design, Power Electronics, Silicon Photonics and Future Telecoms.

The UK and Taiwan have recognised the benefits of collaboration. Collaborative efforts have been initiated through agreements between ITRI and the CSAC, as well as through joint funding of research and development projects by Innovate UK and

ITRI. With the increasing demand for electronics in areas such as electric vehicles, smart cities, telecommunications, and healthcare, along with the need for smaller, faster, and more power-efficient chips, there are significant opportunities for collaboration between the UK and Taiwan. The Global Business Innovation Programme to Taiwan aims to strengthen UK-Taiwan relationships and facilitate innovation partnerships.



英國半導體產業

半導體和量子、人工智慧(AI)、生物工程、未來電信，並列為未來的五大科技。在英國經濟和國家安全中，半導體扮演至關重要的角色，讓英國在世界舞台上被定位為科技強國。

英國半導體業在全球排名第四，2022年營收達到6,017億美元，反映其自2012年以來大幅成長100.6%的事實。該產業料將以6%至8%的年增率成長，直到2030年。由於可應用在通訊基礎設施、人工智慧、智慧裝置、量子與雲端運算、電動與自動駕駛車、電力電子、再生能源等各種領域，半導體的需求預料還會大幅攀升。

英國在科技領域的領導地位由來已久，在蒸氣機、全球資訊網(World Wide Web)等技術創新的開發上，扮演至關重要的角色。對於半導體科技的進步，該國的專業知識也功不可沒。

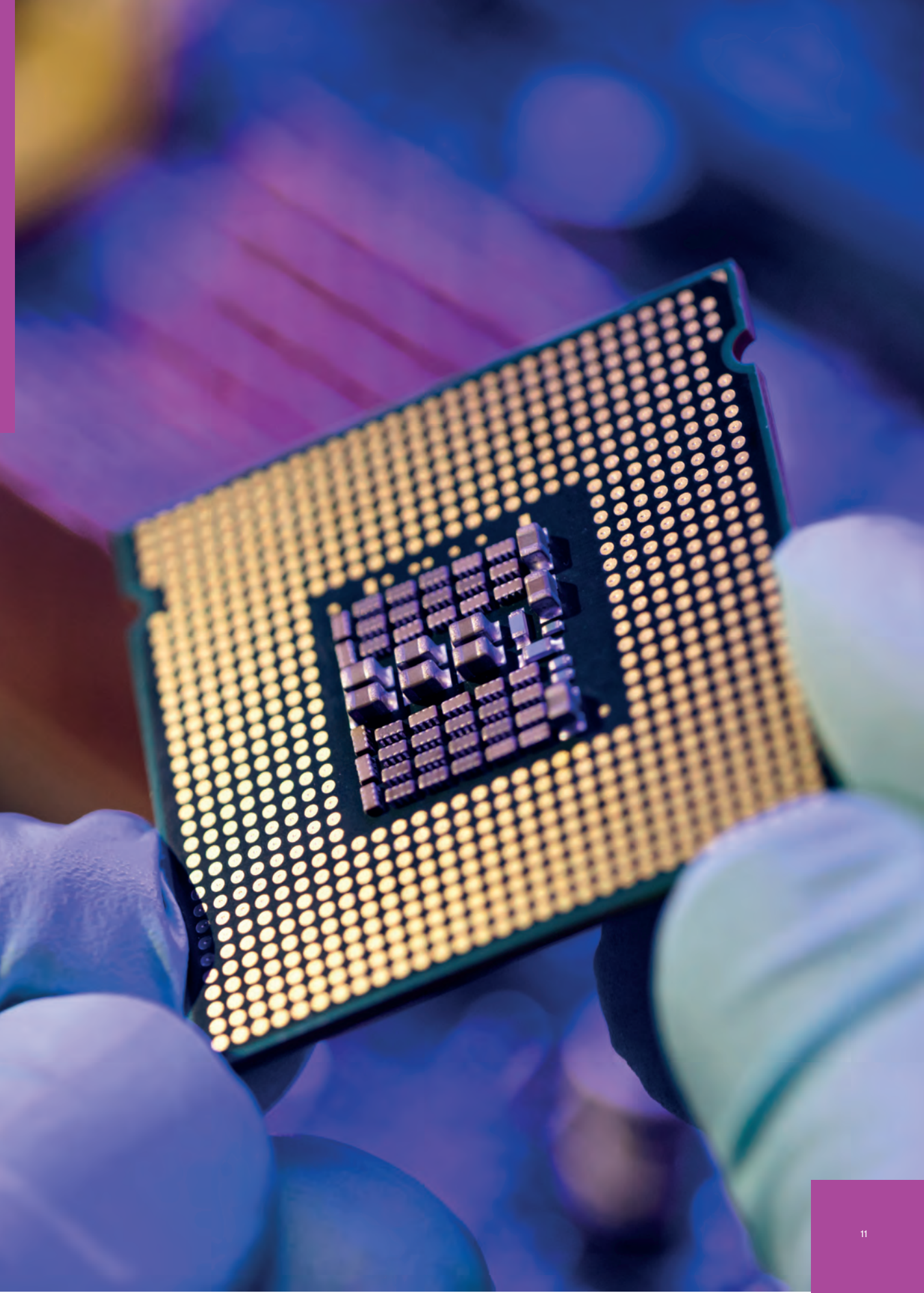
英國希望，透過《英國科學與技術框架(UK Science and Technology Framework)》和《國家半導體戰略(National Semiconductor Strategy)》等舉措，善用其基本優勢，促進新發明和創新，並創造成長和高薪工作機會，以維持該國在未來半導體科技中的世界領先地位，進而為英國經濟的繁榮帶來貢獻。

英國的研發優勢

英國在整個半導體價值鏈均擁有優勢，其中在半導體設計和矽智財、化合物半導體、世界領先的半導體研究實力等三個重大領域，佔有戰略性有利地位，並擁有強大的學術網絡支援。這些優勢散布於英國各地不同地區，包括：劍橋(Cambridge)的電子學；布里斯托(Bristol)的光子學；南威爾斯(South Wales)的化合物半導體；蘇格蘭(Scotland)的光子學、大功率半導體和衛星應用；以及東北英格蘭(North East England)的氮化鎵和砷化鎵射頻(RF)晶片。

研究與創新

就研究與創新而言，英國的半導體專利家族(International Patent Families)在歐洲排名第三，全球則名列第八。世界排名前十名的大學中，英國擁有4所，並具有設計、先進材料、化合物半導體、電力電子、光子學、量子科技和異質整合(heterogeneous integration)領域的研究專長。英國的高水準研究能力，孕育出Pragmatic、Paragraf等新創公司。



設計與矽智財

安謀 (Arm)、進想科技 (Imagination Technologies)、專業半導體設計等逾110家公司，以及布里斯托和劍橋的卓越研發聚落，讓英國在半導體設計和矽智財方面的實力更加強大。蘋果 (Apple)、英特爾 (Intel)、英飛凌 (Infineon) 等國際主要半導體設計公司的進駐，進一步鞏固英國在對繁榮與安全至關重要的新興科技領域的領導地位。

化合物半導體

由於善用其在物理科學和工程研究方面的強大基礎，英國在化合物半導體供應鏈中已取得重要地位。英國是化合物半導體市場的重要國際參與者，透過IQE等公司為產業提供化合物半導體晶圓產品和先進材料解決方案，驅動該國成長。英國在化合物半導體製造的表現也相當出色，包括Sivers (磷化銻)、ClasSiC (碳化矽) 和Lumentum (磷化銻) 等。

過去10年來，英國工程與物理科學研究委員會 (Engineering and Physical Sciences Research Council, 簡稱EPSRC) 透過總額共5.39億英鎊的498筆捐款，支持半導體研究。英國創新局直接向半導體領域的中小企業提供2.14億英鎊捐款，並成立化合物半導體應用創新中心 (Compound Semiconductor Applications Catapult, 簡稱CSAC) 和產、學界合作，幫助英國企業將新技術商業化。投資方面也出現新的專業熱點，例如CSconnected成為全世界第一個化合物半導體聚落。

英國政府的承諾

英國政府透過不久前發布的《國家半導體戰略》，展現其對半導體產業的承諾。展望未來20年，英國政府的目標是透過專注於該國在研發、設計與矽智財、化合物半導體方面的優勢，確保其在半導體科技領域的世界領先地位。這將有助於技術創新、促進成長並創造就業機會、鞏固英國的國際地位，以改善供應鏈韌性，保護並提升國家安全。為了支持前述戰略，英國政府計畫在未來10年投資高達10億英鎊，並啟動《英國半導體基礎建設計畫 (UK Semiconductor Infrastructure Initiative)》，凝聚產業力量，為新創公司和中小企業開發有利的基礎架構。英國還尋求和志同道合的政府加強發展雙邊關係，並建立促進國際合作的框架。

台灣承諾和優勢

台灣生產超過60%的半導體，以及92%最先進的半導體。台灣生產總值(GDP)的15%來自半導體產業貢獻。

台灣積體電路 (IC) 業的2021年總產值達1,457億美元。同期間的IC設計產值為432億美元，占全球的22.0%，名列第二，僅次於美國。台灣長年盤據全球半導體市場龍頭地位，其中半導體代工的市占率達79.7%，IC封測則為59.0%。

台灣的半導體生態體系擁有工業技術研究院 (ITRI) 等機構的支援；在當地高科技產業 (含半導體) 發展過程中，工研院扮演至關重要的角色，為許多產業提供各種服務，包括技術開發、諮詢、測試和分析等。台灣包括尖端技術在內的各项實力中，台積電可說是典型的典範——該公司是世界領先的半導體製造商之一，客戶包含蘋果、高通 (Qualcomm) 和輝達 (Nvidia) 等。

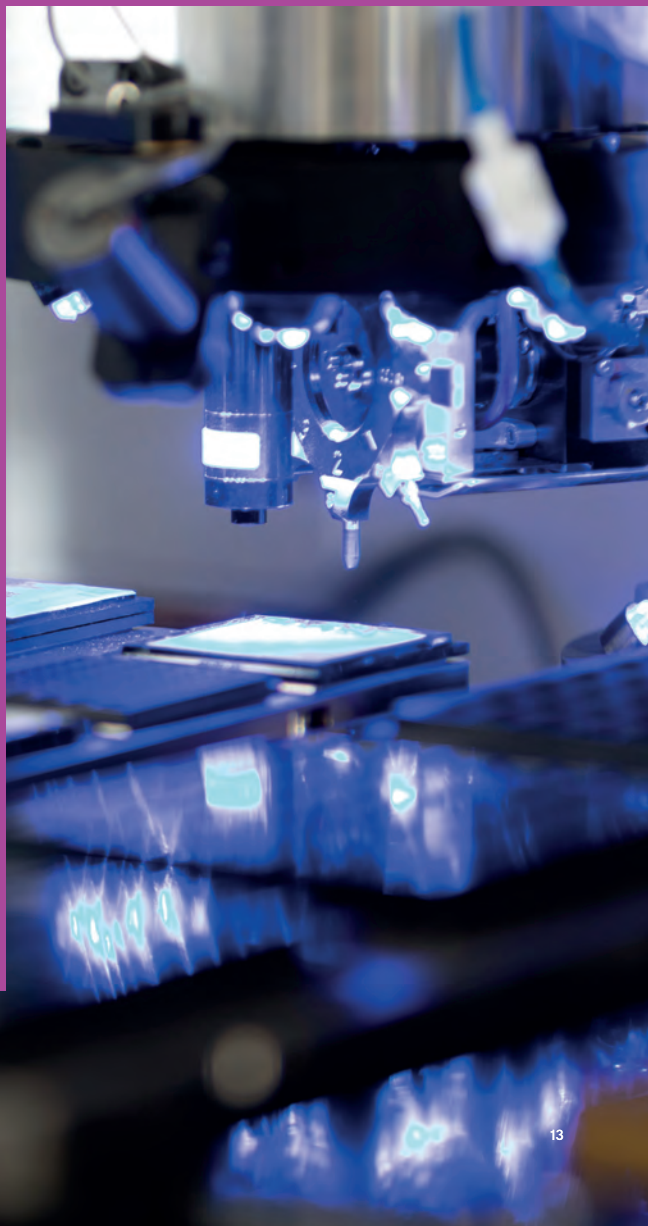
合作機會

英國是新興半導體材料、設計和矽智財、裝置研究、設計自動化等領域的世界領袖之一。

台灣擁有完整的半導體生態體系，包括設計、晶圓代工、組裝、測試等領域，以及龐大的供應商網絡，並受益於支持具韌性供應鏈所需的製造基礎設施。

台灣有能力維持並進一步鞏固其在矽製造領域的主導地位，不過也設下擴大發展化合物半導體、新興材料和先進封裝的目標，和英國在IC設計、電力電子、矽光子學和未來電信領域所擁有的專業知識高度吻合。

英國和台灣已體認到合作的好處，並透過工研院和英國化合物半導體應用創新中心所達成的協議，以及英國創新局和工研院共同資助的各項研發計畫，啟動合作努力。隨著電動車、智慧城市、電信、醫療保健等領域對電子產品的需求越來越高，加上對更小、更快、更節能晶片的需求，英國和台灣之間的合作機會益發重要。英國針對台灣推出的全球商業創新計畫 (Global Business Innovation Programme)，旨在強化英、台關係，並促進創新合作夥伴關係。



About the Compound Semiconductor Applications Catapult

The Compound Semiconductor Applications Catapult is at the centre of the UK's innovation ecosystem and sits within the UK's compound semiconductor cluster.

Established by Innovate UK in 2018, the 3,000m² state-of-the-art Innovation Centre is key to unlocking compound semiconductor innovations in the UK, with four unique laboratories specialising in Power Electronics, Radio Frequency (RF) and Microwave, Photonics and Advanced Packaging technologies.

A non-profit research and technology organisation, the CSA Catapult de-risks research and innovation and helps companies develop electronic products using compound semiconductors by giving access to highly qualified research teams, business expertise and world leading facilities.

Since 2018, the Catapult has helped to grow the UK compound semiconductor sector by increasing product development, testing and evaluation, identifying new domestic and international market opportunities, and through the creation of effective end-to-end supply chains.

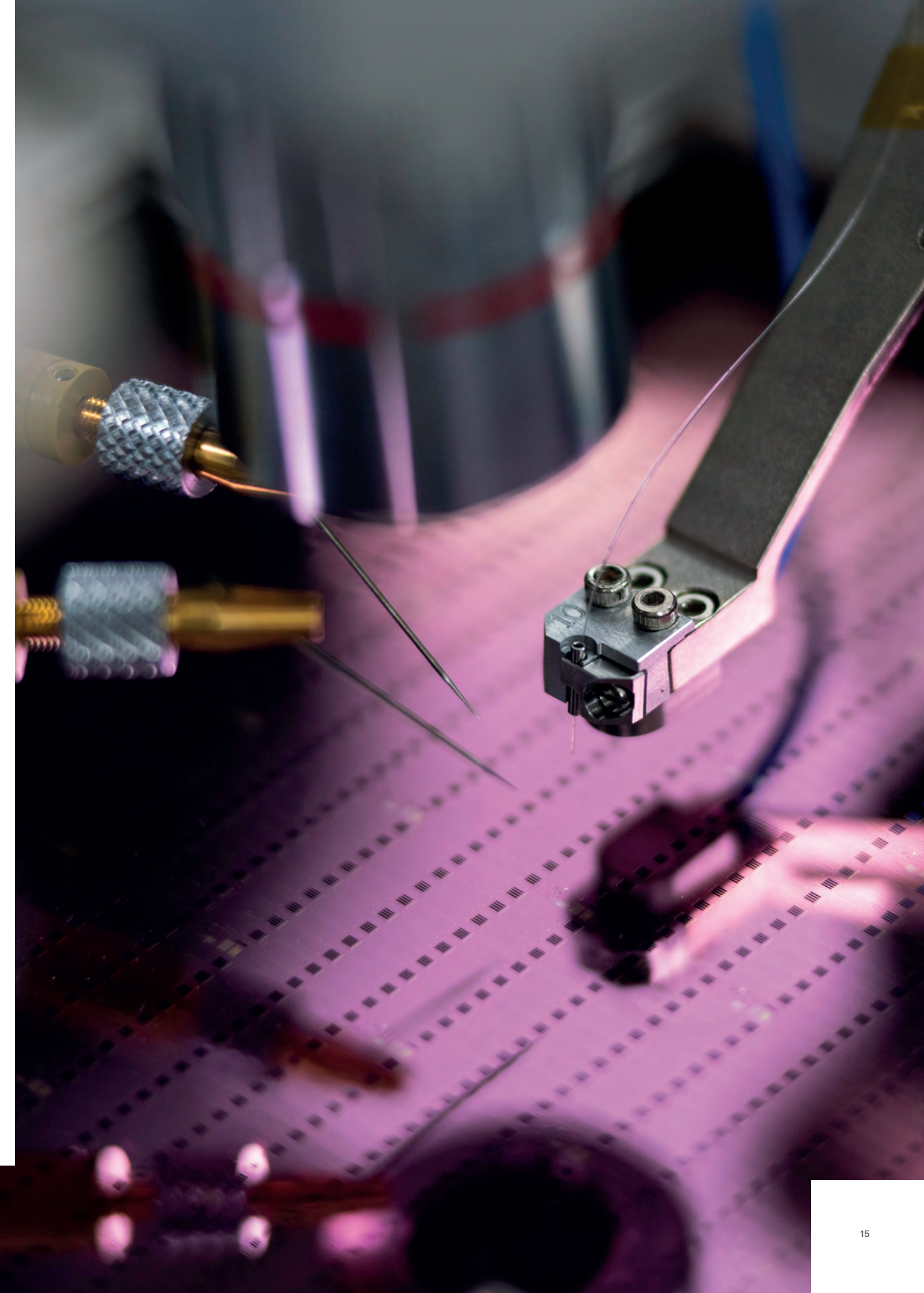
The Catapult has initiated over £170 million of projects and worked with companies developing advanced electronic systems for electric vehicles, future telecom networks, defence and quantum applications to simulate their products, develop prototypes, and carry out validation using state-of-the-art instruments.

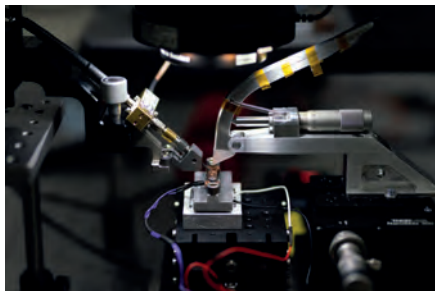


Catapult Projects

ESCAPE (End-to-End Supply Chain for Automotive Power Electronics)

ESCAPE is a £19.5 million project that brought together a consortium of ten companies, one university and the CSA Catapult to develop an electric powertrain for McLaren electric sports cars. The project focused on creating a SiC module which can deliver extremely efficient power that maximises vehicle range. It will also help to address the demand for SiC with the increase in the electric vehicle market and will overcome challenges in vehicle charging and smart energy grids.





ATFutureBEV (Advanced Technologies for Future Battery Electric Vehicles)

Building on the positive outcomes of ESCAPE (significant reduction in charge times, accelerating end-user acceptance, optimising the powertrain by doubling up power density, reducing volume, cost and optimising overall vehicle powertrain efficiency) ATFutureBEV bought together three companies (including BMW), Warwick University and the CSA Catapult, with a further investment of £26 million which took the BEV technology from niche to mainstream.

Secure 5G Open RAN

Secure 5G developed a secure, highly efficient 5G base station complying with the Open-RAN principles. Three companies and the CSA Catapult were supported with a £1.1 million grant from the Department for Science Innovation and Technology to develop a novel modular 5G platform

capable of delivering output powers of up to 10W using a new Software Defined Radio (SDR) chip and of operating up to 10GHz coupled with a very efficient, wideband power amplifier.

This approach means the base station frequency can be selected in software instead of requiring a hardware upgrade. The base station used a novel gallium nitride (GaN) power amplifier that was specifically designed to minimise the 65% energy consumed by base stations. Lastly, the base station features a quantum cloud security layer providing stronger, simpler encryption that is unbreakable even with a quantum computer.



International

The CSA Catapult is keen to develop international partnerships, building on the memorandum of understanding (MoU) signed with Electronic and Optoelectronic System Research Lab (EOSL) of ITRI in 2020.



Compound Semiconductor Applications Catapult
Innovation Centre, Imperial Park, Celtic Way, Newport, NP10 8BE
www.csa.catapult.org.uk

About us

The Global Business Innovation Programme

The Global Business Innovation Programme (GBIP) helps ambitious UK companies that are developing cutting edge technologies in key sectors to enter global markets of strategic importance and find international collaboration partners.

Funded by Innovate UK and managed by Innovate UK EDGE, the intensive three-stage programme:

- Prepares businesses for approaching and operating in market
- Includes a tailored in-country visit, which allows businesses to develop a deeper understanding of the market and facilitates introductions to key partners and contacts from Government, academia and commerce
- Provides ongoing post-visit specialist support to help businesses cement relationships, leverage connections made during the visit, identify partnership opportunities and access R&D funding to drive cross-border collaboration.

Innovate UK

Innovate UK is the UK's innovation agency, helping UK businesses to accelerate growth through the development and commercialisation of new products, processes and services, supported by an easy to navigate, agile and inclusive innovation ecosystem.

Website: www.ukri.org/about-us/innovate-uk

Innovate UK EDGE

Funded by Innovate UK, Innovate UK EDGE delivers bespoke support to ambitious innovative businesses to help them grow and scale. The support provided by Innovate UK EDGE is tailored to meet the needs of businesses across all technology sectors and is designed to respond to their evolving needs as they scale and compete globally.

Website: www.innovateukedge.ukri.org



關於化合物半導體應用創新中心

About the Compound Semiconductor Applications Catapult

化合物半導體應用創新中心 (Compound Semiconductor Applications Catapult, 簡稱CSA Catapult) 座落於英國化合物半導體聚落內, 是英國創新生態體系的核心。

此一占地3,000平方公尺的最先進創新中心, 係由英國創新局 (Innovate UK) 於2018年成立, 是英國解鎖化合物半導體創新的關鍵, 擁有4座專長於電力電子、射頻 (RF) 與微波、光子學、先進封裝等科技的獨一無二實驗室。

該中心為非營利的研究和技術機構, 其宗旨是降低研究與創新的風險, 並透過引介高品質研究團隊、業務專業知識和世界領先的設施, 幫助企業開發使用化合物半導體的電子產品。

自2018年以來, 該中心透過加強產品開發、測試與評估、發掘新的國內外市場商機, 並建立有效端到端供應鏈的方式, 幫助英國英國化合物半導體產業成長。

該中心已發起總規模逾1.7億英鎊的多項計畫, 並和為電動車、未來電信網絡、國防、量子等應用開發先進電子系統的業者合作, 為其產品進行模擬、原型開發, 並利用最先進儀器進行驗證。



化合物半導體應用創新中心推動的計畫

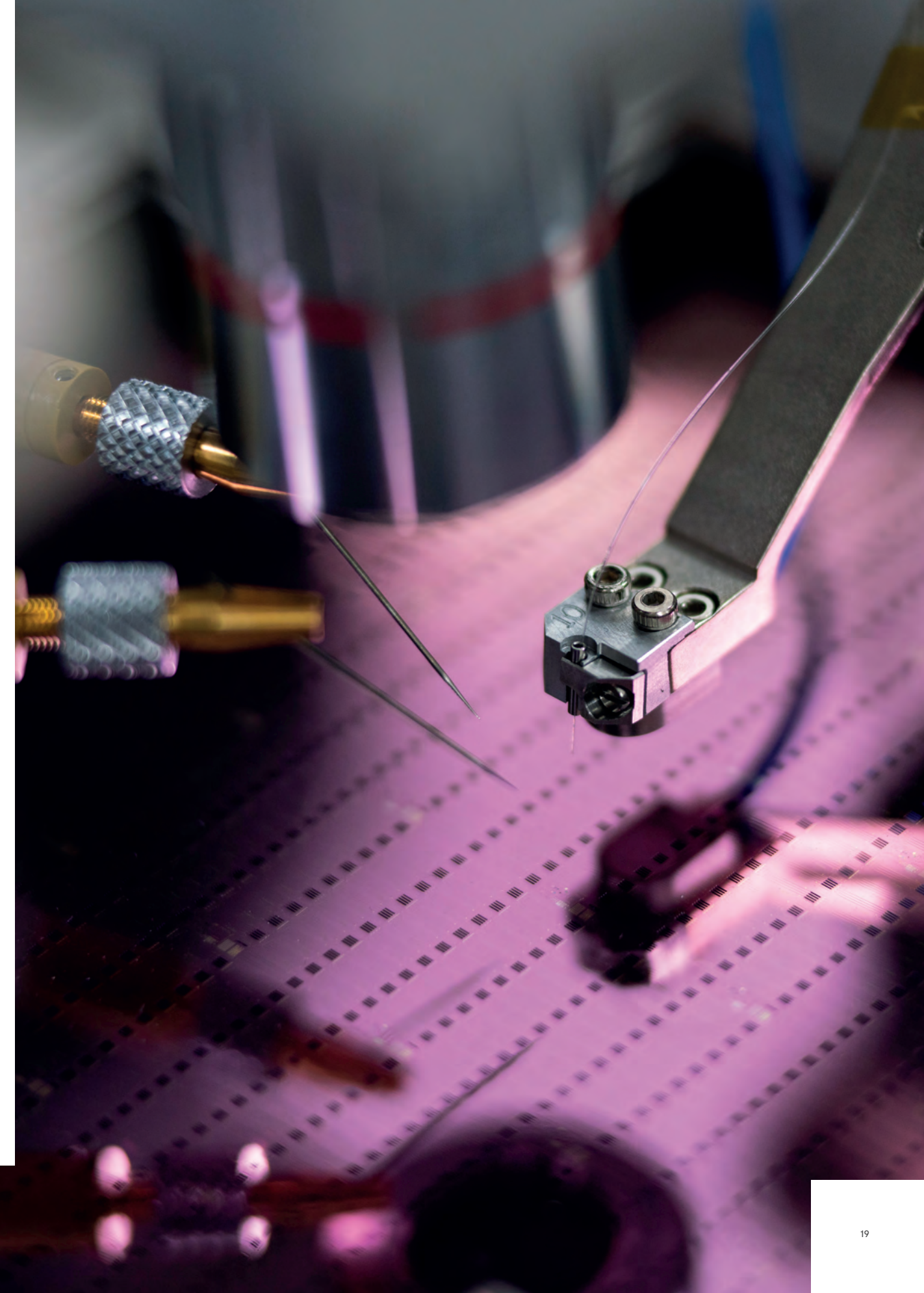
Catapult Projects

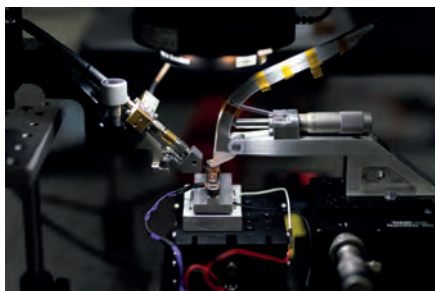
計畫: 汽車電力電子端到端供應鏈 (ESCAPE)

這是一項耗資1,950萬英鎊的計畫, 集結由10家公司共組的財團、一所大學和CSA Catapult, 共同為麥拉倫 (McLaren) 電動跑車開發電動動力系統。該計畫聚焦於創建可提供極高效動力、進而儘可能延長充電續航里程的碳化矽 (SiC) 模組, 這將有助於滿足電動跑車市場對碳化矽持續成長的需求, 並克服電動車充電和智慧電網所面臨的挑戰。

計畫: 未來純電動車的先進技術 (ATFutureBEV)

以前述ESCAPE計畫的正向成果為基礎, ATFutureBEV的目標是大幅縮短電動車充電時間、加速終端用戶的接受度、透過讓功率密度 (power density) 加倍的方式來優化動力系統, 以及減少體積、成本並優化整體車輛動力系統的效率。ATFutureBEV集結寶馬汽車 (BMW)、華威大學 (University of Warwick) 和CSA Catapult等3家機構的力量, 進一步投入2,600萬英鎊資金, 讓純電動車 (BEV) 技術從利基市場走向主流。





計畫:安全5G開放性無線接入網路 (Secure 5G Open RAN)

該計畫開發出符合開放性無線接入網路 (Open RAN) 原則的安全、高效5G基地台。3家企業和CSA Catapult獲得來自英國科學、創新與科技部 (Department for Science, Innovation and Technology) 的110萬英鎊資助,用於開發全新的模組化5G平台,能利用新型軟體定義無線電 (SDR) 晶片提供高達10瓦的輸出功率;該款晶片能在高達10GHz的頻率上運作,並搭配非常高效的寬頻功率放大器。此方法意味可透過軟體選擇基地台頻率,而無須升級硬體。該款基地台採用經過專門設計的新型氮化鎵(GaN)功率放大器,可讓基地台消耗的能源減少65%。最後,該款基地台擁有量子雲端安全層,提供更強大、簡便的加密保護,連量子電腦也無法破解。

國際合作

CSA Catapult渴望以2020年和台灣工業技術研究院 (ITRI) 電子與光電系統研究所 (EOSL) 簽署的合作備忘錄為基礎,擴大發展國際合作夥伴關係。



CATAPULT
Compound Semiconductor Applications

化合物半導體應用創新中心 (Compound Semiconductor Applications Catapult)
地址: Innovation Centre, Imperial Park,
Celtic Way, Newport, NP10 8BE, United Kingdom

網址: www.csa.catapult.org.uk

關於我們

全球商業創新計畫

全球商業創新計畫 (The Global Business Innovation Programme, 簡稱GBIP) 協助在關鍵產業開發尖端科技的英國企業, 進軍具有戰略重要性的全球市場, 並尋求國際合作夥伴。

該計畫由英國創新局 (Innovate UK) 資助, 並由英國創新優勢處 (Innovate UK EDGE) 負責管理, 包含三個階段:

- 協助企業做好進軍市場和持續經營的準備
- 包含量身打造的各國訪問, 使企業能更深入地了解當地市場, 並協助引介重要合作夥伴和來自產、官、學界的人脈。
- 訪問後持續提供專家支援, 幫助企業鞏固關係、善用訪問期間建立的人脈、確立合作機會, 並獲取研發資金, 以推動跨境合作。

英國創新局

英國創新局 (Innovate UK) 是英國的創新機構, 在易於上手、靈活且具包容性的創新生態體系支援下, 幫助英國企業透過新產品、製程和服務的開發和商業化, 加速發展。

網址: www.ukri.org/about-us/innovate-uk

英國創新優勢處

由英國創新局提供資金的英國創新優勢處 (Innovate UK EDGE), 為胸懷大志的創新性企業提供量身打造的支援, 幫助業者成長與擴張。英國創新優勢處所提供的支援, 是專為滿足各科技領域企業的需求而量身打造, 以因應業者在全球擴張和競爭時所不斷改變的需要。

網址: www.innovateukedge.ukri.org





Bay Photonics harnesses the power of light through their expertise in designing, packaging, assembling and testing cutting-edge semiconductor-based photonic devices. The company's portfolio includes state-of-the-art emitters, detectors, and photonic integrated circuits (PICs).

Bay Photonics has been a steadfast supporter of the UK semiconductor photonics development community since 2007, spanning various market sectors such as telecommunications, biomedical, space and remote sensing. With their wealth of experience and highly skilled personnel, the company excels in operating semi-manual workstations tailored for small batch sizes. These workstations are particularly ideal for pioneering process development.

Bay Photonics boasts access to state-of-the-art, fully automatic workstations employed by large volume commercial packaging houses, facilitating design optimisation for mass production, making the company the perfect partner for individuals or organisations ranging from TRL3 (proving feasibility/technology development) to TRL7 (demonstrating system prototypes in operational environments). A privately-owned company, Bay Photonics offers open access to its services for photonic device assembly and packaging.

Bay Photonics' cutting-edge technologies encompass the gamut of downstream semiconductor device processes. The company offers comprehensive support for die-singulation, die-attachment, wire-bonding, encapsulation (ensuring mechanical protection, electrical insulation, photonic connection and thermal control for the encapsulated die), final testing and assembly (integration of photonic integrated circuits into products such as sensors, transmitters and receivers). Recently the company has been focusing on fostering the burgeoning quantum technology revolution. Semiconductor-based photonics plays a pivotal role in enabling aspects of quantum technology. The packaging of quantum photonics entails the intricate task of integrating and packaging photonic devices that generate and manipulate single photons, quantum states of light and quantum information. Even minor disturbances or temperature changes can lead to decoherence or degrade their performance, making Bay Photonics' expertise and precision indispensable in this exciting field.



Dr Andrew Robertson Chief Technology Officer (CTO)

✉ andrew.robertson@bayphotonics.com

☎ +44 (0) 776 988 2657 🖱 www.bayphotonics.com

in www.linkedin.com/company/bay-photonics-limited



Bay Photonics憑藉其在設計、封裝、組裝和測試尖端半導體光子裝置方面的專業知識，駕馭光的力量。該公司的產品組合，包括最先進的發射器、探測器和光子積體電路 (PIC)。

自2007年以來，Bay Photonics一直是英國半導體光子學開發圈的堅定支持者，觸角涵蓋電信、生物醫學、太空和遙感 (remote sensing) 等各市場領域。憑藉其豐富的經驗和高技能人才，該公司擅長運行小批量量身打造的半手動工作站。這些工作站尤其適合用於開創性的製程開發。

Bay Photonics擁有大量商業封裝廠所使用的最先進全自動工作站，有助大規模量產的設計優化，因此對於技術完備度第3級 (TRL3，證明可行性／技術開發) 到第7級 (TRL7，在操作環境中展示系統原型) 的個人或組織來說，是完美的合作夥伴。Bay Photonics是一家私人公司，對外提供光子裝置組裝和封裝服務。

Bay Photonics的尖端技術，涵蓋下游半導體裝置製程的全部領域。針對裸晶切割、黏晶、打線接合、封裝 (確保封膠後的裸晶受到機械保護、電氣絕緣、光子連接和熱控制)、最終測試和組裝 (將光子積體電路整合到感測器、發射器和接收器等產品中)，該公司提供全面支援。Bay Photonics近期專注於促進快速發展的量子技術革命。半導體光子學在促成量子技術方面扮演關鍵性角色。量子光子的封裝，必然涉及整合和封裝生成與操縱單光子、光量子態和量子資訊的光子裝置，這是錯綜複雜的任務。即使是微小的干擾或溫度變化，也可能導致退相干或性能降級；因此在這個令人振奮的領域，免不了必須借重Bay Photonics的專業知識與嚴謹。



Dr Andrew Robertson 博士 技術長 (CTO)

✉ andrew.robertson@bayphotonics.com

☎ +44 (0) 776 988 2657 🖱 www.bayphotonics.com

in www.linkedin.com/company/bay-photonics-limited



Blueshift Memory has developed a proprietary new computer architecture design enabling up to 1000 times faster, energy-efficient memory access.

Blueshift Memory is a semiconductor IP company which has developed a proprietary next-generation (non-Von Neumann) technology that optimises computer memory architecture for more efficient handling of large data sets and time-critical data. Based on the Cambridge Architecture™ the technology overcomes the constraints of the 'Von Neumann bottleneck' or Memory Wall, offering up to 1,000 times faster memory access, up to 50% reduction in energy consumption and giving protection from memory-centric cybersecurity attacks for data-intensive applications such as, high performance computing, AI, machine vision for AR/VR, 5G edge connectivity and the IoT.

The company's team and advisory board have led multiple successful startups and have significant experience in the semiconductor and supercomputing industries. Founder and CTO, Peter Marosan, developed a distributed computing solution and a recommendation AI engine, and has designed supercomputer hardware and Big Data HPC. Co-Founders are Theodore Omtzigt, who is a former Intel and NVIDIA principal engineer and Kitrick Sheets, who was lead engineer on the Cray Jaguar supercomputer.

CMO Helen Duncan has 45 years of experience in the electronics and semiconductor industries, including design engineering and marketing for Plessey and Rohm Electronics.

The company is developing a prototype computer vision AI module incorporating its technology, which also integrates a customised Cudasip RISC-V core. This module design demonstrates the improvements in memory bandwidth, latency and reduced energy consumption that Blueshift Memory's IP can offer to DRAM and other memory vendors, as well as to processor (CPU/GPU) vendors and end users like hyperscalers.

Blueshift Memory is seeking to forge new partnerships with DRAM and other memory vendors, with a view to integrating its IP into next-generation products.



Helen Duncan Chief Marketing Officer (CMO) BSc (Hons) CEng MIET MIEEE MCIPR

✉ helen.duncan@blushiftmemory.com

☎ +44 (0) 7765 250 610 🖱 www.blueshiftmemory.com

in www.linkedin.com/company/blueshift-memory



Blueshift Memory已開發一套專有的新電腦架構設計，可讓速度加快1,000倍，減少記憶體讀取功耗。

Blueshift Memory是一家半導體矽智財公司，開發出優化電腦記憶體架構的專有新一代(非Von Neumann型架構)技術，能更有效處理大型資料集 (data set) 和時效性資料。該技術以劍橋架構™ (Cambridge Architecture™) 為基礎，克服所謂「Von Neumann瓶頸」的記憶體牆 (Memory Wall) 限制，提供加快高達1,000倍的記憶體讀取速率，減少多達50%的功耗，並保護高效能運算 (HPC)、人工智慧 (AI)、擴增實境／虛擬實境 (AR/VR) 的機器視覺 (machine vision)、5G邊連通 (edge connectivity)、物聯網 (IoT) 等資料密集型應用，免於遭受以記憶體為核心的網路安全攻擊。

Blueshift Memory的團隊和顧問委員會曾領導多家成功的新創公司，並在半導體和超級電腦產業擁有顯赫的經歷。該公司創辦人兼技術長 Peter Marosan開發出一套分散式運算解決方案和AI推薦引擎，並曾設計超級電腦硬體和巨量資料 (Big Data) 高效能運算。共同創辦人Theodore Omtzigt曾任英特爾 (Intel) 和輝達 (NVIDIA) 首席工程師，另一位共同創辦人Kitrick Sheets曾是超

級電腦Cray Jaguar的首席工程師。行銷長Helen Duncan在電子和半導體產業擁有45年經驗，包括曾在Plessey和Rohm Electronics公司負責設計工程和行銷。

Blueshift Memory正在開發一套涵蓋該公司技術的原型電腦視覺AI模組，其中還整合客製化的Cudasip RISC-V內核。該模組設計證明，Blueshift Memory的矽智財可為DRAM和其他記憶體供應商、中央處理器 (CPU)／圖形處理器 (GPU) 供應商，以及超大規模資料中心 (hyperscaler) 之類的終端使用者，提供記憶體頻寬、延遲和降低能耗等方面的改進。

Blueshift Memory正尋求和DRAM與其他記憶體供應商建立新的合作夥伴關係，希望能將該公司的矽智財整合到新一代產品中。



Helen Duncan 行銷長 (Chief Marketing Officer) 理學士 (榮譽)／特許工程師 (CEng)／

工程技術學會會員 (MIET)／電機電子工程師學會會員 (MIEEE)／特許公共關係協會會員 (MCIPR)

✉ helen.duncan@blushiftmemory.com

☎ +44 (0) 7765 250 610 🌐 www.blushiftmemory.com

in www.linkedin.com/company/blushift-memory



EMU Technologies is a wafer handling equipment manufacturer focused on supplying cost effective, reliable, automated and manual wafer handling equipment to the global semiconductor industry.

Established in 2005 EMU has successfully delivered over 1,000 wafer handling products to global customers. Products range from automated and manual wafer notch/flat aligners and transfer machines to automated wafer sorters and laser mark readers operating under full host (MES) control. Recent innovations include an award-winning AI edge inspection machine which has potential to become an industry standard. The company has grown by expanding its international footprint, has products installed in the majority of European fabs and has a proven, successful track record of sales in the USA and Singapore. EMU was selected by Wolfspeed USA as supplier of choice for automated substrate handling and ID reading.

Traditionally products have been utilised by silicon wafer fabs, however, in recent years there has been a significant uptake of EMU technologies by compound semiconductor manufacturers. EMU collaborates with over 60 compound semiconductor, silicon and emerging materials manufacturers, providing standard and customised automation solutions, which often involves adopting new technologies to cope with the handling and detection of novel substrate materials such as GaAs, SiC, GaN, InP, Glass.

The company's recent move to a new facility with dedicated clean manufacturing, design and rapid prototyping and source inspection areas has ensured

the continuation of first-class service delivery to customers as industry requirements progress.

EMU's three product categories are:

1. Standard market-ready products - a competitively priced, high quality, reliable suite of wafer handling products that are compliant with semiconductor manufacturers' requirements
2. Macro AI inspection products - commercialised, with ongoing customer support to fully exploit the AI algorithm's capabilities
3. Micro AI inspection products - at the R&D prototyping stage, with many of the key elements of the product developed, with micro inspection available as a lab product or on EMU's existing automation platform.

With a project planned to develop and commercialise a new, low-cost front-end robot, to meet the future requirements of silicon and compound semiconductor manufacturers, EMU is seeking a collaboration with a Taiwanese partner with equipment that can satisfy the following key areas:

- high throughput wafer sorter
- front end module for process and metrology
- core automation element of the next generation AI micro inspection station



David Hyland CEO, BEng

✉ david.hyland@emutech.com

☎ +44 (0) 1935 813 313 🖱 www.emutech.com

in www.linkedin.com/company/emu-technologies



EMU Technologies是一家晶圓處理設備製造商，專注於向全球半導體業供應具經濟效益且可靠的自動化和手動式晶圓處理設備。

創立於2005年的EMU，已向全球客戶成功交付1,000多項晶圓處理產品。其產品範圍包括自動化和手動式晶圓凹口／平面對準器和傳送機、完全主機（製造執行系統）控制運行的自動晶圓揀選機和雷射標記讀取器等。該公司最近完成的一項創新，是曾經獲獎的人工智慧（AI）邊緣檢測機，可能會成為業界標準。該公司以擴大國際影響力的方式持續壯大，歐洲多數晶圓廠都裝有該公司的產品，且在美國和新加坡都有經過驗證的成功銷售紀錄。EMU獲美國碳化矽（SiC）材料領導大廠Wolfspeed遴選為自動化基材處理和記號辨識讀取的首選供應商。

傳統上，該公司產品的使用者一直是矽晶圓廠；但近年來採用EMU技術的化合物半導體製造商大量增加。

EMU和逾60家化合物半導體、矽和新興材料製造商合作，提供標準化和客製化的自動化解決方案，其中常常涉及採用新技術來處理並檢測砷化鎵（GaAs）、碳化矽（SiC）、氮化鎵（GaN）、磷化銦（InP）玻璃等新型基材。

EMU最近遷移到新工廠，設有專門的清洗製造、設計、快速原型製作和源頭檢驗區域，確保會隨著業界要求的進步，持續為客戶提供一流服務。

EMU的產品可分為三大類：

一、標準市場即用型產品：價格具競爭力、高品質、可靠的晶圓處理產品套件，符合半導體製造商的要求。

二、巨觀型人工智慧檢測產品：已商業化，持續提供客戶支援，以充分利用人工智慧演算法的功能。

三、微型人工智慧檢測產品：處於研發／原型設計階段，已開發出產品的許多關鍵元件，微型檢測可作為實驗室產品或在EMU既有的自動化平台上使用。

EMU計畫開發新型的低成本前端機器人，並完成商業化，以滿足矽和化合物半導體製造商的未來需求。該公司正尋求和台灣夥伴合作，提供能滿足下列重要領域的設備：

- 高產出率晶圓揀選機
- 用於製程和計量的前端模組
- 新一代AI微檢站核心自動化元件



David Hyland / 工程學士 (BEng) 執行長 (CEO)

✉ david.hyland@emutech.com

☎ +44 (0) 1935 813 313 🖱 www.emutech.com

in www.linkedin.com/company/emu-technologies



KuasaSemi Ltd specialises in advanced semiconductor design solutions, with a focus on wide-bandgap technologies. The company's state-of-the-art software and comprehensive support enables engineers and designers to unlock the full potential of semiconductor design and drive transformative innovation.

Founded by a family of power electronics and software engineers, KuasaSemi Ltd is the first and only UK based TCAD company. The company is developing and commercialising software to aid in the design of emerging wide-bandgap (WBG) semiconductor devices. These devices are at the forefront of power electronics used in electrified transport and are a core building block of the world's electrical grid infrastructure.

The TCAD software helps semiconductor design engineers optimise device performance, reliability and yield by predicting device behaviour under different conditions. With its modern intuitive interface, users can effortlessly create semiconductor designs that seamlessly connect to every detail of the process.

KuasaSemi's TCAD software can simulate the behaviour of semiconductor devices at different levels of abstraction, thereby providing a comprehensive understanding of their physical behaviours.

This is a great benefit at the design stage, helping to identify and solve problems early in the development process and reduce the risk of costly and time-consuming redesigns. The TCAD tool has a focus on emerging materials such as Silicon Carbide (SiC) and Gallium Nitride (GaN).

Additional benefits of KuasaSemi's TCAD tool include; reducing the time and cost required for product development, by enabling designers to explore and optimise designs before fabrication; and helping semiconductor manufacturers improve the yield and performance of their devices, leading to higher-quality products and increased profitability.

KuasaSemi's TCAD tool will also support the development of new technologies and devices, opening-up new markets and opportunities for innovation in the semiconductor industry.



Michael Mawby Director & Co-founder, MEng, CEng

✉ michael.mawby@kuasasemi.com

☎ +44 (0) 7534 095 750 🖱 www.kuasasemi.com

in www.linkedin.com/company/kuasasemi



KuasaSemi Ltd 專門從事先進半導體設計解決方案，側重於寬能隙 (WBG) 技術。該公司提供最先進軟體和全面性支援，讓工程師和設計師能開啟半導體設計的所有潛能，驅動變革性創新。

KuasaSemi Ltd 由一個電力電子和軟體工程師家族創立，是第一家、也是唯一一家總部位於英國的科技電腦輔助設計 (TCAD) 公司。該公司正在開發軟體並將之商業化，以幫助設計新興寬能隙半導體裝置。這些裝置處於電氣化運輸的前哨，是全世界電網基礎建設的核心基礎要素。

該公司的 TCAD 軟體藉由預測裝置在不同狀況下的表現，幫助半導體設計工程師優化裝置的性能、可靠度和良率。透過軟體的現代直覺式介面，使用者可輕鬆創建半導體設計，無縫連接製程的所有細節。

KuasaSemi 的 TCAD 軟體可模擬半導體裝置在不同抽象層級的特性，進而全面了解其物理性質。這在設計階段是一個很棒的好處，有助於在早期開發過程找出並解決問題，降低昂貴且耗時的重新設計風險。該公司 TCAD 工具的關注重點，在於碳化矽 (SiC) 和氮化鎵 (GaN) 之類的新興材料。

KuasaSemi 的 TCAD 工具還有其他好處，包括：設計師能在製造前探索並優化設計，減少產品開發所需的時間和成本；幫助半導體製造商提升設備的良率和性能，進而帶來更高品質的產品，並改善盈利能力。

KuasaSemi 的 TCAD 工具未來也將支援新技術和設備的開發，為半導體業的創新開拓新市場和商機。



Michael Mawby / 工程碩士 (MEng) / 特許工程師 (CEng) 總監兼共同創辦人

✉ michael.mawby@kuasasemi.com

☎ +44 (0) 7534 095 750 🖱 www.kuasasemi.com

in www.linkedin.com/company/kuasasemi



microbritt

Microbritt is a micro-manufacturing service company that manufactures novel, bespoke, microscale products using a patented micromachining method 'micromilling' for companies serving the defence, semiconductors, automotive, photonics and healthcare industries.

A spinout company from Newcastle University, Microbritt was formed following years of research funded by ESPRC to exploit a novel micromachining 'micromilling' method established by adapting a subtractive CNC micromilling technology for use with brittle materials.

The technology is akin to 3D printing but subtractive down to microscale which allows complex shapes to be formed in brittle materials such as silicon, glass and graphite.

Microbritt can fabricate from scratch, or during post-processing, making it an attractive technology to foundries manufacturing high-value silicon/glass wafers.

Microbritt's micromilling technology offers significant advantages:

- Geometries can be formed which cannot, or are difficult to form, using conventional micro-manufacturing processes. Allowing novel designs to be realised
- No chipping or rough edges which are common issues with conventional chemical etching and allowing for defect-free geometries and high-quality microscale production
- Overcomes impossible post-processing of microscale chips and enables machining

through multiple layer types (stacks) - reducing time

- Rapid and easily reconfigurable technology which does not require tooling (photomasks), multiple instruments, and multiple process steps which supports rapid processing
- Less energy intensive, no harsh chemical production reducing the carbon footprint
- Hole drilling of manufactured microchips, taper-free, with no burring which can be used on sensitive layers where laser processing may cause damage due to heat or reflections. Large holes which can be produced with wafer thicknesses to 10 mm – used for vapor cell technologies

Microbritt's notable manufacturing partners include IMEC, Fraunhofer IMM and INEX Microtechnology. Processed Si wafers manufactured in Taiwan are also received which require the company's unique capabilities. Microbritt is keen to collaborate directly with Taiwanese foundries to complement their existing activities.

Microbritt is currently developing an AI system to automate wafer processing to allow higher through-put and is seeking collaboration partners.



Dr Carl Dale CEO

✉ carl.dale@microbritt.com

☎ +44 (0) 7849 432 645 🖱 www.microbritt.com

in www.linkedin.com/company/microbritt



microbritt

Microbritt是一家微型製造服務公司，採用擁有專利的微製程方法「微銑削 (micromilling)」，為國防、半導體、汽車、光子學和醫療保健產業的企業客戶，製造客製化的新穎微型產品。

Microbritt是英國新堡大學 (Newcastle University) 的衍生企業，在接受工程與物理科學研究委員會 (EPSRC) 多年資助研究後所成立，旨在將一種減材電腦數控 (CNC) 微銑削技術加以改進，進而建立新穎的微製程方法「微銑削」，並將之應用於脆性材料 (brittle materials) 上。

該技術類似3D列印，但縮小至微尺度，使矽、玻璃、石墨等脆性材料形成複雜的形狀。

Microbritt有能力從一開始就進行製造，也可在後製程階段展開製造。對於製造高價值矽／玻璃晶圓的半導體製造廠來說，這是深具吸引力的技術。

Microbritt的微銑削技術具有下列顯著優勢：

- 塑造無法或難以利用傳統微製造程序形成的幾何形狀，讓新穎的設計得以實現。
- 沒有傳統化學蝕刻常見的邊緣碎裂或粗糙問題，能進行無瑕幾何形狀和高品質微尺度生產。
- 克服微型晶片所不可能做到的後期處理，並可透過多層型態 (堆疊) 進行機械加工，同時縮短時間。

- 快速且易於重組的技術，不需要工具 (光罩)、多種儀器和多重程序步驟，支援快速製程。
- 能源密集度較低，不會產生刺激性化學品，減少碳足跡。
- 在完成製造的微晶片上鑽孔，不會產生錐度，也沒有毛刺，可用於雷射製程中可能因熱或反射而造成損壞的敏感層。可使用厚度達10公釐 (mm) 的晶圓製造大孔，能應用於蒸汽室 (vapor cell) 技術。

Microbritt擁有不少知名的製造合作夥伴，包括比利時微電子研究中心 (IMEC)、德國Fraunhofer微工程與微系統研究院 (Fraunhofer IMM)、英國INEX微技術 (INEX Microtechnology) 公司等。Microbritt也收到台灣加工矽晶圓廠的合作邀請，因為須借重該公司的獨有能力。Microbritt渴望和台灣晶圓製造商直接合作，以充實既有業務。

Microbritt正致力開發晶圓製程自動化的人工智慧 (AI) 系統，以提高產能，目前正在尋找合作夥伴。



Dr Carl Dale 博士 執行長 (CEO)

✉ carl.dale@microbritt.com

☎ +44 (0) 7849 432 645 🖱 www.microbritt.com

in www.linkedin.com/company/microbritt



Paragraf is the first company in the world to mass produce graphene-based electronic devices using standard semiconductor processes.

From a Cambridge University spinout startup in 2017, Paragraf has grown to employ a team of over 130 experts and holds over 100 patents.

The company has experienced rapid growth culminating in the opening of its graphene device foundry in 2023, enabling high volume product manufacturing. Paragraf has continued to strengthen its position and expand its footprint into the USA with the recent acquisition of graphene biosensor leader Cardea Bio.

The company's patented contamination-free deposition technology delivers game-changing opportunities for the commercialisation of graphene by enabling the manufacture of high-purity 2D graphene sheets at scale.

Utilising unique, silicon-compatible, wafer-scale processes, Paragraf can seamlessly integrate graphene into ready to use products that can be quickly deployed by customers and partners to support the advancement and performance of existing, new and emerging technologies.

Products include:

- High-performance magnetic sensors for current sensing and position sensing which deliver higher sensitivity and superior noise tolerance in application areas such as automotive, automation and consumer
- Biosensors which deliver faster time to result, lower test costs and reduce sample preparation in industries such as agri-tech and healthcare

Paragraf is working with technology leaders to bring the benefits of graphene and other 3D materials to leading edge applications such as solid-state devices.

The company is committed to materially transforming electronics through the development of high-purity graphene products that will facilitate massive improvements in the performance of technologies across all aspects of life.



Dr Thomas Wilson Chief Commercial Officer

✉ t.wilson@paragraf.com

☎ +44 (0) 7554 174 504 🖱 www.paragraf.com

in www.linkedin.com/company/paragrafltd



是全球第一家使用標準半導體製程量產石墨烯基電子裝置的公司。

Paragraf自2017年從劍橋大學 (University of Cambridge) 分拆獨立成為新創公司後，一路成長茁壯，如今擁有逾130位專家組成的團隊，並擁有逾100項專利。

Paragraf經歷快速成長期後，於2023年開設自家的石墨烯裝置製造廠，得以自行大量製造產品。該公司持續強化其地位，不久前購併石墨烯生物感測器龍頭Cardea Bio，將業務版圖擴張到美國。

Paragraf擁有獲得專利的無污染沉積技術，透過大規模製造高純度2D石墨烯片，為石墨烯商業化帶來顛覆遊戲規則的機會。

Paragraf利用獨家矽相容晶圓級製程，能將石墨烯無縫整合到客戶和合作夥伴可快速部署的即用型產品中，協助既有新興技術的精進和性能。

該公司的產品包括：

- 高效能磁性感測器：用於電流檢測和位置感測，為汽車、自動化和消費電子等應用領域，提供更高的靈敏度和更卓越的雜訊耐受性。
- 生物感測器：可加快獲得結果的時間，降低測試成本，並減少農業科技 (agri-tech) 和醫療保健等產業的樣品製備。

Paragraf正和多家技術領導者合作，將石墨烯和其他3D材料的優勢，帶到固態元件等尖端應用中。

該公司致力透過高純度石墨烯產品的開發，為電子產品帶來實質改變，有助於大規模提升生活中各層面的技術性能。



Dr Thomas Wilson 博士 商務長 (Chief Commercial Officer)

✉ t.wilson@paragraf.com

☎ +44 (0) 7554 174 504 🖱 www.paragraf.com

in www.linkedin.com/company/paragrafltd



The world leader in flexible semiconductors

Headquartered in Cambridge (UK), Pragmatic has developed the world's fastest and most sustainable semiconductor manufacturing process. Pragmatic operates a 200mm and 300mm production-line in the UK and has developed a modular, small-footprint (600m²) modular production-line that can be installed and operated anywhere in the world.

Pragmatic's ultra-low-cost, flexible integrated circuit technology makes it quick and easy to embed intelligence almost anywhere. With rapid cycle times (days) that substantially accelerate time to market, Pragmatic's foundry provides high-volume fabrication at a fraction of the cost of silicon, and with significantly lower environmental impact.

Example applications include radio frequency identification (RFID) and near field communications (NFC), allowing everyday objects to interact with their environment and be given unique digital identities. This brings game-changing benefits to the entire product lifecycle, including inventory reduction, traceability, counterfeit detection, proof of provenance, and customer interaction.

Pragmatic's technology is a key enabler for circular economy and supporting sustainability goals, preserving valuable resources by allowing organisations to effectively reduce, recycle and reuse products and materials.



Dr Richard Price CTO

✉ richard@pragmaticsemi.com

☎ +44 (0) 7764 940 189 🖱 www.pragmaticsemi.com

in www.linkedin.com/company/pragmatic-semiconductor



總部位於英國劍橋 (Cambridge) 的Pragmatic，開發出世界上最快且最具永續性的半導體製程。該公司在英國經營一條200公釐 (8吋) 和300公釐 (12吋) 的產線，並開發一條佔地不大 (600平方公尺) 的模組化生產線，可在世界任何地方進行安裝和操作。

Pragmatic憑藉超低成本的軟性積體電路技術，能快速輕鬆地將智慧 (intelligence) 嵌入幾乎任何地點。由於快速的週期 (天數) 大大加速上市時間，該公司的晶圓廠能以矽價格的一小部分，提供批量製造服務，並大幅減少對環境的衝擊。

該公司技術的示例應用包括無線射頻辨識 (RFID) 和近場通訊 (NFC)，讓日常物體能和周遭環境互動，並被賦予獨一無二的數位身分識別。這為整個產品生命週期帶來顛覆遊戲規則的好處，包括庫存降低、可追溯性、假冒檢測 (counterfeit detection)、來源證明和客戶互動等。

Pragmatic的技術是循環經濟的一大關鍵推動力，支持永續發展目標，讓各機構透過有效的產品和材料減量、回收和再利用，保護珍貴的資源。



Dr Richard Price 博士 技術長 (CTO)

✉ richard@pragmaticsemi.com

☎ +44 (0) 7764 940 189 🖱 www.pragmaticsemi.com

in www.linkedin.com/company/pragmatic-semiconductor

Quantopticon specialises in cutting-edge simulation software products dedicated to modelling quantum photonics systems. The company's flagship product, Quantillion, is the world's first and only software platform for rapid and cost-effective design of quantum-photonic components, devices and integrated circuits.

Today, designing quantum-photonic components, devices and circuits is tremendously arduous, time-consuming and cost-intensive. Due to the lack of purpose-built software design tools to guide the process, quantum-photonic engineers must repeatedly build, test and iterate on physical prototypes, until they eventually meet the desired specifications.

Quantopticon has overcome this problem by creating a state-of-the-art design and optimisation platform for quantum-photonic hardware. Quantillion eliminates the need to carry out multiple trial-and-error experiments by replacing them with accurate and realistic simulations.

Developed in-house from first principles over the course of 20 years by world-leading multidisciplinary experts, Quantillion is a ground-breaking proprietary algorithm, uniquely capable of determining the optimal parameters and materials required to quickly and efficiently build high-quality, peak-performant components for photonic quantum computers, as well as terrestrial and satellite-borne quantum communication systems. The algorithm has been thoroughly validated and the results have been published in numerous articles in top peer-reviewed journals.

Popular simulation software packages, such as Lumerical and QuTiP, are being utilised to design quantum-photonic devices. However, these simulation engines employ physical models which are patchy and inadequate for this purpose. Quantillion

overcomes these shortcomings by providing a complete and faithful picture of the underlying quantum-electromagnetic processes occurring within these devices, making it the only extant piece of software capable of predicting and optimising the performance of quantum-photonic devices. Operating at the physical layer of the design stack, the software suite is equipped with a library of quantum systems, photonic structure geometries and other user-selectable features, which empowers hardware engineers to identify the right parameters of their device first-time, simply by running a simulation.

Quantillion slashes component development costs by up to \$250,000 and timelines by 24 weeks and accelerates time to market for commercial users. Fully taking fabrication tolerances into account, the software ensures consistent and reliable peak device performance, thus unlocking the path to high-volume manufacturing and relegating 'hero devices' to the past.

Alongside the European Space Agency, Quantopticon is currently designing single-photon sources with ultra-high purity and indistinguishability for the European network of quantum encryption satellites. These next-generation single-photon sources will close existing security loopholes in quantum communications and considerably increase data transmission rates along these channels.



Dr Mirella Koleva CEO

✉ mirella@quantopticon.co.uk

☎ +44 (0) 7989 144 626 🖱 www.quantopticon.co.uk

🌐 www.linkedin.com/company/quantopticon-ltd

Quantopticon專長開發專用於量子光學系統建模的尖端模擬軟體產品。該公司的旗艦產品Quantillion是全世界第一個、也是唯一一個以快速且具經濟效益的方式，設計量子光學元件、裝置和積體電路的軟體平台。

Quantillion由世界領先的多專業 (multidisciplinary) 專家從基礎原理著手，經過長達20年的內部開發。這是一套突破性的專有演算法，能確定所需的最佳參數和材料，俾能快速且有效建構用於光子量子電腦，以及地面和星載量子通訊系統的高品質、高性能元件。該演算法已通過徹底驗證，並在由同儕審閱的頂尖期刊發表多篇研究成果文章。

Lumerical和QuTiP之類的熱門模擬軟體套件，目前被用來設計量子光學裝置。但這些模擬引擎所採用的物理模型並不完整，且不足以達到所希望的目的。針對裝置內所發生的潛在量子電磁過程，Quantillion提供完整且如實的模擬，以克服其他模擬軟體套件的前述缺點，因而成為唯一能預測並優化量子光學裝置性能的既有軟體。Quantillion運作於設計堆疊 (design stack) 的實體層 (physical layer)，並配備量子系統、光子結構幾何，以及其他可由用戶選擇的功能庫，因此硬體工程師只需使用軟體進行模擬，就可在第一時間找出其裝置的正確參數。

Quantillion將元件開發成本削減多達25萬美元，時程也減少24週，並加速供商業用戶使用的上市進度。該軟體將製造誤差充分納入考量，確保裝置能有始終如一且可靠的峰值表現，進而開啟批量生產的大門。

在歐洲太空總署 (European Space Agency) 的合作下，Quantopticon目前正在為歐洲量子加密衛星網路，設計具有超高純度和不可區分性的單光子源 (single-photon source)。這些新一代的單光子源將填補量子通訊中的既有安全漏洞，並大大提高通道的資料傳輸速率。



Dr Mirella Koleva 博士 執行長 (CEO)

✉ mirella@quantopticon.co.uk

☎ +44 (0) 7989 144 626 🖱 www.quantopticon.co.uk

in www.linkedin.com/company/quantopticon-ltd



Quantum Dice seeks to provide trusted and secure randomness, leveraging the unique properties of quantum systems along with its patented DISC protocol.

Quantum Dice aims to protect a connected future by harnessing the fundamental quantum properties of light to enable secure encryption. Leveraging its patented source-device independent self-certification (DISC) protocol, Quantum Dice is developing the world's first compact, high-speed and continuously self-certifying quantum random number generator.

The technology is suitable for a wide range of applications ranging from protecting terrestrial networks to providing quantum-secure entropy for satellite and IoT systems.

Founded in April 2020, Quantum Dice is an award-winning venture-backed spinout from Oxford University's world-renowned quantum optics laboratory where the architecture for the innovative quantum source of entropy was originally invented.

Quantum Dice offers a source-device independent, self-certifying random number generator, a device that leverages quantum processes to generate verifiably random keys.

The patented DISC architecture assures the user a minimum amount of randomness that can be guaranteed even if the source of the device is maliciously influenced. The protocol considers imperfections of the source of randomness in the device; fluctuations are accounted for when assessing the amount of quantum randomness that can be extracted from the on-chip laser source.

This allows for continuous assessment of the device's performance, preventing silent failure and protecting against external attacks.

Quantum Dice is active in the telecommunication, banking and space sectors but is seeking to exploit IoT opportunities by miniaturising the technology.

The company is keen to collaborate with Taiwanese partners with expertise in advanced manufacturing processes for photonic integrated circuit fabrication using complementary CMOS.



Marko von der Leyen CTO DPhil

✉ marko.leyen@quantum-dice.com

☎ +44 (0) 7360 105 721 🖱 www.quantum-dice.com

in www.linkedin.com/company/quantum-dice



Quantum Dice希望利用量子系統的獨特屬性和該公司擁有專利的DISC傳輸協定，提供可靠且安全的隨機性 (randomness)。

Quantum Dice的目標，是藉由控制光的基本量子特性來實現安全加密，進而保障網路連結的未來。該公司正利用其擁有專利的源裝置獨立自我驗證 (source-device independent self-certification，簡稱DISC) 協定，開發全世界第一款小巧、高速且能連續自我驗證的量子亂數生成器。

該技術適用於相當廣泛的應用，包括保護地面網路、為衛星和物聯網 (IoT) 系統提供量子安全熵 (secure entropy) 等。

Quantum Dice成立於2020年4月，是世界聞名的牛津大學 (University of Oxford) 量子光學實驗室的衍生企業，並獲得優質創投機構的支持。牛津量子光學實驗室是創新量子熵源架構的原創地。

Quantum Dice所提供的源裝置獨立自我驗證亂數生成器，利用量子過程生成可驗證的隨機密鑰。擁有專利的DISC架構，可確保用戶使用數量最少的亂數，即使在裝置源受到惡意影響的情況下，也能保證安全。該傳輸協定會考量裝置中亂數來源的缺陷；在評估可從片上雷射源提取的量子亂數數量時，會考量擾動問題，因此能持續評估裝置的性能狀況，以防止隱藏失效，並防範外部攻擊。

Quantum Dice目前活躍於電信、銀行和太空等產業，但也正尋求利用小型化技術來開發物聯網 (IoT) 商機。該公司渴望和擁有利用互補式金屬氧化物半導體 (CMOS) 技術進行光子積體電路先進製程專業知識的台灣夥伴合作。



Marko von der Leyen 技術長 (CTO)

✉ marko.leyen@quantum-dice.com

☎ +44 (0) 7360 105 721 🖱 www.quantum-dice.com

in www.linkedin.com/company/quantum-dice



Quantum Science is a leading semiconductor innovation company that specialises in the development and commercialisation of quantum dots (QDs), nanomaterials, and technologies for infrared imaging and sensing applications.

The company's cutting-edge INFIQ® QD products and technologies have been successfully launched commercially at Merck Sigma and abcr and have been widely adopted by several leading short-wave infrared (SWIR) businesses.

The company's team consists of world-leading experts in QD synthesis and scale-up, nanocrystal and nanoparticle surface engineering, ink formulation, thin-film processing, and QD semiconductor device engineering.

Quantum Science develops colloidal stable nanocrystals called INFIQ® QDs. These tiny nanocrystals, typically ranging from 2-10 nm, demonstrate energy band tunability, enabling their energy levels to be fine-tuned through wet chemistry to efficiently absorb and emit light across the entire visible and infrared range. This provides an effective approach to design a wide range of infrared wavelengths for versatile infrared imaging and sensing applications. The technology can be solution processed and integrated with complementary metal-oxide-semiconductor monolithically, enabling high-performance infrared sensing and imaging at significantly lower costs (normally 10-1000 times lower) compared to conventional technologies such as InGaAs.

Quantum Science pushes the boundaries of innovation further by producing QD ink through surface engineering. The QD ink allows for single-layer deposition, as opposed to the traditional 16 layers of QD processing, greatly simplifying the manufacturing process and enhancing yield and efficiency.

In response to potential regulatory risks associated with the use of heavy-metal lead, Quantum Science develops SWIR lead-free QDs that meet the demands of large businesses and deliver market-leading performance.

The company benefits from a strong intellectual property portfolio and possesses full development capacity, from materials to QD devices. Quantum Science is equipped for QD synthesis, scale-up, surface functionalisation, and device fabrication, and collaborates with sensor design houses, foundries, and large semiconductor businesses to integrate its QD devices with ROIC (Readout Integrated Circuit) to produce SWIR QD sensors and cameras used in infrared imaging and sensing applications.

Taiwan's reputation for semiconductor manufacturing makes it an attractive partner for Quantum Science which is looking to accelerate the development of new products or services.



Takami Kawakami Director of Global Business Development BEE

✉ takami.kawakami@qscis.com

☎ +44 (0) 7493 762 031 🖱 www.quantumscis.com

in www.linkedin.com/company/quantum-science-ltd



Quantum Science是一家領先的半導體創新公司，專門從事量子點 (QD)、奈米材料，以及紅外成像與感測應用技術的開發與商業化。

Quantum Science的INFIQ®尖端量子點產品和技術，已在默克西格瑪 (Merck Sigma) 和abcrc成功商用，並獲得多家領先的短波紅外線 (SWIR) 企業廣泛採用。

Quantum Science的團隊，由世界領先的量子點合成與放大、奈米晶體及奈米顆粒表面工程、油墨配方、薄膜加工和量子點半導體裝置工程等領域的專家組成。

Quantum Science開發名為INFIQ®量子點的膠體穩定奈米晶體。這些微小的奈米晶體通常在2至10奈米之間，具有能帶 (energy band) 可調性的特性，其能階 (energy level) 可透過濕化學方式進行微調，因而能在整個可見光和紅外線範圍內有效吸收和發射光線。這為各種紅外線波長的設計提供一種有效方法，適用於各種紅外線成像和感測應用。該技術可進行溶液加工，並和互補式金屬氧化物半導體進行單晶整合，因此能以顯著低於砷化銦鎵 (InGaAs) 等傳統技術的成本 (通常僅為十分之一至千分之一)，實現高性能紅外線感測和成像。

該公司利用表面工程 (surface engineering) 生產量子點墨水，進一步突破創新界限。相較於傳統的16層量子點處理方式，量子點墨水允許單層沉積，大大簡化製造流程，並提高產量和效率。

針對使用重金屬鉛的潛在監管風險，Quantum Science開發出SWIR無鉛量子點，以滿足大型企業的需求，並提供市場領先的性能。

Quantum Science不但受益於強大的知識財產組合，還擁有從材料到量子點裝置的全面性開發能力。該公司具備量子點合成、放大、表面功能化 (surface functionalisation) 和半導體元件製造的能力，並與感測器設計商、晶圓代工廠和大型半導體企業合作，將其量子點裝置與讀出積體電路 (ROIC) 進行整合，生產用於紅外線成像和感測應用的SWIR量子點感測器和攝影機。

台灣在半導體製造方面素享盛譽，對Quantum Science而言是深具吸引力的合作夥伴。Quantum Science正尋求加速開發新產品與服務。

針對使用重金屬鉛的潛在監管風險，Quantum Science開發出SWIR無鉛量子點



Takami Kawakami / 電機工程學士

全球業務發展總監 (Director of Global Business Development)

✉ takami.kawakami@qscis.com

☎ +44 (0) 7493 762 031 🖱 www.quantumscis.com

in www.linkedin.com/company/quantum-science-ltd



ULTRARAM™ is an ultra-efficient revolutionary quantum powered universal computer memory.

QuInAs Technology is a spinout from Lancaster University which has been formed to exploit the patented memory technology, ULTRARAM™ that successfully combines the attributes of universal memory. The company is a beneficiary of Innovate UK's prestigious pre-accelerator ICURe programme for researchers seeking to commercialise technology.

The \$165bn pa memory market is dominated by dynamic random-access memory (DRAM, \$100bn) and NAND flash (\$65bn). Flash is non-volatile, retaining data when unpowered, but is slow and has poor program/erase cycling endurance. In contrast, DRAM is fast with excellent endurance, but it is volatile, and requires data to be constantly refreshed. For decades there has been a quest for a memory that combines all these advantages without the disadvantages i.e. a memory that is fast and non-volatile, with high endurance and ultra-low switching energies otherwise known as 'universal memory'.

ULTRARAM™ combines the non-volatility of flash, with a performance that is expected to exceed that of DRAM.

The technology is a charge-based memory that is flash-like in its operation. The logic state of the memory (0 or 1) is determined by the presence or absence of charge on a floating gate and readout occurs by measuring the current through an underlying channel.

The novelty underpinning ULTRARAM™ is its use

of a quantum-mechanical process called resonant tunnelling to control the movement of electrons in the device.

Unlike DRAM and flash, which are silicon based, ULTRARAM™ uses III-V compound semiconductors. This allows engineering of the memories' electrical properties to exploit the underlying physics to full effect, whilst also being capable of volume manufacture using established processes in the compound semiconductor and silicon industries.

The 6.1-angstrom family of semiconductors (GaSb, InAs and AlSb) are used to create a flash-like floating-gate memory. However, unlike flash, which uses a highly resistive oxide barrier to retain charge in the floating gate, ULTRARAM™ uses atomically thin layers of InAs/AlSb to create a triple-barrier resonant-tunnelling (TBRT) charge-confining structure. It is this mechanism that gives ULTRARAM™ its remarkable properties.

ULTRARAM™ has a retention time of >1,000 years, endurance >10⁷ (with no degradation), switching energy 100x lower than DRAM and 1,000x lower than flash (at equivalent node) and when fully scaled is expected to switch 10x faster than DRAM.

QuInAs Technology is seeking to secure collaborations and partnerships for R&D and manufacturing, specifically fabrication partners for test-chips and standard/advanced packaging technologies such as chiplets.



James Ashforth-Pook CEO BSc Electronics & Communications Engineering

✉ jamesap@quinas.tech

☎ +44 (0) 7775 578 880 🖱 www.quinas.tech

in www.linkedin.com/company/quinas

ULTRARAM™是一款超高效的革命性量子驅動通用型電腦記憶體。

QuInAs Technology是英國蘭卡斯特大學 (Lancaster University) 為了開發專利記憶體技術ULTRARAM™所成立的衍生企業。該技術成功結合通用型記憶體的各種屬性。英國創新局 (Innovate UK) 旗下素享盛譽的前導加速器「ICURe計畫 (ICURe Programme)」致力協助研究人員將技術商業化，QuInAs Technology即是其輔導對象之一。

規模達1,650億美元的記憶體市場，由動態隨機存取記憶體 (DRAM，市場規模1,000億美元) 和 NAND快閃記憶體 (NAND flash，650億美元) 占主導地位。快閃記憶體是非揮發性記憶體，斷電時能保留資料，但速度較慢且讀寫循環耐用性較差。反觀DRAM速度快且耐用性佳，但資料容易消失，必須不斷重新整理 (refresh)。數十年來，人們一直在尋找一種具備前述所有優點、卻毫無上述缺點的記憶體，也就是快速、非揮發性、耐用性高且超低功耗的記憶體，亦稱為「通用型記憶體 (universal memory)」。

ULTRARAM™結合快閃記憶體的非揮發性，以及預料能超越DRAM的性能。

這是一種以電荷為基礎的記憶體，其運作方式類似於快閃記憶體。記憶體的邏輯狀態 (0或1) 由浮動閘極 (floating gate) 是否存在電荷來決定，並透過測量流經底層通道的電流來進行讀取。

ULTRARAM™的獨到之處，在於利用名為共振穿隧 (resonant tunnelling) 的量子力學過程，控制裝置的電子運動。

不同於以矽為基礎的DRAM和快閃記憶體，ULTRARAM™使用三五族化合物半導體 (III-V compound semiconductors)，讓記憶體的電特性工程能充分利用物理原理，同時還能採用化合物半導體和矽產業的既有製程進行批量製造。

包括銻化銻 (GaSb)、砷化銻 (InAs)、銻化鋁 (AlSb) 在內的6.1埃系列半導體，被用於創建類似快閃記憶體的浮動閘極記憶體。然而，不同於快閃記憶體利用高電阻氧化物勢壘將電荷保留在浮動閘極內，ULTRARAM™使用原子級的砷化銻／銻化鋁薄層，創建三重勢壘共振穿隧 (TBRT) 電荷限制結構。此機制賦予ULTRARAM™卓越的性能。

ULTRARAM™的保存期限逾1,000年；耐用度超越107次 (在未劣化情況下)；功耗率較DRAM低100倍，較快閃記憶體低1,000倍 (相等節點情況下)；全速運作時，預料可較DRAM快10倍。

QuInAs Technology正尋求研發和製造方面的合作機會和夥伴，尤其是測試晶片，以及小晶片 (chiplet) 之類的標準／先進封裝技術專業半導體製造夥伴。



James Ashforth-Pook 共同創辦人兼執行長

電子與通訊工程 (Electronics & Communications Engineering) 理學士

✉ jamesap@quinas.tech

☎ +44 (0) 7775 578 880 🖱 www.quinas.tech

🌐 www.linkedin.com/company/quinas



Established in 1962 Thermco Systems is the original pioneer of diffusion furnaces and a market-leader in semiconductors serving over 400 global customers in R&D, automotive, communications, consumer electronics, power and data processing industries.

From facilities in the UK, USA and China the company supplies a range of systems for current, emerging and new technologies. In-house design of all mechanical, electrical, electronic systems and software development ensures systems stay at the cutting edge of processing technology. Obsolescence and items affected by supply chain deficiencies are designed out ensuring true lifetime support. A new division, Thermco SiC coatings was established in 2022 to accommodate the growing demand in SiC coatings.

Thermco Systems offers unique solutions that support a wide range of substrate sizes up to 300mm and materials such as silicon, SiC, III-V and other novel materials:

1. Thermco has the largest installed base of horizontal diffusion furnaces in the world. With extensive experience and process know-how the company ensures efficient thermal processing systems design, offering maximum uptime, fast throughput and lowest cost of ownership. Solutions offer a full range of characterised atmospheric and LPCVD deposition processes, which can be adapted for use in new and emerging markets

2. The EpiPro family of systems or epitaxial growth solutions CSD, offer high throughput volume processing of silicon and SiC wafers used primarily in the emerging power device sectors

3. T-Clean offers a full range of manual and fully automated systems to support semiconductor cleaning, chemical etching, lift off, electroless plating and RST drier processes and provides leading edge equipment for gas and chemical delivery, distribution and abatement systems for the storage and safe delivery of bulk chemicals and gases

4. Chemical Handling Equipment: gases, chemicals and other materials employed in the manufacturing process of semiconductors including the storage, delivery and recovery of the materials

The company is active in R & D and open for collaboration. Current projects include:

- Reducing QSS charge on the surface of the wafer and controlling native oxide growth
- Prototyping SiC coatings and high temperature thermal treatment, 2000C to 3000C, systems to control native oxide growth, GaN deposition and GaN diffusion



Iain McGregor Business Director

✉ imcgregor@thermcossystems.com

☎ +44 (0) 7795 973 106 🖱 www.thermcossystems.com

in www.linkedin.com/company/thermcossystems



Thermco Systems成立於1962年，是擴散爐 (diffusion furnace) 的原創先驅，也是半導體市場領導者之一，為全球逾400家研發、汽車、通訊、消費電子、電力和資料處理等產業的客戶提供服務。

Thermco Systems透過位於英、美、中三國的工廠，針對既有、新興和嶄新的技術，提供一系列的系統。該公司由內部團隊負責所有的機械、電氣、電子系統和軟體開發設計，確保系統始終採用最尖端的製程技術。透過設計排除過時和受供應鏈吃緊影響的品項，確保享有真正的終身支援。該公司在2022年成立全新部門Thermco SiC Coatings，以滿足市場對碳化矽 (SiC) 塗層不斷成長的需求。

Thermco Systems提供獨到的解決方案，支援最高達300公釐 (即12吋) 的多種基板尺寸，以及碳化矽、三五族半導體 (III-V semiconductors) 和其他新型材料之類的物料：

一、Thermco Systems擁有全球最大的臥式擴散爐安裝基礎。該公司憑藉豐富的經驗和製程知識，確保提供高效的熱處理系統設計、最持久的上線時間 (uptime)、快速的生產能力和最低的擁有成本。其解決方案提供全方位的特有常壓和低壓化學氣相沉積 (LPCVD) 製程，可適用於嶄新和新興市場。

二、該公司的EpiPro系列系統，是使用化學溶液沉積 (CSD) 的磊晶成長 (epitaxial growth) 解決方案，為主要用於新興功率器件 (power device) 領域的矽和碳化矽晶圓，提供高產能的批量製程。

三、該公司的T-Clean提供全系列手動和全自動系統，以支援半導體清洗、化學蝕刻、掀離 (lift off)、無電鍍 (electroless plating) 和RST乾燥製程，並針對散裝化學品和氣體的儲存和安全輸送，提供氣體和化學品輸送、分配和廢氣排放系統的尖端設備。

四、化學品處理設備：處理半導體製程中使用的氣體、化學品和其他材料，包括材料的儲存、輸送和回收在內。

Thermco Systems積極從事研發，並對合作抱持開放態度。目前正在進行的計畫包括：

- 減少晶圓表面的QSS電荷，並控制天然氧化物生長。
- 碳化矽塗層和攝氏2,000至3,000度高溫熱處理的原型製作，系統可控制天然氧化物生長、氮化鎵 (GaN) 沉積和氮化鎵擴散。



Iain McGregor 業務總監

✉ imcgregor@thermcossystems.com

☎ +44 (0) 7795 973 106 🖱 www.thermcossystems.com

🌐 www.linkedin.com/company/thermcossystems

Leading the visit



Louise Hooker

Global Business Innovation Programme Lead

Louise has worked on the Global Business Innovation Programmes since 2018 and has successfully led twelve Global Business Innovation Programmes to target countries and supported nearly 200 companies to achieve their international ambitions. Louise is a qualified barrister and solicitor and previously specialised in criminal law and dispute resolution.

✉ louise.hooker@innovateukedge.ukri.org

☎ +44 (0)7850 300 575

🔗 www.innovateukedge.ukri.org

in www.linkedin.com/in/louisehooker



Elizabeth Stanway

Global Business Innovation Programme Specialist

Elizabeth provides specialist support and preparation to UK businesses with international ambitions. With a focus on Asian markets, she has assisted over 140 companies across 10 Global Business Innovation Programmes.

✉ elizabeth.stanway@innovateukedge.ukri.org

☎ +44 (0)7467 762 823

🔗 www.innovateukedge.ukri.org

in www.linkedin.com/in/elizabeth-stanway



Dr Iain Mauchline

Innovation Lead – Electronics, Sensors & Photonics
Innovate UK

Iain joined Innovate UK in October 2021 to expand Innovate UK's work in electronics, sensors and photonics as a key enabling and cross-cutting technology and develop competition themes and application areas. His role involves helping to build collaborations between industry, managing competitions and overseeing programme delivery.

After obtaining an Electrical & Electronic Engineering degree and PhD specialising in glass integrated optics he joined the research staff at the University of Strathclyde before joining OptoSci, a photonics systems and sensors SME as Engineering Director.

His expertise covers many areas including design and manufacture of systems for photonics education, training and research, and fibre optic sensing systems for harsh and industrial environments. He has successfully commercialised over twenty major product lines.

✉ Iain.Mauchline@iuk.ukri.org

☎ +44 (0)7880 055 297

🔗 www.innovateukedge.ukri.org

in www.linkedin.com/in/iain-mauchline



Dr Andy G Sellars FIET

Strategic Development Director and Founder, CSA Catapult

Andy developed and submitted the business case and strategy for the Compound Semiconductor Applications Catapult to HM Treasury in 2015 and led the set-up of the £50 million centre in 2017. He has represented the Catapult during roundtable discussions with the Prime Minister and is regularly called as an expert witness to provide evidence to Parliamentary committees, most recently on the National Security and Investment Act, the Telecom Security Act and the Parliamentary committee on semiconductors.

Andy chairs the Catapult Network Research and Technology Group and is a leading member of the Strategic Advisory Board of the EPSRC Future Compound Semiconductor Manufacturing Hub: The Future Compound Semiconductor Manufacturing Hub (compoundsemiconductorhub.org)

Previously at Innovate UK he delivered £15 million of strategic investments in electronics, smart materials and compound semiconductors. His early career was spent leading R&D teams with Rolls Royce, Spirent PLC and Abbott Diagnostics, and he was prime consultant on film and TV lighting for James Bond and Sky News.

Andy holds an Executive MBA from Glasgow University, a research doctorate from Strathclyde University and is a Fellow of the IET.

✉ andy.sellars@csa.catapult.org.uk

☎ +44 7931 533 855

🔗 www.csa.catapult.org.uk

in www.linkedin.com/in/andygsellars

訪問團領隊人員



Louise Hooker / 全球商業創新計畫負責人

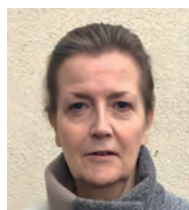
Louise自2018年起，致力推動全球商業創新計畫 (Global Business Innovation Programme)，成功領導12項針對特定目標國家的全球商業創新計畫，並支持近200家企業實現其國際抱負。Louise擁有大律師 (solicitor) 和事務律師 (solicitor) 資格，以往專門從事刑事和爭端解決業務。

✉ louise.hooker@innovateukedge.ukri.org

☎ +44 (0)7850 300 575

🌐 www.innovateukedge.ukri.org

in www.linkedin.com/in/louisehooker



Elizabeth Stanway / 全球商業創新計畫專員

Elizabeth為有志進軍國際的英國企業提供專業的支援和準備。她專注於亞洲市場，曾在10項全球商業創新計畫中協助逾140家公司。

✉ elizabeth.stanway@innovateukedge.ukri.org

☎ +44 (0)7467 762 823

🌐 www.innovateukedge.ukri.org

in www.linkedin.com/in/elizabeth-stanway



Iain Mauchline博士

英國創新局

電子、感測器和光子學事務——創新負責人

Iain於2021年10月加入英國創新局，負責拓展該局在電子、感測器和光子學領域的工作，使之成為重要的致能 (enabling) 和跨領域技術，並負責開發競賽主題和應用領域。他的職責包括協助建立產業合作、主管各項競賽並監督計畫執行。

在獲得電機工程學位和專長玻璃整合光學 (glass integrated optics) 的博士後，Iain成為斯特拉斯克萊德大學 (University of Strathclyde) 研究人員，後來加入製造光子學系統與感測器的中小企業OptoSci，擔任工程總監一職。

他的專業知識涵蓋許多領域，包括設計並製造光子學教育、培訓和研究系統，以及針對惡劣和工業環境設計的光纖感測系統。他曾將逾20項主要產品線成功商業化。

✉ Iain.Mauchline@iuk.ukri.org

☎ +44 (0)7880 055 297

🔗 www.innovateukedge.ukri.org

in www.linkedin.com/in/iain-mauchline



Andy G Sellars博士／英國國際工程技術學會會員 (FIET) 化合物半導體應用創新中心 (CSA Catapult) 策略發展總 監兼創辦人

Andy於2015年將其為化合物半導體應用創新中心制定的業務論證 (business case) 與策略, 提交給英國財政部 (HM Treasury), 耗資5,000萬英鎊的該中心得以在2017年成立。Andy代表該中心參加英國首相主持的圓桌會議, 並定期以專家證人身分前往英國國會各委員會作證, 不久前曾針對《國家安全和投資法 (National Security and Investment Act)》、《電信安全法 (Telecom Security Act)》和半導體等議題, 前往國會委員會。

Andy是英國創新中心網絡 (Catapult Network) 研究和科技小組 (Research and Technology Group) 主席, 也是英國工程與物理科學研究委員會 (EPSRC) 未來化合物半導體製造中心 (Future Compound Semiconductor Manufacturing Hub) 策略諮詢委員會 (Strategic Advisory Board) 的主要成員, 請參見: The Future Compound Semiconductor Manufacturing Hub (compoundsemiconductorhub.org)。

他曾在英國創新局 (Innovate UK) 執行1,500萬英鎊的戰略投資案, 投資領域包括電子、智慧材料和化合物半導體。他的早期職業生涯曾加入勞斯萊斯 (Rolls Royce)、思博倫 (Spirent PLC) 和亞培診斷 (Abbott Diagnostics) 的頂尖研發團隊, 並曾擔任詹姆斯龐德 (James Bond) 電影和英國天空新聞台 (Sky News) 的首席燈光顧問。

Andy擁有英國格拉斯哥大學 (University of Glasgow) 高階工商管理碩士 (EMBA) 學位、斯特拉斯克萊德大學 (University of Strathclyde) 研究博士學位, 並且是英國國際工程技術學會 (IET) 會員。

✉ andy.sellars@csa.catapult.org.uk

☎ +44 7931 533 855

🖱 www.csa.catapult.org.uk

in www.linkedin.com/in/andygsellars

