Designing the Future of Additive Manufactured Electronics

Online Workshop Programme

Wednesday 21 April 2021
13:00 - 16:00 (UK)

Thursday 22 April 2021
13:00 - 16:00 (UK)

UKRI Engineering and Physical Sciences Research Council

Design for AM NETWORK

Contents

Welcome To Designing the Future of Additive Manufactured Electronics Workshop

Addressing the Key Challenges of the Future Adoption of Additive Manufacturing for Electronic Systems

The revolution in additive manufacturing is creating new opportunities for the manufacture of electronics products instead of standard surface mount assembly on printed circuit boards. The potential benefits include miniaturisation and improved performance through integration of the electronics within the structure of the component and truly flexible manufacturing for customisable products.

However, the performance, density and reliability of high-density multilayer boards and advanced packaging techniques are significantly more advanced than what has been demonstrated to date with Additive Manufacturing technologies. This Workshop aims to generate a greater understanding of the drivers and motivation that will facilitate multidisciplinary discussions, cross-fertilisation of ideas and drive future innovation in designing for the future of additive manufacturing for electronic systems.

This event provides an opportunity to listen to the latest advances in additive manufacturing for electronics from world renowned experts at the University of Leeds, The Manufacturing Technology Centre in the UK and from The University of Texas, El Paso. Case studies are also presented including additive manufacturing for space and wiring harness applications.

Based on this foundation of state of the art presentations, we will be asking attendees to contribute their views on the outstanding challenges and potential solutions to increasing the adoption of additive manufacturing for electronics systems.

We hope you enjoy this Online Workshop.

Dr Patrick Pradel

Lecturer in Product Industrial User-Centred Design
Digital Design and Fabrication Research Group
PI – EPSRC Design for AM Network

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Designing the Future of Additive Manufactured Electronics Workshop Agenda

Wednesday 21 April 2021

13:00 **Welcome and Introduction to DfAM Network and IMAPS-UK**

13:15 **Overview of Additive Manufacturing for Electronic Systems**
Dr Robert Kay, University of Leeds

14:00 **Latest Advances in Additive Manufacturing for Electronic Systems**
Naim Kapadia and Dr Farhan Khan, The Manufacturing Technology Centre

14:45 **Workshop Session**
What is needed now and into the future?

- Identify the grand challenges and rank them.
- Identify who is involved.
- Define the state of the art

16:00 **End of Day 1**

Thursday 22 April 2021

13:00 **Summary of Day 1 and Introduction to Day 2**

13:15 **Multi-Function Additive Manufacturing**
Professor Eric MacDonald – University of Texas, El Paso

14:00 **Case Study Presentations**

- Vittorio Tornielli and Maarten Van der Vorst – ESA
- Stephen Bennington – Q5D Technologies
- Jay Chandrappan – CSA Catapult

14:45 **Workshop Session**
What are the main challenges?
What areas need to be addressed through collaboration?

- Identify the areas where innovation will give the most benefit to the community
- Enable multidisciplinary collaboration
- Define where the UK is and what needs to be done to overcome roadblocks and barriers

15:45 **Outcomes and Summary**

16:00 **Close of Event**

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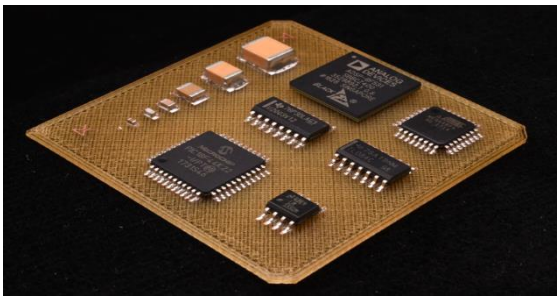
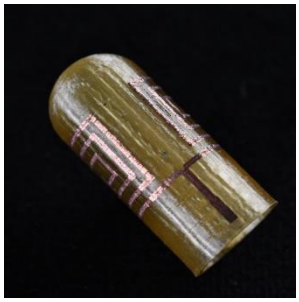
Overview of Additive Manufacturing for Electronic Systems

Dr Robert Kay, University of Leeds

Additive manufacturing also known as 3D printing has been forecasted to revolutionise the way we design and make products with ever increasing applications in industries such as medicine, aerospace and automotive. Based on the concept of successively adding material to create a 3D object straight from a computer model, additive manufacturing offers advantages over traditional production methods by allowing products to have a high degree of geometrical complexity and personalisation. However, the performance, density and reliability of mass-produced electronics is significantly more advanced than what has been demonstrated with Additive Manufacturing technologies to-date thereby providing a barrier for entry. A greater understanding of the drivers and motivation of electronics manufacturing requirements is needed to facilitate multidisciplinary discussions, cross-fertilization of ideas and drive future innovation. This talk will provide an introduction to this rapidly evolving field by discussing existing process and material challenges while also highlighting recent technological advancements.





Dr Robert Kay, Associate Professor in Advanced Manufacturing

I aim to develop disruptive manufacturing techniques that allow the creation of functional devices and exploit these ideas to benefit industry, society and scientific research. During my doctoral studies, I developed a novel electroforming process used by the electronics packaging sector. To take the impact beyond the academic outputs, I founded MicroStencil Limited in 2003, where I secured £1.2m equity funding, scaled the technology for commercial production, built a diverse customer base with leading electronic manufacturing firms, and established a manufacturing partnership licence in Asia.

With a combined background in fundamental scientific research and enterprise, I returned to academia in 2012 with the vision of developing digital fabrication methods that allow synergistic combination of multi-material arrangements and compositional complexity. This vision allowed me to secure blue-sky funding routes within the Engineering and Physical Sciences Research Council (EPSRC) on grants to successfully develop speculative manufacturing concepts, and to work with a range of industrial partners in supporting translation benefits within the engineering sector. In particular, this funding has aided the development of science in additive manufacturing and direct write processing. More recently my research is beginning to attract direct industry funding and enable impact across wider disciplines with applications covering tissue engineering, material science, metamaterials, condition monitoring and medical devices.

UNIVERSITY OF LEEDS

Latest Advances in Additive Manufacturing for Electronic Systems

Naim Kapadia - Technology Manager and Dr Farhan Khan, The Manufacturing Technology Centre

Additive Manufacturing Electronics (AME), also known as Structural Electronics, is a transformative approach to industrial production that enables the creation of lighter, cost effective and smarter parts. AME is deemed as an emerging technology and the next stage in the evolution in electronics. The disruptive and innovative technology for IoT and digital data collection are ideal for sensors, printed electronics and antennas to reduce weight, cost and to be environmental friendly.

The latest advances in additive manufacturing for Electronic systems presentation is set to be presented in two parts:

The 1st part of the presentation will discuss the purpose of AME followed by the advantages & disadvantages. The content will elaborate the technological progress including the MTC's latest investment of the Dragonfly LDM. The presentation will also cover the advancement in post processing for 3D objects. To finish off the presentation will give some examples of use cases to help simulate ideas for real world application.

The 2nd part of the presentation will discuss general design for AM workflow, current challenges, unknowns and opportunities to use design to maximise the potential of using AM. It will touch on how the existing knowledge could be translated to electronics AM.

Naim Kapadia has been working with the MTC since 2012, developing capability in advance production system (APS) and additive manufacturing in Electronics (AME).
Naim Kapadia has been responsible and leading the Smart Factory for Electronics Manufacturing using legacy equipment project.
Prior to joining Naim has over 25 years of experience in the electronics manufacturing working for contract manufacturers and PCB fabricators.
Naim has participated and led many programs in the UK disseminating Montreal protocol, the development of Surface Mount Technology and lead-free implementation.

Dr M Farhan Khan is an Advanced Research Engineer in the Design for Additive Manufacture team at the Manufacturing Technology Centre (MTC).
Before joining the MTC, Dr Khan worked at the University of Derby's Institute of Innovation in Sustainable Engineering (IISE) in a knowledge transfer role where he advised an aerospace company in the adoption of additive manufacturing for tooling and product development.
His main interests include design for polymer and metal AM. He has a background in mechanical engineering and has gained experience at the world leading additive manufacturing groups at Loughborough University, UK (2011-2012) and The University of Nottingham, UK (2012-2015). Dr Khan also has experience in delivering design for additive manufacturing training and has presented at numerous academic and industrial events.

mtc
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Additive Manufacturing of Elastomer, Ceramic and Metal Multi-functional Structures

Professor Eric MacDonald, Friedman Chair for Manufacturing, University of Texas, El Paso

3D printing has been historically relegated to fabricating conceptual models and prototypes; however, increasingly, research is now focusing on fabricating functional end-use products. As patents for 3D printing expire, new low-cost desktop systems are being adopted more widely and this trend is leading to a diversity of new products, processes and available materials. However, currently the technology is generally confined to fabricating single material static structures. For additively manufactured products to be economically meaningful, additional functionalities are required to be incorporated in terms of electronic, electromechanical, electromagnetic, thermodynamic, chemical and optical content. By interrupting the 3D printing and employing complementary manufacturing processes, additional functional content can be included in mass-customized structures. This presentation will review work in multi-process 3D printing for creating structures with consumer-anatomy-specific wearable electronics, electromechanical actuation, electromagnetics, propulsion, embedded sensors in soft tooling and including metal and ceramic structures.

Other projects to be presented include stereovision process monitoring of powder bed fusion, 3D printed smart molds for sand casting, complex ceramic lattices for electromagnetic lenses, elastomeric lattices for the athletic gear, computation geometry and complexity theory for 3D printing, thermography stereovision for directed energy deposition.

Eric MacDonald, Ph.D. is a professor of mechanical at the University of Texas at El Paso and engaged in the W.M. Keck Center for 3D Innovation. Dr. MacDonald received his doctoral (2002) degree in Electrical and Computer Engineering from the University of Texas at Austin. He worked in industry for 12 years at IBM and Motorola and subsequently co-founded a start-up specializing in CAD software and the startup was acquired by a firm in Silicon Valley. Dr. MacDonald held faculty fellowships at NASA's Jet Propulsion Laboratory, US Navy Research and was awarded a US State Department Fulbright Fellowship in South America. His research interests include 3D printed multi-functional applications and process monitoring in additive manufacturing with instrumentation and computer vision for improved quality and yield. As a co-founding editor of the Elsevier journal Additive Manufacturing, MacDonald has help direct the journal to have the highest impact factor among all academic journals worldwide in manufacturing. Recent projects include 3D printing of structures such as nano satellites with structurally-embedded electronics (one of which was launched into Low Earth Orbit in 2013 and a replica of which was on display at the London Museum of Science). He has over 100 peer-reviewed publications, dozens of patents (one of which was licensed by Sony and Toshiba from IBM). He is a member of ASME, ASEE, senior member of IEEE and a registered Professional Engineer in the USA state of Texas.

Case Study: An Overview of Additive manufacturing for RF Components in Space Applications

Vittorio Tornielli and Maarten Van der Vorst, European Space Agency (ESTEC)

Advanced Manufacturing plays a key-role that opens up new industrial possibilities in terms of design freedom, streamlined production stages and reduced cost, along with enhanced performance of the final product. In the space environment these are critical aspects in dynamic and competitive markets such as telecommunication services, earth observation and global satellite navigation satellites. Radio Frequency equipment and antennas can greatly take advantage of the flexibility offered by additive manufacturing in different ways. The flexibility to make complex shapes offered to the designer can overcome the inherit limitations of conventional CNC. In a complex RF payload system the ability to integrate several previously-independent microwave equipment into a single mono-bloc structure can further reduce the mass and complexity of the assemblies. Thanks to this high level of integration several functions, not restricted to RF, can be further integrated into a single part to obtain better thermal management and mechanical robustness. In this domain, the focus is not limited to metallic structures, but also on the development of complex ceramic and polymer elements that can be shaped with advanced manufacturing in order to further reduce the size and improve the RF performance of the components. The time and labour cost associated to the assembly and integration is a key advantage for further reduction of the costs and faster delivery of the finished product.

Vittorio Tornielli di Crestvolant received the Laurea Triennale degree in telecommunications engineering from the University of Parma, Parma, Italy, the Laurea Specialistica degree from the Politecnico di Milano, Milan, Italy, in 2010, and the Ph.D. degree from the University of Birmingham, Birmingham, U.K., in 2015, under the supervision of Prof. M. Lancaster, in a Network/Partnering Initiative (NPI) with the European Space Agency, Noordwijk, The Netherlands, and Airbus Defence and Space, Stevenage, U.K. In 2016, he joined Airbus Defence and Space, as an RF Design Engineer with the Feeds and Filters Group. His activities include the design of microwave filters, diplexers, and multiplexers for the feed chain assemblies in commercial satellite programs. From 2019 he joined the RF Equipment and Technology Section, RF Technology Division of ESA/ESTEC. Among his research interests are the synthesis and design of microwave filters, multi-port distribution networks with inherent filter transfer functions, based on all-resonator circuits and advanced manufacturing for RF microwave passive components.

Maarten van der Vorst received the M.Sc. and the Ph.D. degrees from Eindhoven University of Technology, Eindhoven, The Netherlands, in 1995 and 1999, respectively, both in electrical engineering. From 1999-2000 he worked at the TNO Physics and Electronics Laboratory, The Hague, The Netherlands, where the main topic was on Radar Cross Section calculations. In Sept. 2000 he joined the Antenna Section of the European Space Agency. Currently, his research interests include millimetre-wave and submillimetre-wave integrated antennas, radiometer and radar technology and the last 5 years got involved in the additive manufacturing technology applied to antennas.

Case Study:
Robotic Wiring Harnesses Manufacture

Stephen Bennington, Q5D Technologies

Wiring in aircraft, cars and many consumer electrical goods is done by hand. It is an expensive and laborious process that is prone to errors that can cause failures and sometimes even fires. Q5D Technology makes robotic tooling to automate these processes.

In the presentation we will discuss how the combination of 5-axis additive manufacture, printed electronics and tools to embed wiring are used to add electrical function to products in the automotive and aerospace sectors.

Stephen Bennington started his working career as a scientist working at the Rutherford Appleton Laboratory, primarily building and operating large pieces of scientific infrastructure, but also working as a visiting professor at University College London.
In 2011 he founded Cella Energy to make hydrogen storage materials and develop the lightweight power systems that use the materials. The company had collaborations in the aerospace and automotive and defence sectors. During that time he raised around $10m from: High Net Worth, Strategic and Venture Capital Investors.
Since leaving Cella he has been running a consultancy business called Krino Partners, which works with SME and UK university technology transfer offices to provide interim management and the expertise needed to find the funding and establish new technology businesses.
In April 2019 he set up a new business called Q5D Technologies which uses robotic tools automate the addition of electrical function in the automotive, aerospace and other sectors. He recently raised seed funding and is busy growing the company.

Q5D TECHNOLOGY

Case Study: Additive Manufacturing Activities at the CSA Catapult

Dr Jayakrishnan Chandrappan, Head of Packaging, CSA Catapult

Development of additive manufacturing processes for electronics forms part of the roadmap that the Compound Semiconductor Applications Catapult is undertaking to provide solutions for a wide range of sectors including photonics, RF/Microwave, sensors and power electronics. This presentation will cover the additive manufacturing methods that are being assessed and give an overview of the equipment and capabilities available at the CSA Catapult.

Dr Jayakrishnan Chandrappan is the head of Advanced packaging group at CSA Catapult providing innovative packaging solutions through package design & modelling, micro-assembly and rapid prototyping for Power Electronics, RF and Photonics applications. With over 20 years of international experience in the industry and industrial research, Jay's expertise ranges from Material engineering, Microelectronics, Photonics, Advanced packaging and reliability testing. Prior to joining the team at CSA Catapult, Jay's career includes roles at companies such as Global Foundries Inc., Institute of Microelectronics, A-Star Singapore, and Scientist, Ministry of Electronics & Information Technology, India. He is a recipient of Europe's most prestigious Marie-Skłodowska-Curie fellowship and won the Royal Society of Chemistry 'Emerging Technology Showcase' award in 2015.

CATAPULT
Compound Semiconductor Applications

About The EPSRC Design for Additive Manufacturing Network

The EPSRC Design for Additive Manufacturing Network – www.designforam.ac.uk

The purpose of the EPSRC Design for AM Network is to connect the wider UK Design for AM academic research community alongside those in industry that are experienced practitioners of additive manufacturing technologies, such that we can benefit from sharing knowledge, developing research themes and working collaboratively to ensure that Design for AM is given the best platform possible.

By bringing together the Design for AM community, the network aims to reach out to the widest possible audience that might benefit from Design for AM research; identify future research directions, and facilitate larger and more adventurous research collaborations.

The Key Research Themes will form the basis for workshop events and will be defined by the Steering Committee with input from Network members.

The thematic workshops will:

- Showcase the current state-of-the-art within the specific theme
- Define future and forthcoming research areas in DfAM
- Explore new collaborations within and between different disciplines
- Define future research proposals
- Produce a position paper as an outcome for each event

Future workshops in the planning stage include:

- Design for Additive Manufacturing in Education
- Design for Additive Manufacturing in Textiles

The Network Partners are:

Loughborough University, Lancaster University, Brunel University London, University of Nottingham UK | CHINA | MALAYSIA, The University Of Sheffield., University of Leeds, University of Strathclyde Glasgow, University of Cambridge, Manchester 1824 The University of Manchester, De Montfort University Leicester, mtc, Northumbria University Newcastle

For further information regarding EPSRC Design for AM Network please contact **design.for.am@lboro.ac.uk**.

You can also get in contact and follow us on **LinkedIn** and **Twitter**.

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About IMAPS - UK

The **International Microelectronics, Assembly and Packaging Society (IMAPS)** is the largest society dedicated to the advancement and growth of microelectronics and advanced electronics packaging. Our Society offers chapters around the globe, creating a global network with more than 6,000 worldwide members. The United Kingdom Chapter of IMAPS was the first international Chapter and continues to maintain strong links with other European countries, the USA and Asia.

IMAPS-UK is a registered Charity and plays a leading role in the UK's advanced electronics industry. We work closely with other governing bodies, societies, industrial and academic institutions, to ensure that members are kept up to date with the latest developments and innovations. We continue to provide a leading forum for the industry to meet and shape its future.

The Society's objectives are achieved through regional seminars, workshops, major international conferences and exhibitions, the publication of newsletters and technical papers as well as other activities relevant to promoting knowledge within the industry.

Further Information

If you have any other enquiries please visit www.imaps.org.uk/ or contact us at: office@imaps.org.uk

Future Events in 2021

Title	Event Type	Date	Summary
Wafer and Package Dicing Technology	Professional Development Course	20-25 May 2021	In-depth training course on dicing technologies
CPE Annual Conference	Blended Conference	13-15 July 2021	Centre for Power Electronics Annual Conference
EMPC2021	Online Conference	13-16 September 2021	23rd European Microelectronics and Packaging Conference – Online

Further Packaging Tutorials, Conferences and Workshops will be announced in due course

Programme may be subject to change depending on circumstances

IMAPS-UK Membership

Annual membership of IMAPS-UK ensures you or your Company become part of the worldwide IMAPS organisation, providing reduced entry into many IMAPS-UK & partner events, technical information and publications, as well as access to a major global network of microelectronics research institutions, businesses & individuals.

In addition, IMAPS-UK members automatically become annual "Affiliate Members" of IMAPS-North America (IMAPS-NA). This provides enhanced benefits, including access to the society magazine, Advancing Microelectronics and The Journal of Microelectronics and Electronics Packaging (both as online versions), IMAPS-NA News Bulletins and the IMAPS-NA Industry Guide, discounted entry to IMAPS-NA events and the opportunity to search the "iMAPSource" Technical Database and download discounted papers.

IMAPS-UK offers four forms of annual (Jan-Dec) membership:

- Student Membership (*Free)
- Individual Membership (£60 plus VAT)
- Academic Membership (£95 Plus VAT + £35 per additional Member)
- Corporate Membership (£395 Plus VAT + £45 per additional Member)

* *Bona Fide Students in Academic Institutions are eligible for Free membership of IMAPS-UK on an annual basis*

Feedback and Input on Future Events

The Design for Additive Manufacturing Network and IMAPS-UK welcome your feedback and input on future events.

Please take a moment to tell us a few things about this event and what would you like IMAPS-UK to be considering for future events ….

A Questionnaire link will be issued during and after the Workshop for completion by the attendees.

Acknowledgements

The Design for Additive Manufacturing Network and IMAPS-UK offer their sincere thanks to all the presenters for their time and we thank them for supporting this event.

Additionally, The Design for Additive Manufacturing Network and IMAPS-UK would like to extend its appreciation to the events organising team, who have made the workshop possible:

- Patrick Pradel – Loughborough University
- Nancy Honnor – Loughborough University
- Robert Kay – University of Leeds
- Allan Rennie – Lancaster University
- Liam Mills - MTC
- Andy Longford – PandA Europe
- Steve Riches – IMAPS-UK

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IMAPS leads the Microelectronics Packaging, Interconnect and Assembly Community, by providing the means of communicating, educating and interacting at all levels.