Designing the Future of Additive Manufactured Electronics Workshop

21st and 22nd April 2021

The EPSRC Design for Additive Manufacturing Network and IMAPS-UK organised an online Workshop entitled "Designing the Future of Additive Manufactured Electronics", with over 150 people registered on both days. The Workshop featured state of the art presentations and interactive sessions to identify the main challenges faced in introducing additive manufacturing within the electronics sector.

The Workshop Organiser, Patrick Pradel (Loughborough University) welcomed participants to the on-line event with an overview of the activities of the Design for Additive Manufacturing Network and Steve Riches (IMAPS-UK) presented an introduction to IMAPS-UK.

Day 1: Wednesday 21st April 2021

Overview of Additive Manufacturing for Electronic Systems – Robert Kay – University of Leeds

Robert introduced the motivation for organising this event of bringing together the two communities of additive manufacturing and electronics to identify common challenges and propose solutions through collaboration. Some of the terminology of the additive manufacturing community was explained covering the multitude of processes (defined by ISO/ASTM 52900) and the current limitations when applied to electronics manufacturing (such as production of Si devices at the nanometre level) were described. The potential benefits of utilisation of additive manufacturing through design for 3D geometries, mass customisation and multiple material deposition were highlighted.

Research at the University of Leeds has focused on three main areas:

- Polymer electronics
- Ceramic electronics
- Spatial control of materials

For polymer electronics, functioning circuits can be created by fused filament deposition of polyetherimide (PEI), followed by a surface treatment, addition of silver based nanoparticles, laser patterning and plating with copper, which can achieve electrical conductivities around 2/3rds of bulk copper. Rigid and flexible substrates can be produced, which are resilient to repeated bend testing (up to 50k cycles with <1% change in resistance). Circuits can be manufactured to include strain gauge, actuation (shape memory alloy) and wireless charging structures and electronic components can be surface mounted using solder (lead free) reflow processes.

For ceramic electronics, the University of Leeds has designed and manufactured bespoke equipment that can carry out both additive and subtractive processes to create ceramic/metal circuits that are similar in performance to mass produced LTCC ceramic circuits, but without the significant tooling costs.

For the spatial control of materials, additive manufacturing offers the opportunity to dynamically alter the permittivity of structures through incorporation of materials or voids within the component.

In summary, additive manufacturing has the potential to revolutionise the way electronic circuits are manufactured to exploit the advantages of digital design capabilities. However, significant barriers remain in terms of production throughput, quality and reliability. Sustainability was also raised as an issue, where separation of multi-materials from a structure at the end of life may be challenge.

Latest Advances in Additive Manufacturing for Electronic Systems – Naim Kapadia and Farhan Khan– The Manufacturing Technology Centre (MTC)

Naim presented an overview of the Manufacturing Technology Centre (MTC) and how it was set up to bridge the valley of death between research and manufacturing. Additive manufacturing is believed to be the next stage in the evolution of electronic systems assembly, particularly in the adoption of electronics embedded within structures to enhance functionality. The current additive manufacturing processes were reviewed and examples of products made by Printed Electronics Ltd, Tactotek and Nano-Dimension were described. The MTC has a DragonFly Lights Out Digital Manufacturing (LDM) Nano-Dimension system available at their facility, which is capable of producing multilayer circuit boards in 3 dimensions. Development is also being carried out in post processing activities to assemble components onto circuit boards.

Farhan, representing the National Centre for Additive Manufacturing, which is hosted at the MTC, continued the presentation to explain the design approach needed for additive manufacturing, where tooling requirements need to be reconsidered due the additive nature of the processing. Deposition of material where required means that the design can be adapted to a specific application, but it is necessary to follow closely the design guidelines of the equipment manufacturer, which may restrict the materials that can be processed successfully. As the additive manufacturing processes are different, substantial work is normally required at the design stage to convince companies of the benefits of the approach, particularly for higher volume, large scale applications.

Questions were raised concerning the dependence on equipment software, which is constantly evolving and improving and whether the MTC is involved in the production of nano-inks. The Centre for Process Innovation (www.uk-cpi.com), which is another part of the High Value Manufacturing Catapult infrastructure in the UK is developing nano-inks for additive manufactured electronics.

Workshop Session: Identifying the Grand Challenges for Additive Manufacturing

An interactive workshop session was organised to identify the main challenges surrounding the possible adoption of additive manufacturing for electronics. The following themes were highlighted from the session:

- Computational Design Tools
- Material Advancements
- Sustainability
- Process Innovation
- Standards/Policy
- Education Challenges
- Circular Economy
- Quality and Reliability

Day 2: Thursday 22nd April 2021

Robert Kay introduced the Agenda for Day 2 of the workshop. Attendees were invited to vote on the themes identified above to rank their interest and define the workshop topics for later in the afternoon.

Case Studies:

An Overview of Additive Manufacturing for RF Components in Space Applications - Vittorio Tornielli and Maarten Van der Vorst, European Space Agency (ESTEC)

Vittorio presented examples of guided RF passive components used in the space industry, including waveguides and resonant cavities for filters and couplers. The reasons why additive manufacturing are attractive were explained, which included reduction in the number of the components, simpler manufacturing with complex structures, improved RF performance and reduction in weight and size. Ceramic filters are also being manufactured to create new design freedoms, although post-metallisation processes are required.

Maarten continued the presentation to cover for additive manufacturing for antennae, with advantages claimed of reduced waste, time to market and costs. Examples were demonstrated of improved RF performance, although the printing direction may have an effect. The future for additive manufacturing is in the production of larger arrays and the possibility of printing components in space.

Robotic Wiring Harnesses Manufacture - Stephen Bennington, Q5D Technologies

Stephen gave an overview of a high tolerance 5-axis equipment platform that has been designed for multi-material 3D printing, laser sintering of conductor tracks and pick and place of surface mount (SM) components. The equipment offers an alternative to wiring of harnesses, which is predominantly carried out manually and is a common point of failure.

The 5-axis equipment offers greater precision (~50 micron) than robotics and can be used to embed wires and filaments within a polymer structure, which can result in improved reliability compared to existing wiring harnesses. The importance of software in controlling the additive manufacturing processes was emphasised.

Additive Manufacturing Activities at the CSA Catapult – Jayakrishnan Chandrappan – CSA Catapult

Jayakrishnan described the capabilities and equipment available at the Compound Semiconductor Applications (CSA) Catapult for packaging of electronic devices. The CSA Catapult has invested in metal and ceramic printing equipment to explore the manufacturing processes required for the next generation packaging technology, where additive manufacturing can be used to produce complex embedded structures and eliminate interfaces. They are developing a concept of “No Assembly Packaging” utilising directly printed passives and heat sinks, embedded die and possibly integrated liquid cooling.

Additive Manufacturing of Elastomer, Ceramic and Metal Multi-functional Structures - Professor Eric MacDonald, University of Texas

Eric joined the workshop in the early morning in the United States to provide a fascinating overview of the wide range of activities being undertaken in multi-material additive manufacturing research and development at various institutes. The possibilities of extending the functionality beyond just electronics to include propulsion, actuation and sensing within a system were described; examples were presented on a capacitive sensing lattice for monitoring of deformation in helmets and different concepts for battery manufacture.

The field of printed ceramics and metals for high temperature applications was reviewed; this can be realised by producing parts in the green state and then co-sintering of the ceramics/metals (e.g. W/Ni/Zr) at high temperature to produce the final component. This allows for more complex systems to be produced, although allowance for shrinkage always needs to be considered. Applications include RF antennae and lenses. The high temperature capabilities could also be applied for producing smart components that can be used for monitoring of metal casting processes or embedding sensors within turbine blades.

Workshop Session Day 2:

The workshop participants voted on the main challenges identified from Day 1 and then reviewed the following selected topics in more detail, covering what needs to be addressed, the status of R&D in the UK, collaborative opportunities and challenges to be overcome:

- Computational Design Tools
- Material Advancement
- Process Innovation
- Sustainability
- Quality and Reliability

The outputs from these sessions will be analysed by the Design for Additive Manufacturing Network and summarised in a report to be issued, which will form the basis of a roadmap for defining the future of additive manufacturing in electronics.

Allan Rennie of Lancaster University concluded the workshop, expressing thanks to the speakers, organisers and helpers. This was the first Key Research Theme Workshop to be organised by the Design for Additive Manufacturing Network and more events are planned for later in 2021, including:

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

For further information, please visit the Design for Additive Manufacturing Network (www.designforam.ac.uk) and IMAPS-UK (www.imaps.org.uk)