POWER ELECTRONICSUK
Underpinning Research

EPSRC
Engineering and Physical Sciences Research Council

CENTRE FOR POWER ELECTRONICS NEWS

Newsletter Autumn 2017

Introducing our New Topics

In June this year, EPSRC approved five new projects for the Centre, totalling £6 million under the theme: "Realising the Potential of Wide Band-Gap Semiconductors."

The successful projects are:

Switch Optimisation - University of Warwick

Heterogeneous Integration - University of Nottingham

Reliability and Health Management - University of Warwick

Virtual Prototyping - University of Nottingham

Converter Architectures -University of Bristol.

Professor Mark Johnson, Director of the Centre said:" I am confident that the new projects will make a huge contribution to the Centre for Power Electronics and I look forward to working with the new project leads as their research progresses."

Read more inside.

Inside this issue:

"Good presentations. Well organised throughout. Good venue."

"Good spread of academic and industrial presentations."

Annual Conference 2017

Our conference this year was a sell-out with over 170 delegates attending.

Keynote speakers included Dr Alan Mantooth from the University of Arkansas, and Dr Roland Rupp from Infineon.

Visit our website for the full report.

Kit car gets kids racing

Researchers from CPE have helped students at Round Hill Primary School in Beeston, build their very own electric kit car to compete in the annual IET/Greenpower Formula Goblin nation-wide competition.

With guidance from the researchers, the children assembled the car, designed the body-work using recycled materials and painted its exterior. The EPSRC Centre for Power Electronics funded the project and supplied the team with helmets, gloves and racing overalls - to make sure the children were equipped for the national Formula Goblin races which took place earlier in the summer.

Dr Liliana De Lillo, Senior Research Fellow, who mentored students said: "I was delighted to help the children at Round Hill Primary School build their kit car. It was encouraging to see the excitement with which the children embraced the project. It's been fantastic working with them and I looked forward to seeing them every week. The car was easy to build, it's lightweight, low cost and massive fun – plus, it's been a great way to explain the science behind the driving."

Prof Mark Johnson, Director of CPE said: "I am delighted that we have lent our support to this project - it exposed the children to concepts involving electricity, materials, maths and design technology, as part of a fun and hands on activity."

Daisy, aged 10, said "Driving the car was fun but also building it and designing the body-work."

Her friend, Elisa agreed and added "It's nice to enter a different kind of competition and with other schools in the whole country."

The project is a University outreach initiative in collaboration with the Power Electronics Spoke of the Advanced Propulsion Centre (APC) and the Centre for Power Electronics (CPE). It is part of the formula Goblin Kit Car project, a national competition being held in conjunction with the Institute of Engineering and Technology (IET) and the Greenpower Education Trust. It aims to inspire youngsters across the UK and give them an opportunity to see what a career in engineering is really like.

Round Hill Primary was one of seven schools across the UK that were given the opportunity to build and race their own electric vehicles with support from the EPSRC Centre for Power Electronics, APC and APC Spoke Community.

Post Graduate Summer School

Our Post Graduate Summer School was held at Holywell Conference Centre, Loughborough in early July. The themes this year were connecting with industry and developing communication skills.

In the morning sessions, the group heard from Senior Engineering Manager, Thomas Gietzold from US UTAS who gave a presentation on Power Electronics from an Industry Perspective. He was followed by Director, Pete James from Lyra Electronics who shared his journey as an entrepreneur . Attendees then took part in a series of workshops run by Wellcome Trust Engagement Fellow Dr Steve Cross and his team. These were designed to help delegates find new ways of communicating complex research to non-academic audiences.

The day culminated in awards for the best posters.

1st place – Xu Deng, Newcastle University

2nd place – Tianxiang Dai, University of Warwick

3rd place – Asad Fayyaz, University of Nottingham

CENTRE GETS DOWN TO BUSINESS

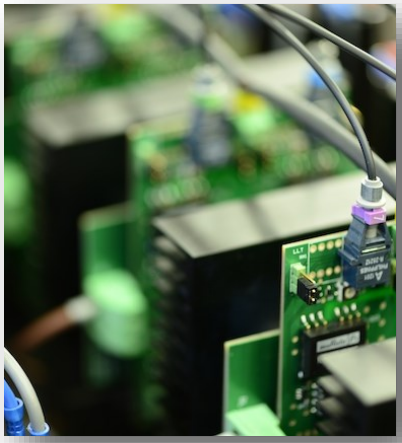
The business development team within the Centre is off to a great start. It is focusing on mapping academic skills and capacity across the UK to achieve a deep understanding of industry needs. This will help us to identify partner organisations for collaborations that are mutually beneficial. This includes understanding research grants within universities so that we can signpost companies towards this research, make it accessible to them and help contextualise it for their own applications. So far we've engaged with over 55 companies in the last 6 months, supported 2 collaborative academic and industry project funding applications worth over £1,500,000, and helped 2 university spin-outs meet with investors.

On top of this, we have a focus on trying to understand what the whole sector needs and how we can come together as a community to support its future. This, of course, means bringing that community together to identify strengths and gaps and using the resources we have. Such as the Power Electronics UK White Paper to provide the insight to supply chain and create relevant industry policy at a government level.

This is only the start of this conversation and we are open to many more. If you are industry and want to meet or understand the academic world more, please get in touch. Or if you are an academic and want to work closer with industry, get in touch.

businessdevelopment@powerelectronics.ac.uk

Future Power Challenge



The Future Power Challenge is for projects that involve students in research activities, working with qualified research teams, or as part of an industrial team in a placement with industry. A prize of **£2,000** is on offer for the winning team, but the experience itself should be highly rewarding for those taking part.

Eligible projects will be carrying out research that has the potential to accelerate the introduction of high speed switching electronic converter designs into future production.

Research may have already started, or may be a totally new investigation. There is no need for it to be complete by the date of the competition.

Your team will be asked to present a poster at the Future Power Challenge Poster Event in March 2018.

Entries will be judged on the quality of the research and its potential for generating impact.

Last year's winning team from Imperial College presented a joint paper with GaN Systems on wireless charging at APEC this year. A video of a demonstrator of their winning project, was featured by BBC Click and has resulted in considerable interest in their work.

In addition, a team from the University of Bristol have patented a wide-band current sensor and licensed the technology to RAM Innovations to create a family of products. Teams that include the Universities of Bath, Nottingham and Cambridge have submitted applications for collaborative funding together with industry partners to the Advanced Propulsion Centre (APC) and Innovate UK.

Next steps

Register your entry with the Centre for Power Electronics by **1 October 2017,** by sending an email to the Centre for Power Electronics. Make sure you include the **title** of your proposed entry and the **name** of your team. Further information will be sent to you once you have registered.

The Future Power Challenge 2017 is sponsored by GaN Systems Inc, Efficient Power Corporation Inc, Analog Devices Inc, and Peregrine Semiconductor. It is supported by the EPSRC Centre for Power Electronics.

Email: correspondence@powerelectronics.ac.uk

POLICY

In March this year, Power Electronics UK published a White Paper entitled "Driving Innovation in Power Electronics Across the UK Community—A Route Map to Success". The aim of this White Paper is to put forward a Joint Industry Action Plan to strengthen the UK's position as a global in leader in power electronics across many sectors. CPE's Director, Professor Mark Johnson was one of the contributors to this paper.

The key points of the White Paper are as follows:

- Establish Power Electronics UK as a trade body to facilitate and disseminate best practice and shared knowledge across the whole UK power electronics community.
- Power Electronics UK to coordinate activity between Catapult Centre, innovation funding bodies and government to reduce duplication and maintain a coherent focus for technologies using power electronics.
- Support power electronics as a major pillar of the Compound Semiconductor Applications Catapult.
- Initiate three major grand challenge programmes that will unite academia, industry and innovation support organisations to accelerate the development of key technologies.
- Develop and grow the UK skills base through recognition that power electronics is a unique discipline in its own right and a core competence for UK competitiveness.

The full White Paper is downloadable from the Power Electronics UK website.

PUBLICATIONS

For a list of CPE publications visit the research section of our website:

www.powerelectronics.ac.uk

In April 2017 EPSRC announced Electrical Motors and Drives and Electromagnetics as one of only 12 areas for growth.

Switch Optimisation

The Switch Optimisation topic focuses on the development of Silicon carbide (SiC) N-channel IGBTs that have the potential to enable new and highly efficient ultrahigh voltage (10 kV+) applications such as the Smart Grid and HVDC. Exploiting a consortium made up of experts from the fields of SiC materials, simulation and fabrication, and building on a recent history of SiC MOSFET, Si IGBT and SiC materials research, the aim of the Switch Optimisation theme of Underpinning Power Electronics is to be amongst the first groups in Europe and the world to develop these devices, and to push the boundaries of what has been achieved in this fledgling field to date. The project aims to:

- Produce epitaxial layers with a very low density of extended defects and high carrier lifetime by further developing post-epi treatments.
- Develop the processes (frontside and backside) necessary for SiC IGBT fabrication.
- Carry out the simulation, design, fabrication and testing of SiC IGBTs ranging in voltage from 5 kV to 15 kV.
- Modify the standard process to investigate the effects of trench gates and integrated IGBT-MOSFET devices.

PI Peter Gammon said: *"We aim to be one of the first in the world to develop these devices and to push the boundaries of what has been achieved in the fledgling field to date."*

Heterogeneous Integration

'Heterogeneous Integration' can be loosely described as 'the combination of dis-similar materials and components to create multi-featured, functional blocks or systems' and as such, this project theme, as part of the Centre for Power Electronics, will address aspects related to the inclusion of components more traditionally seen at a system level, within new and innovative power module structures. The outcomes of this research will underpin the effective use of Wide Band-Gap (WBG) semiconductors within power electronic converters.

Work will develop manufacturing techniques and design methodologies using a layered manufacturing approach to produce the next generation of power modules. Key aims are to:

- Understand how the design of layered, 3D-integrated structures can be optimised to maximise the electromagnetic, thermal and mechanical performance of power modules.
- Understand how new materials and interconnection techniques (for example copper wirebonding, sintering, exothermic bonding) can be best utilised in the design of power modules to improve their performance.
- Investigate new and/or cost-effective manufacturing processes that will allow these new modules to be brought to market. (Including 3D printing, laser machining, electroplating).
- Produce proof-of-concept demonstrators.

PI Lee Empringham said: *"The outcomes of this research will underpin the effective use of Wide Band-Gap semiconductors within power electronic converters."*

Virtual Prototyping

Virtual prototyping uses software to evaluate the performance and iteratively improve prospective power electronic system designs, eliminating the need for construction and testing of physical prototypes. Simulation tools that capture the influence of system design on the multi-domain physics (electromagnetic, thermal, mechanical) underpinning system operation are needed to enable this. The focus of the proposed research is the development of simulation techniques and algorithms that allow fast, fully coupled multi-domain simulation of power electronic systems. The project aims to:

- Develop techniques (for electromagnetic, electro-thermal, semiconductors) that allow faster, geometry dependent simulation of the next generation of power modules with integrated passives and thermal management solution than is possible with commercial Finite Element packages.
- Produce computationally efficient models for magnetic component design that can accurately predict core and winding losses.
- Investigate alternatives to full CFD for fast estimation of heat-transfer by convection in power electronics thermal management systems.
- Develop fast, geometry dependent mechanical stress and strain prediction techniques that allow estimation of system reliability and lifetime for arbitrary design geometry and materials.
- Integrate all developed in a design tool demonstrator and work with the converter architecture and heterogeneous integration teams to validate.

PI Paul Evans explains: *"The focus of the research is the development of simulation techniques and algorithms that allow fast, fully coupled, multi-domain simulation of power electronic systems."*

Converter Architectures

This Converter Architecture (CA) project will investigate optimal converter architectures, advanced passive components design methods, fast control techniques and holistic optimisation methods to realise the full potential of WBG devices in achieving higher efficiency, high power density with extended voltage, frequency and power handling capability. Key aims of the project are:

- Develop new converter topologies to achieve MHz power conversion at kW levels.
- Develop scalable multilevel converter architectures for medium voltage power conversion.
- Optimise the design of topology specific passive components and devise new design methodologies and structures for air-cored magnetic components.
- Provide effective solutions to digital control issues identified related to high speed, high frequency, modular WBG converters with reasonable and practical hardware resources.
- Deliver a high-profile demonstrator showcasing the research of the topic and bringing the Centre activities together.

PI Xibo Yuan said: *"We aim to deliver a high-profile demonstrator that will show the research of the topic and bring the centre's activities together."*

Reliability and Health Management

The central objective of this research is the development of a condition monitoring and health management strategy using underpinning research in the following four topics:

1. Device level electro-thermal reliability.
2. Power module thermo-mechanical reliability.
3. Advanced gate driving for reliable operation.
4. Converter control for condition monitoring and health management implementation.

The project aims to:

- Develop device level condition monitoring techniques for applications including: temperature estimation in SiC and GaN devices using temperature sensitive parameters and gate oxide health estimation.
- Develop intelligent gate-drives that can allow online device level condition monitoring in converters.
- Understand the failure mechanisms present in next-generation power module interconnects (including copper wirebonds and silver sintering) through experimental testing and subsequently develop lifetime models for use by system designers and in prognostic applications.
- Validate these techniques in converter demonstrators and use these converters to develop control techniques to allow deployment in the field.

PI Olayiwola Alatise, from the University of Warwick said: *"We aim to develop a lasting framework for reliability and health management in high power density WBG based power electronics".*

REALISING THE POTENTIAL OF WIDE BAND-GAP POWER ELECTRONICS - EVENT

Date: 11 October 2017

Venue: Jubilee Conference Centre, Nottingham University

This **free** one day event will explore the future direction of Wide Band-Gap Power Electronics. It will be of interest to anyone working in the field - whether you are from academia or from industry. The agenda will include:

- Highlights of previous Centre for Power Electronics research in Wide Band-Gap.
- An introduction to our work in the area for the next three years.
- The latest developments from Power Electronics UK, the Compound Semiconductor Applications Catapult and leading semiconductor manufacturers.
- The Future Power Challenge - a competition to stimulate university / industry research.
- An overview of the relevant strategic initiatives relating to Wide Band-Gap Power Electronics.
- An opportunity to take part in cross-sector workshops to provide in-put into the industrial strategy for UK Power Electronics.

Visit **www.powerelectronics.ac.uk** to register your interest.

Devices Theme

Work that aims to produce improved Silicon Carbide PiN diodes has shown promising results. A high-temperature carrier lifetime control process developed at the University of Warwick has resulted in a 50% improvement in carrier lifetime on small 3.3kV test diodes which results in lower forward voltage and therefore improved efficiency. The team are now going to apply this technique to larger, higher current 3.3kV diodes.

Lateral Silicon IGBTs, designed for integration with CMOS circuits that are being developed at Cambridge have been demonstrated in an LED driver application. Reliability testing of these devices has also shown excellent results with the latest designs passing > 2500 hours of testing with no failures.

For GaN devices, Cambridge are in the process of developing SPICE GaN HEMT transistor model that can account for both device level and package parasitic effects. Bristol have completed a failure model analysis of these devices and the results published in a paper "Dynamic RON in Commercial GaN-on-Si HEMTs: HTRB Stress and Modelling" and the ROCS 2017 workshop.

Components Theme

A flexible PCB interconnect technique for power modules, developed at Nottingham has been shown to be two times more reliable that traditional wire-bond interconnects. The technique uses flexible circuit boards combined with sintering technology to achieve interconnects with improved reliability and reduced inductance.

Imperial College have been testing a resonant gate-drive circuit for high frequency power converters. The new circuit is able to reduce power consumption to 7W compared with 20W for a traditional gate drive. The team are now working on fine tuning the design so that it can be integrated into a 3kW prototype power converter.

Work underway at Bristol to produce an active shaping gate-drive circuit for fast-switching devices will be presented at ECCE2017 and has been accepted for publication in IEEE Transactions on Power Electronics. The technology developed works by precisely controlling the gate waveform during switching and allows the reduction of unwanted effects such as ringing, whilst having a negligible effect on switching losses.

Work at Greenwich has produced a multi-objective optimisation method that can be used to rapidly determine optimal power module design parameters. Work is underway to integrate this into Greenwich's "PowerLife" software.

The University of Nottingham has taken delivery of a new, state of the art Keysight B1505AP Semiconductor Analyser. This equipment allows breakdown and forward characterisation of power devices and modules with ratings up to 10kV and 500A.

Warwick hosted a guest lecture from Prof Stig Munk Nielsen on "Power Electronics Packaging and Reliability Work" in February 2017.

Drives Theme

The theme presented a combined total of 5 papers at IEMDC 2017, Miami, including: integrating LCL filters into the design of high speed machine windings and active thermal management of permanent magnet machines.

Manchester presented a multi-drive demo at the Industry 4.0 – Factories of the Future Expo and have also been working in partnership with Smart Fibres Ltd to investigate real time temperature measurement in drives using optical fibres.

Converters Theme

Prof Paul Mitcheson showed a video of a battery free, wirelessly powered drone at IEEE APEC conference in Tampa and demonstrated the drone on the GaN systems stand.

Work at Bristol has shown that by using Silicon Carbide Bipolar Transistors in place of SiC MOSFETs, the volume of a 5kW, 3 phase inverter can be reduced by 20% due to an increase in the allowable junction temperature.

Prof Andrew Forsyth gave a talk on magnetic component and converter manufacturing challenges at an NMI/Power Electronics UK workshop and Neville McNeill will present a tutorial on 'High Efficiency power conversion with Silicon' at the IEEE International Symposium od Industrial Electronics in Edinburgh, June 2017.

CROSS -THEME REPORTS

Pressure-Pack SiC

The construction, testing and analysis of the SiC press-pack modules has results in a significant number of interesting areas, please refer to the publications section of our website for details.

O. Alatise gave an invited talk on "Thermal Effects in Power Devices" at ECPE workshop on Condition and Health Monitoring in Power Electronics, Aalborg.

Design Tools

This project has produced a design tool that can quickly evaluate the effect of design geometry on electrical and thermal performance. The design tool can provide up to 10x increase in thermal simulation speed compared with finite element design software. Final, ongoing project work at Greenwich aims to replicate these speed gains for electromagnetic modelling of magnetic components. To validate the design tool, a 50kHz, 2kW single phase inverter has been constructed and is undergoing testing.

In May, Dr Xibo Yuan visited Zhejiang University in China and presented work on virtual prototyping and application of SiC devices. Future collaboration through Newton Fund is planned.

POWER ELECTRONICSUK Underpinning Research

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OCTOBER 2017

1 October	Deadline for submission of interest for the Future Power **Challenge**
	Call for Expressions of Interest for Challenge Network feasibility studies.
11 October	Realising the True Potential of Wide Band-Gap Power Electronics event. Nottingham University, Jubilee Conference Centre.
	Free to attend, this event will be of interest to those working in the field of Wide Band-Gap.
	Register your interest
TBC	Sandpit for Challenge Network feasibility studies

NOVEMBER AND DECEMBER 2017

TBC	Business Clubs—where academics and industrialists can network and share information.
	Locations (tbc): Bristol, Edinburgh, London, Newcastle. Nottingham, Warwick.

JANUARY 2018

31 January	Deadline for Future Power Challenge poster submission

MARCH 2018

TBC	Future Power Challenge Poster competition

APRIL 2018

TBC	APC all-spokes conference
17-19 April	PEMD conference, Liverpool

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