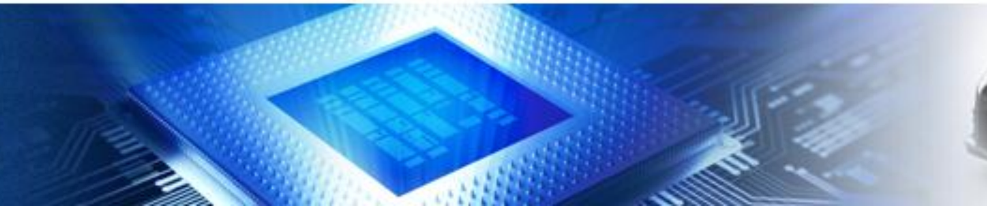
Vehicle Electrical Systems Integration

Aim: Reduce cost, size and improve reliability of the electrical **power** systems by integration of functionality in Automotive applications

Low TRL level to support EV Technology development - Underpinning the Future Supply Chain for the UK



University Partners: each having international reputation

- The University of Nottingham
- Cranfield University
- Newcastle University
- Manchester 1824 – The University of Manchester
- The University of Warwick
- VESI – Vehicle Electrical Systems Integration
- University of Bristol
- University of Southampton
- City University London
- The University Of Sheffield.
- Liverpool JMU

Industrial Supporters

TECH/OPS SEVCON

Scottish and Southern Energy

Infineon

International IOR Rectifier

PRECISION SCORPION PERFORMANCE

LAND ROVER

TATA

ARNOLD MAGNETIC TECHNOLOGIES

conekt powered by TRW

Allied Vehicles Driving For Perfection

TT electronics SEMELAB

HIFLUX HIFLUX

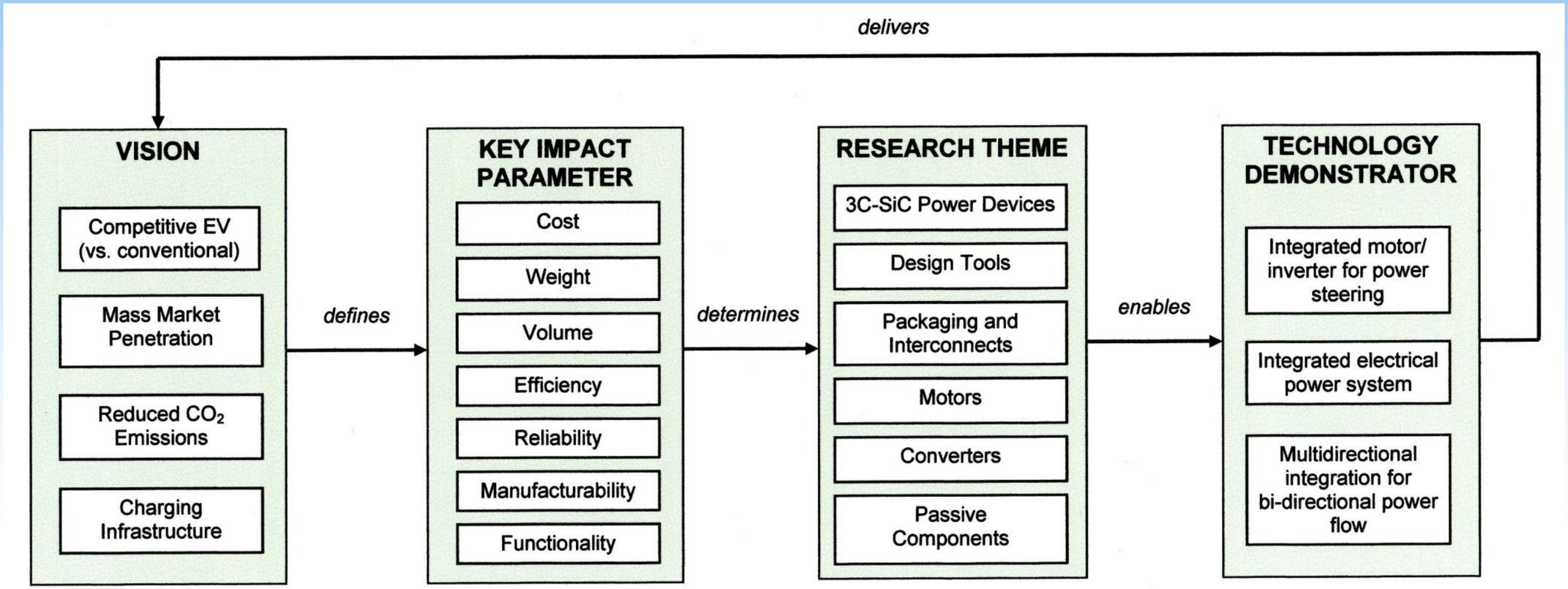
HILTech Developments Limited

DYNEX

ABB

ves

Project Rationale



	THEME 1 Semiconductors	THEME 2 Design Tool	THEME 3 Packaging	THEME 4 Motors	THEME 5 Converters	THEME 6 Passives
	Warwick	Newcastle Bristol, City, Manchester Sheffield	Nottingham	Newcastle Cranfield	Manchester Strathclyde Liverpool JM Newcastle	Bristol Sheffield Manchester
CHALLENGE	• switching • efficiency (heat dissipation) • cost	• interacting electrical, thermal and mechanical effects • lifetime and failure rate	• physical integration of currently discrete components	• uncertain supply of earth metals	• non-optimised, poor thermal management	• very heavy—reduce mass
APPROACH	• 3C SiC grown on Si substrate	• develop design tool for complete power drive train	• develop modular assemblies • develop reliability models • consider operational constraints	• optimise and benchmark motors in realistic drive cycle scenarios	• optimise and increase power density • interweave available research	• use models to miniaturise • alternative cooling
IMPACT	• Increased power density • reduced chip cost	• weight/volume savings • reduced development/testing timeline	• performance and space gains at die level • increased power density	• high temperature operation • optimised layout for integration with PE	• reduce weight • decrease external charge times	• reduced weight • enhanced reliability

TECHNOLOGY DEMONSTRATORS

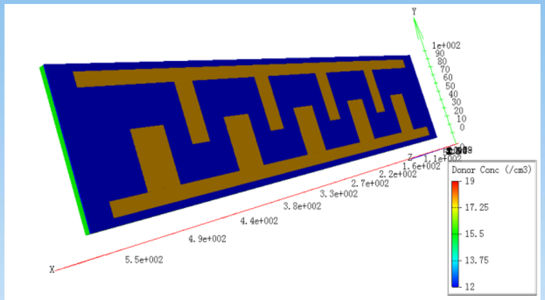
State of the Art in Production Technology

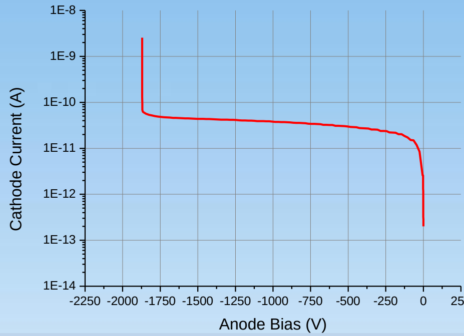
Summary

- 4 year Project Started in October 2011
- 10 University Partners
- £3.5m
- Initial focus on underpinning technologies
- Last 2 years focus on Demonstrator projects

Theme 1 – Semiconductor(3C-SiC/Si) power devices

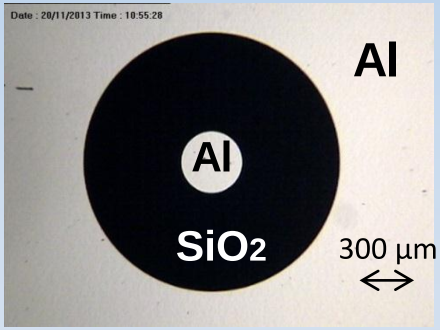
Finite element model for a novel 3C-SiC/Si RESURF lateral Schottky diode. (Warwick)

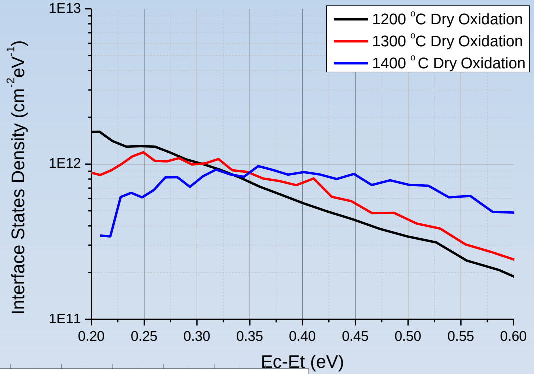


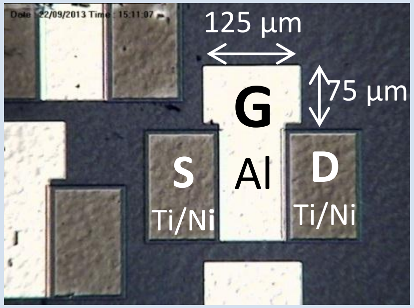


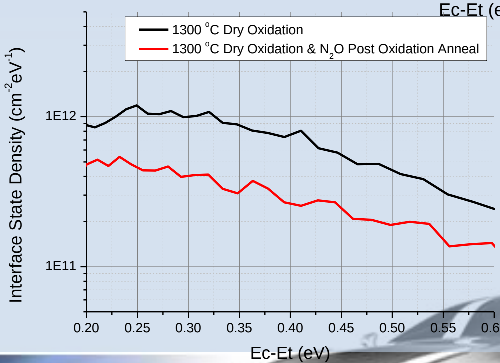
Breakdown voltage more than 1200 V is possible with only 4 µm 3C-SiC epilayer on Si.

Lateral MOS-C and MOSFET used to investigate 3C-SiC/SiO2 interface. Oxidising temperature, N2O annealing and CVD deposited gate oxide were looked into. (Warwick)









Dit below 1e12 cm-2eV-1 is obtained without any passivation

New SiC Epitaxial growth machine

Theme 2 – Design Tools

Approach:

Step 1

Characterise missing electrical, thermal and mechanical links of today's simulators

Step 2

Select missing links and describe effects analytically and validate by experiments.

Of particular interest is:

- Prediction of convective heat transfer in electric machines
- Physics-of-failure based models of new assembly techniques
- Loss mechanism and heat removal in inductors for dc/dc converters

Step 3

Development of new heat removal techniques

Of particular interest is:

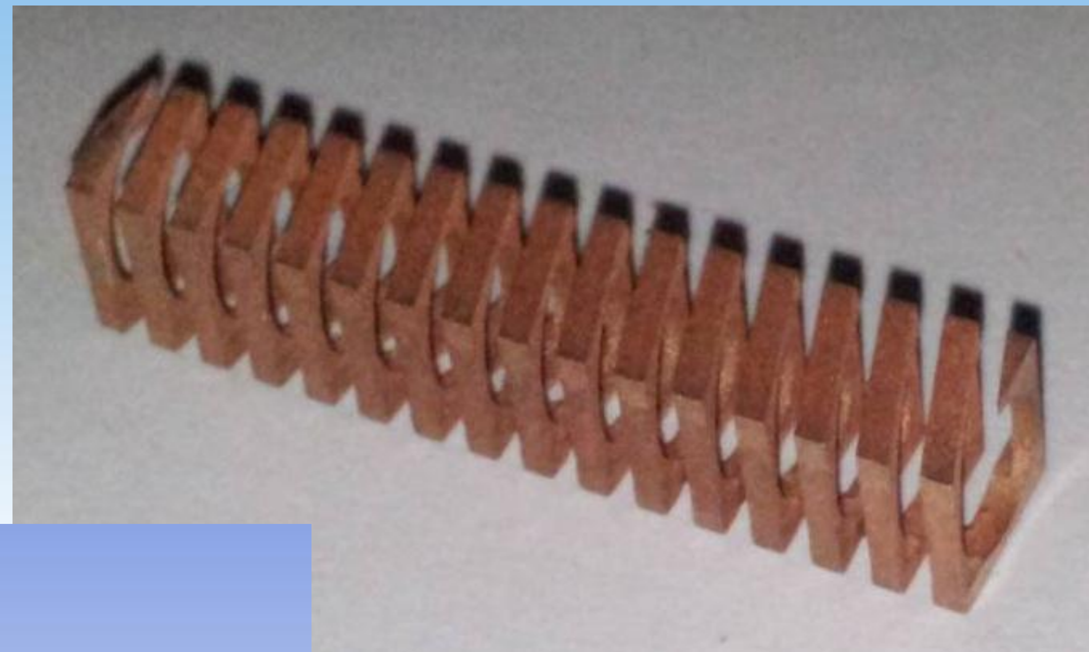
- Cooling plate with locally changing thermal impedances
- High thermal conductivity potting compounds

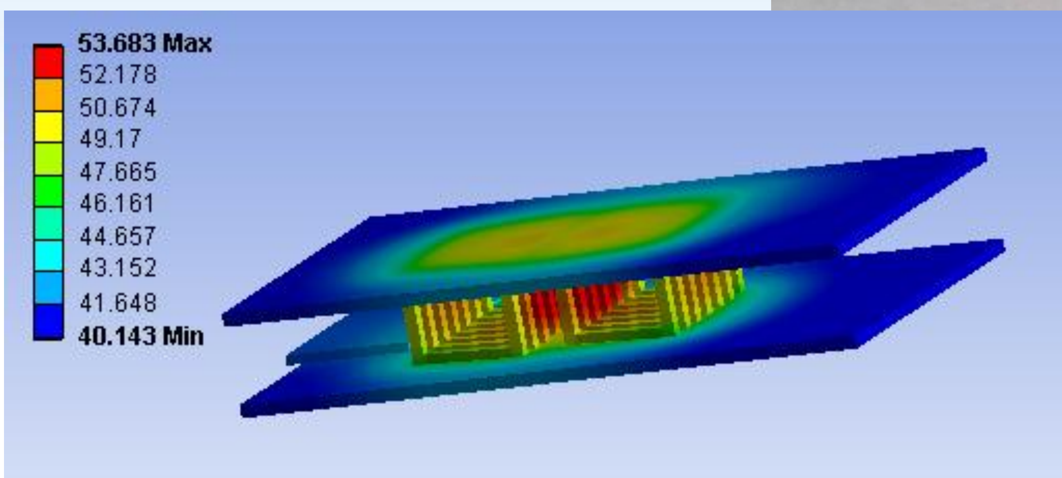
Theme 3: Packaging and Integration

- Multi cellular approach to high power
  - Multiple smaller switching cells
  - Reduced commutation loops
  - System performance (overshoot / EMI) ensured by physical design
- Circuit simulations – EMI / switching behaviour comparison of VESI modular topology with traditional power modules
  - Finite element extraction of parasitic inductances result in a reduction in commutation inductance by an order of magnitude
- Integrated inductance demonstrator rig:
  - High inductor current density achieved (100A/mm^2)
  - Energy density 2.5 times typical inductor using a ferrite core material
- Validation of thermal simulations
  - Convection coefficients used in thermal models fine tuned following tests on the integrated inductance

Integrated Inductance demonstrator

- Integrated
- High current density
- Concept test
- Model Validation

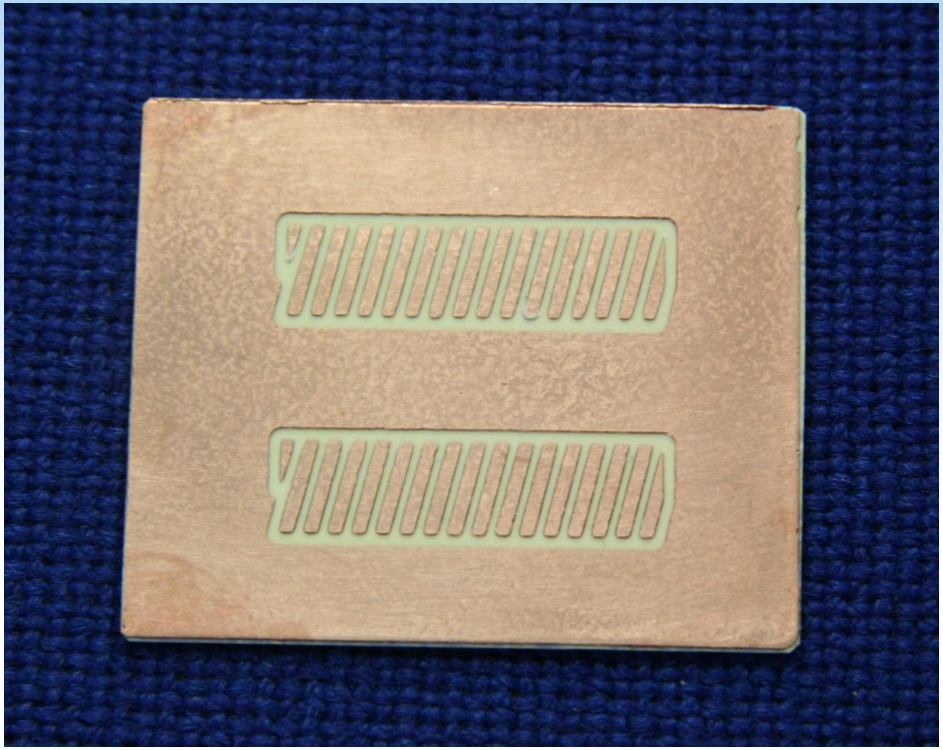


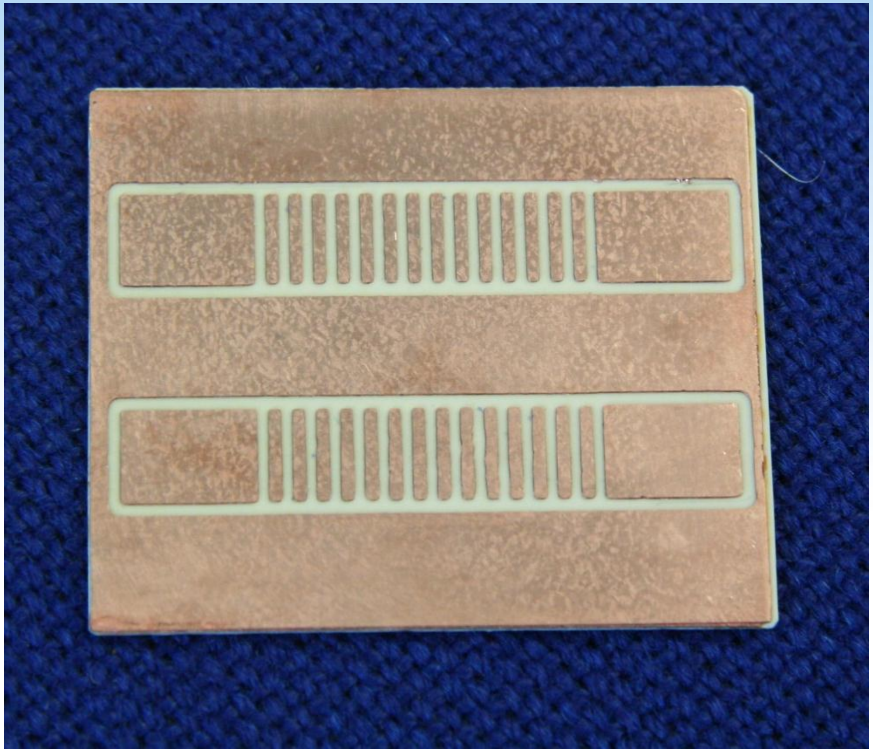


- – Inductor
- – Substrate
- – Cooler

Substrates

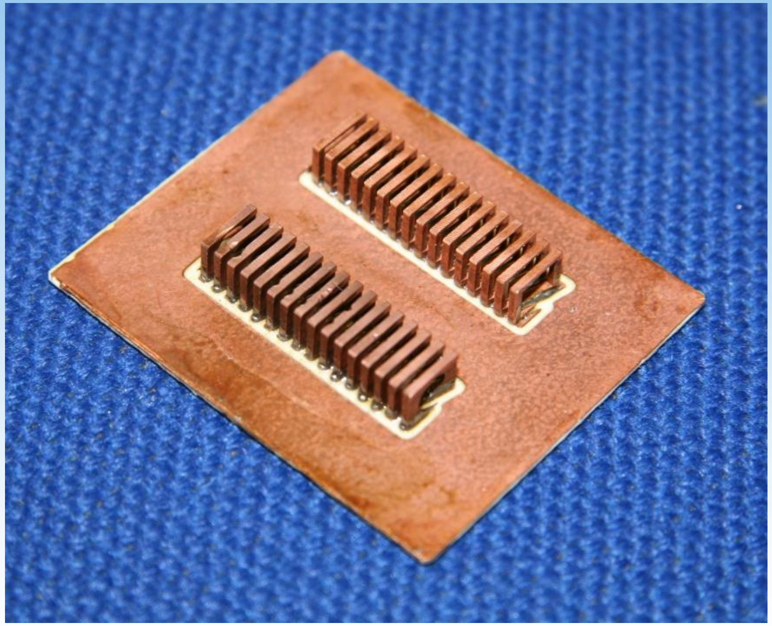
- Aluminium Oxide DBC
- Chemical etching used to create conductors

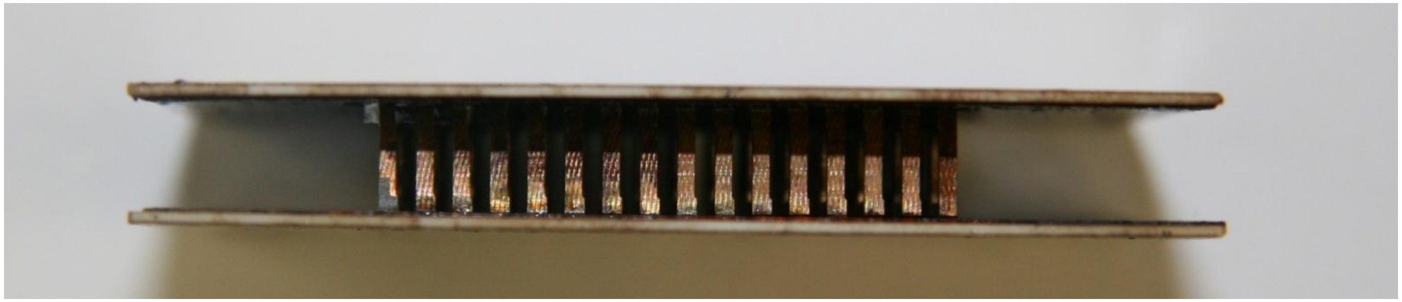




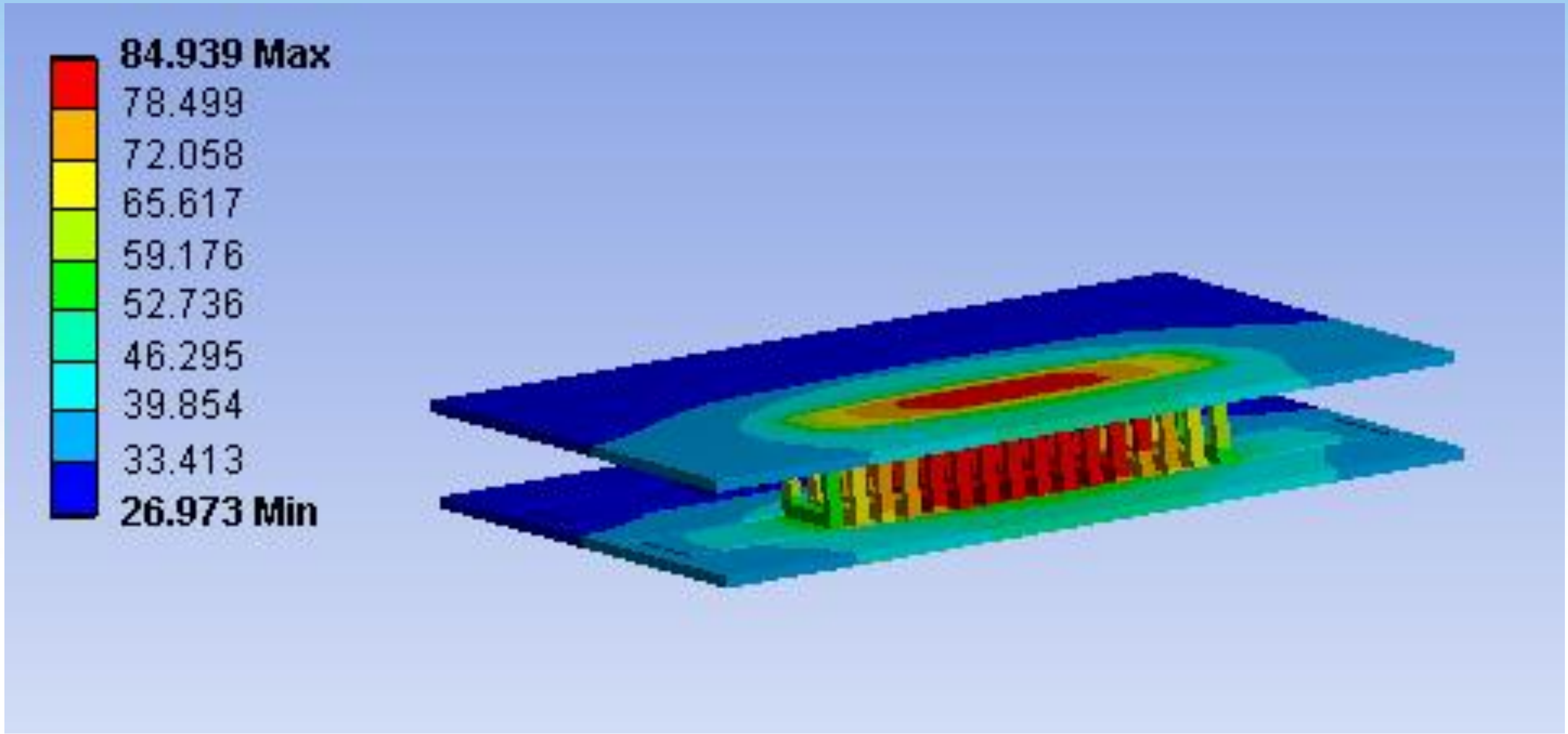
Double sided structure

- Inductors soldered into place





Model Validation



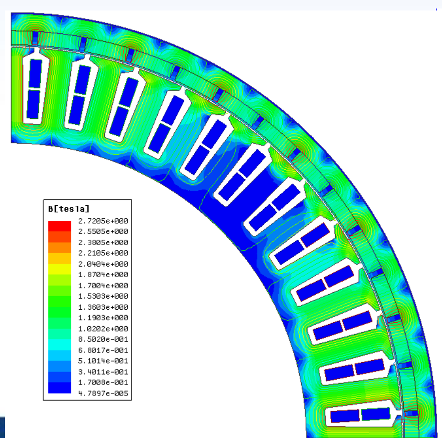
Theme 4 – Motors (Professor Patrick Luk, Cranfield University)

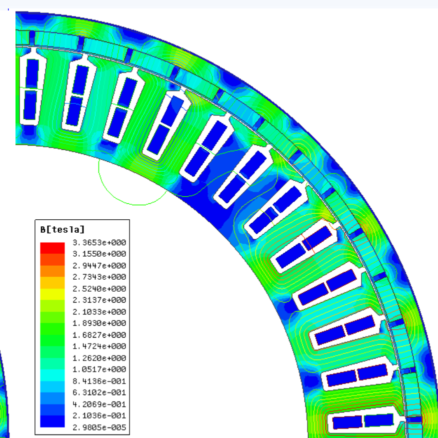
Rare Earth in-wheel Permanent Magnet Synchronous Machine

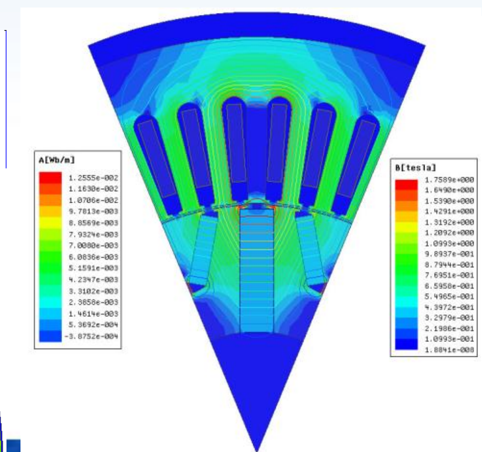
- Electromagnetic optimization with different pole-slot combinations by Particle Swarm Optimization (PSO)
- Further electromagnetic optimization based on NEDC to achieve cycle
- Magnetic radial force and vibration analysis of the machine
- Mechanical design of the final optimal machine

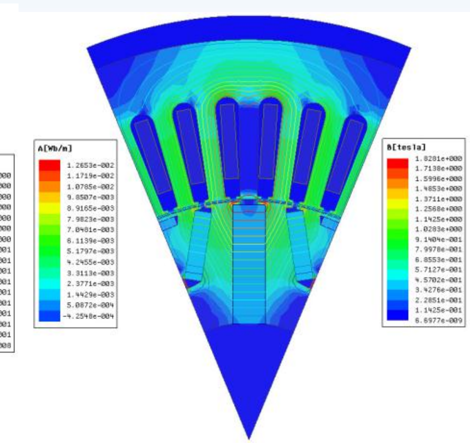
Ferrite Interior Permanent Magnet Synchronous Machine

- Electromagnetic Optimizations with different magnet layer numbers for flux enhancement
- Rotor mechanical integrity analysis at maximum operational speed
- Performance comparison with rare earth counterparts







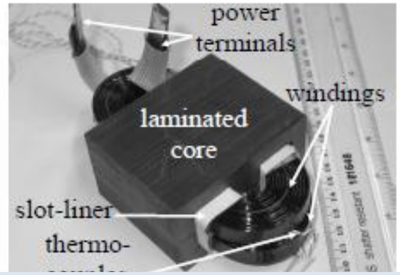


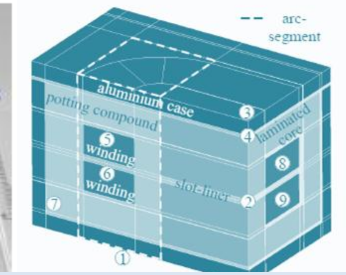
WP5 Converters

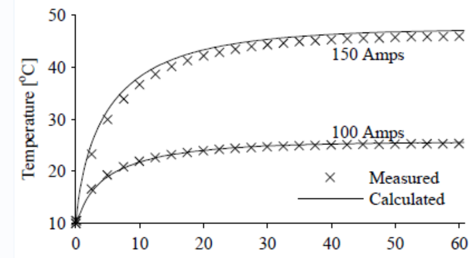
- AC-DC and DC-AC converters
  - Analysis of multi-function topologies for traction drive and grid-linked battery charging (LJM)
- DC-DC converters
  - Analysis of instability in dual interleaved boost converters (Ncl)
  - Comparison of topologies for 48 V auxiliary supplies (Mcr)
- Vehicle-to-grid systems
  - Hardware-in-the-loop testing of communication channel and algorithms for vehicle-to-grid control (Soton)

Theme 6 – Compact passive components

High fidelity reduced order thermal models for wound components
(Bristol PDRA)

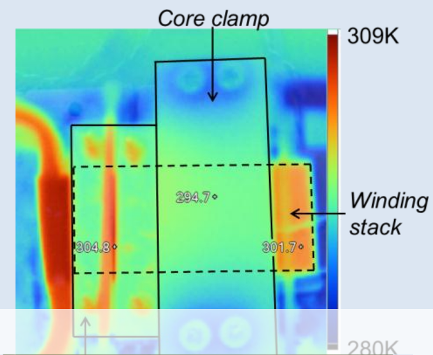




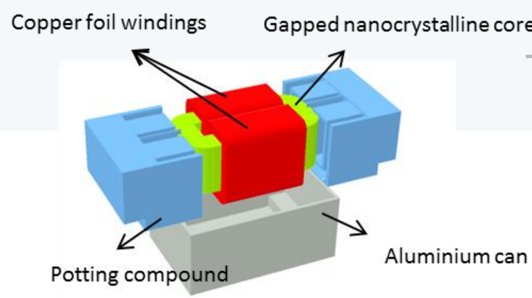


Implementing thin strip aluminium windings in wound components
(Sheffield PhD)

Aluminium oxide insulation



Improved loss models for DC inductors with nano-crystalline cores
(Manchester PhD)



Finite element thermal model assembly

Potted inductor with embedded thermal sensors

Demonstrator 1:

PI:	Dr Patrick Luk (Cranfield University)
CoI(s):	Professor Volker Pickert (Newcastle University); Professor Keith Pullen (City University); Dr Weizhong Fei (Cranfield University)
Title:	Integrated Non-Rare-Earth High Performance Drive
Start Date:	01/10/2013
Duration:	18 months
Total Funding:	£311,982 (100%); £249,586 (80%)
Industry:	Liberty E-Tech; Scorpion Power Systems; Motor Design Ltd.

Demonstrator 2:

PI:	Professor Phil Mellor (University of Bristol)
CoI(s):	Professor Andrew Forsyth (University of Manchester); Professor Mark Johnson (University of Nottingham)
Title:	Integrated power conversion for reduced EMI
Start Date:	01/10/13
Duration:	24 months
Total Funding:	£310,661 (100%); £248,529 (80%)
Industry:	Jaguar LandRover; Motor Design Ltd; IST Power Products;Lyra Electronics; Tirius.

Demonstrator 3:

PI:	Professor Emil Levi (Liverpool John Moores University)
CoI(s):	Professor Andrew Cruden (Southampton University); Dr Lee Empringham (University of Nottingham)
Title:	An integrated on-board battery charger using a highly integrated drive and a nine-phase machine, with V2G capability
Start Date:	01/10/13
Duration:	24 months
Total Funding:	£269,437 (100%); £215,550 (80%)