Advanced Ceramics Research Group at Loughborough University, United Kingdom

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The Advanced Ceramics Research Group (ACRG, **Figure 1**) at Loughborough University's (LU) Department of Materials has over 25 years of expertise in advanced ceramic materials processing.

Figure 1. The Advanced Ceramics Research Group (ACRG).

Research Vision

To create the necessary scientific understanding and provide innovative, interdisciplinary solutions using better, simpler and eco-friendlier manufacturing routes for advanced materials and devices with special emphasis on functional ceramics and knowledge exchange/transfer from laboratory to industry through the motto of "Research that Matters".

With the above vision, the ACRG led by Professor Bala Vaidhyanathan has pioneered the development of energy efficient microwave, hybrid, flash and ultra-fast high-temperature processing methods and Additive Manufacturing for the fabrication of advanced functional materials over the years and LU is currently regarded as one of the world leaders in the utilization of these techniques.

The range of products worked on is very wide, from traditional to nanostructured materials, for energy, electronic, healthcare and defence applications (**Figures 2-3**).

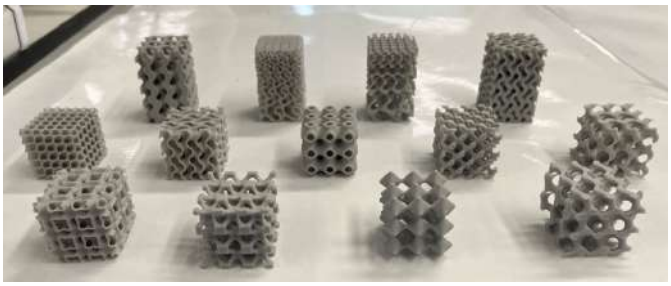

Figure 2. Examples of products worked on at ACRG.

Figure 3. Further examples of products worked on at ACRG.

LU Materials department is also the home of the Loughborough Materials Characterisation Centre (LMCC), a specialized facility for state-of-the-art materials characterisation in all length scales from surface to bulk, from microscopic to macroscopic structure determination & testing and ACRG commands significant analytical expertise on structure-property correlations.

Our recent funding via The Midlands Industrial Ceramics Group (MICG, that has 15+ industrial members, 3 leading universities, several government bodies, and RTOs) aims to "position the Midlands as a world leader in advanced ceramics" [1], through the creation of a £33 Million Advanced Ceramics Campus in East Midlands.

ACRG also won the first ever Faraday Institution Grant for LU [2] in 2022 to work on Si-C composite battery anodes.

The team was also involved in a multi-university, multi-industry 5-year EPSRC Grand Challenge £5 Million SYMETA project (Atoms to Devices and Applications [3]). Recently we were also engaged in developing energy efficient methods to manufacture nuclear waste disposal materials through a project funded by Nuclear Decommissioning Authority.

The specific properties demonstrated at LU are superior hydrothermal ageing resistance, unrivalled electro-chemical performance, wear performance, ablative resistance (in ultra-high temperature composites for hypersonic and space-reentry vehicles), dielectric performance of nanomaterials surpassing existing commercial devices, ability to produce 'soft' nano granules and concentrated nano suspensions of industrially important ceramics/composite systems. Recently BBC telecasted a documentary on our 3D printed bioceramic implants [4] titled "Materials for the Modern Age" – that outlines 6 major technologies that will shape the future! End applications ranging from valve components for petrochemical industry, through to wear components, ballistic protection, high energy capacitor/varistors, Li/Na- batteries [5], solar driven hydrogen generation, UHTCs, microwave catalysis for wastewater treatment and hip/knee/dental implants.

Some of the patents related to microwave processing and nanotechnology were licensed to companies in UK, USA, and Europe. Our work on the microwave assisted processing of NASICONs, base metal capacitors at high pO2 atmospheres, FIC glasses for ROM devices, SiCf-SiC and UHTC composites for aerospace/ space applications, microwave-assisted catalysis for wastewater treatment, 3D printed biomedical implants and microwave devices were regarded as the first such reports in the field.

The ACRG was also responsible for re-optimising peak performance in nanostructured ceramics based on grain size dependent phase boundary shifting. The recent activities are focused on the hybridisation of additive manufacturing and field assisted processing.

Under the leadership of Professor Vaidhyanathan, we are committed to fostering collaboration globally with industry and academia. We welcome connections with like-minded academics and industrialists, eager to explore mutually beneficial partnerships in the field of advanced ceramics.

Exceptional facilities @ ACRG:

- Microwave, Hybrid, Flash and Cold Sintering furnaces for oxides and non-oxides
- 3D printing of Advanced Ceramics with Digital Light Projection, Binder Jetting, Robocasting, Fused Filament Fabrication and Stereolithography techniques
- BET Surface area, Malvern Particle analyser, Rheometers, Impact & Gas gun Testing
- Glovebox for Battery fabrication, Impedance Spectroscopy, Battery stack testing
- High frequency Dielectric Measurements up to 50 GHz
- Iso-Pressing, Freeze Drier, Spray Drier, Tape/Slip/Slurry casting & Spin coating
- State-of-the-art ceramic characterisation tools at all length scales: FEGSEM, TEM, SEM with both heating and bias, FEGTEM, STEM, EDX and WDX, IR, Raman, HT-XRD etc via LMCC.

Research topics @ ACRG:

- Advanced Ceramics, Field Assisted Processing and Additive Manufacturing
- Cold Sintering, Carbon/Ceramic Composites, Nuclear Materials, Armour Ceramics & Testing
- Materials Chemistry, powder synthesis and Nanomaterials
- Batteries, Solid Oxide Fuel Cells and Hydrogen Generation
- Chemical Vapour Infiltration, Slip and tape casting, Screen Printing
- Functional Ceramics and Energy Materials & Devices
- Energy Materials, Non-equilibrium Processing, Ferroelectrics
- Modelling of Glass and Ceramics; Biomedical Materials

For further reading

1. https://micg.org.uk/micg-government-funding/

2. https://www.lboro.ac.uk/departments/materials/news/2022/the-school-of-aeronautical-automotive-chemical-and-materials-engineering-join.html
3. https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/N010493/1
4. https://www.lboro.ac.uk/departments/materials/news/2018/materials-at-loughborough-featured-in-bbc-4-documentary.html
5. https://www.lboro.ac.uk/departments/materials/news/2021/loughborough-receives-ukri-funding-to-develop-the-next-generation-of-batteries.html

About the author

Bala Vaidhyanathan (Vaidhy) is a Professor of Advanced Materials and Processing and was the Associate Dean for Enterprise at the School of Aeronautical, Automotive, Chemical and Materials Engineering at Loughborough University (LU). He leads the very active Advanced Ceramics Research Group in the Materials Department and has over 190 peer reviewed publications (>4980 citations, h-index 38), named inventor on 17 patents, delivered >60 Plenary/keynote/invited presentations in international and national conferences and written six book chapters. He is the Editor of Advances in Applied Ceramics, a high impact UK journal published by Taylor & Francis and on the Editorial Board for four International Materials Journals. He held/holds >47 research grants totaling >£30.2M in the last 10 years alone funded by UKRI, EPSRC, Innovate UK, Royal Society, DSTL, Government/Charity organisations and many of these are with multi-partner, multi-institutional involvements and 40 of them had direct industrial steer and contribution. He is a member of ACerS, ECerS, ICS (life member), MRS, AMPERE, DCERN, IOM3and is a Fellow of the IOMMM and IoN. He is also the fellow of Higher Education Academy, UK. He won numerous awards and prizes including the prestigious 'Glory of India' Award for his contribution to Science, Technology and Education in 2010 and Verulam Medal and Prize for his significant contributions to the field of ceramics by the Institute of Materials, Minerals and Mining (IOM3), UK in 2015 and the Pfeil Award for the best paper in the ceramics field in 2017. Vaidhyanathan has pioneered the development of energy efficient microwave, flash and hybrid methods for the advanced processing of functional ceramic materials and Loughborough is currently regarded as one of the world leaders in the utilization of these techniques and hosts the largest nanoceramics group in UK. With over 25 years of experience, he is one of the leading exponents in the field of microwave-assisted materials manufacturing, additive manufacturing of advanced ceramics, pioneered the development of hybrid two stage sintering methods and was the first to set up an atmosphere controlled, gradient field assisted sintering facility for the processing of oxide and nonoxide materials and devices. The range of products worked on has been very wide, from traditional to nanostructured materials, for energy, electronic, defence and healthcare applications. LU Materials department is also the home of the Loughborough Materials Characterisation Centre (LMCC), a specialised facility for state-of-the-art materials characterisation in all length scales from surface to bulk, from microscopic to macroscopic structure determination and Vaidhy's team commands significant analytical expertise on structure-property correlations.