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Trends in RF and Microwave Heating

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Our Road from OEM Modules to Full Medical-Grade Devices

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As most of the readers certainly know, LEANFA is an Italian Company specialized in design and manufacturing of solid-state microwave and radiofrequency amplifiers and generators, now member of the MUEGGE Group for one year.

Our specialty has always been to provide compact generator modules to manufacturers of industrial, scientific and medical devices, with the precise aim of being their trusted technical partners allowing them a quick introduction of innovative technologies in the market. So, during the first years of activity, our team has mainly worked in providing customization engineering support and helping customers with mechanical, electronic and software integration of our generator modules into their systems, progressively more with manufacturers of medical devices.

The characteristics of our solid-state microwave generators that mainly attracted our customers in the medical world have been their accuracy, long-term reliability and performance repeatability, all fundamental characteristics for the compliance of medical devices to the relevant international standards. In particular, all the new medical devices manufacturers in the EU have to comply with the new European MDR (Medical Devices Regulation), mainly aiming at assuring the highest clinical safety while guaranteeing transparency in defining market access rules. From a more technical point of view, the international reference standards for microwave-driven medical devices are mainly EN 60601-1 (basic safety and essential performance), EN 60601-1-2 (EMC requirements), EN 60601-1-8 (alarm systems requirements), EN 60601-2-6 (particular requirements for microwave therapy devices) and IEC 62304 for the software sections. Compliance to the standards is an essential prerequisite to get access to clinical tests and to official validation tests in accredited laboratories, to finally aim at international market certifications as CE and FDA. Almost all the listed reference standards apply also to RF-driven medical devices, our experience has embraced both technologies.

Being initially suppliers of the generator modules, typically in the range of few tens of Watts to 250W, our involvement has been focused on technical documental support and on providing technical know-how on radiofrequency and microwaves to get the maximum benefit from the clinical procedures. With both technologies the operator aims at quickly heating a pathological tissue to a temperature higher than 60°C to induce *coagulative necrosis* of its cells, while trying to preserve the surrounding healthy tissues. Typically needles or catheters are introduced into the target tissue to let the RF or microwave energy be effectively transferred to the target cells.

Heating induced by a RF generator is linked to the Joule effect associated with the RF current flow, in a procedure typically supported by impedance control algorithms that avoid dehydrating the tissue too quickly before the target reaches the desired temperature and final necrosis. A MW generator transfers electromagnetic energy to the polar molecules of the tissue (e.g., water), progressively raising their temperature, in procedures that are typically supported by temperature control algorithms and that are less susceptible to drying phenomena and allow larger volumes to be heated uniformly in less time.

Starting from 2019, our team has been asked not only to provide the core generator modules, but also to develop full medical-grade devices including chassis, hardware, software and all the accompanying technical documentation essential for the clinical tests and the final certification. This new approach has been real impacting at the beginning, but the flexibility of our young team of R&D engineers, the top performances of our solid-state generators and very focused consultancy received by highly skilled biomedical engineers have all contributed to build remarkable success

stories in the fields of cancer therapy and treatment of chronic pain.

After four years working with medical-grade devices, our team has gained during 2023 two memorable milestones for the LEANFA history: the first official FDA certification (through the so called 510k process) for an RF-driven multi-probe generator and the ISO 13485 quality certification, both precious excellence seals that give us even more energy to progressively expand the scope of our solid-state microwave technology towards a better life, worldwide.

About the author

Marco Fiore received his M. Sc. degree in electronics engineering at Politecnico di Bari, Italy. He has worked for more than 15 years in the field of digital telecommunications and broadcasting, from design tasks to operational management, always dedicated to implement deep interaction between high-frequency power electronics and programmable digital devices. He is co-founder of LEANFA in 2014, fully devoted to foster new business opportunities in Industrial, Scientific and Medical fields by means of innovative solid-state generators powered by distributed software applications.

Current Research Activities on Microwave Technologies at the Universidad Politécnica de Cartagena

Juan Monzó Cabrera

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After twenty-five years at the Universidad Politécnica de Cartagena (UPCT), the research group "Electromagnetismo y Materia" (GEM) has consolidated its structure with four professors, one senior lecturer, one lecturer, and three assistant researchers. It has also continued to receive funding for microwave and electromagnetic technology-related projects from national, regional, and European programs. While it's challenging to categorize everything we do, over the past few years, we have mostly worked with permittivity measurement, microwave filter design, microwave cloth dryers, calibration techniques, microwave-assisted waste recycling, radiomap generation, microwave sterilization, and axion search measurements using microwave haloscopes.

Methods for measuring permittivity

An original approach for characterizing the permittivity of liquids and granular materials in relation to temperature, density, and moisture content changes based on the Dielectric Kit for Vials from the ITACA Institute at the Universidad Politécnica de Valencia has been developed within the GEM, allowing us to characterize a significant number of materials, including cloth aggregates, cypress and rockrose biomass, coffee, quinoa (**Figure 1**), etc. Furthermore, for materials with non-canonical forms, we have refined our inverse measurement techniques to reduce the uncertainty of sample position within waveguides [1, 2].

High-power stop-band coaxial filter design

High-power band-stop coaxial filters offer significant benefits to microwave applicators because they make it possible to add instruments and probes that could be used to enhance or monitor microwave heating applications. As seen in **Figure 2**, the initial use of these filters was the addition of metallic stirrers inside the microwave applicators that did not exhibit any discernible leakage. This

avoided bearing ball heating and maintained radiation levels within allowable bounds [4].

However, further applications are being explored and will be shown to the microwave-heating community in the next few months.

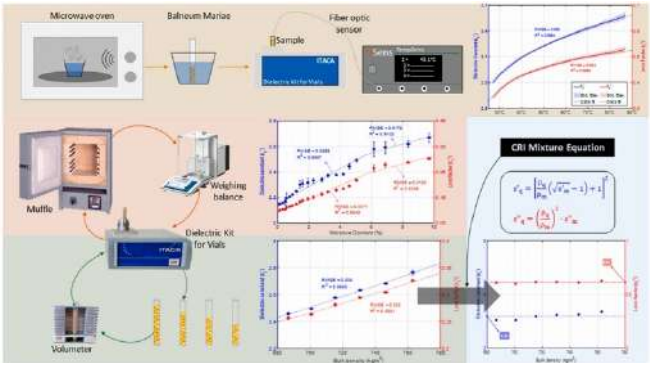

Figure 1. Characterization of quinoa permittivity under several temperature, moisture content, and density conditions. Figure reproduced from [2] under a Creative Commons license [3].

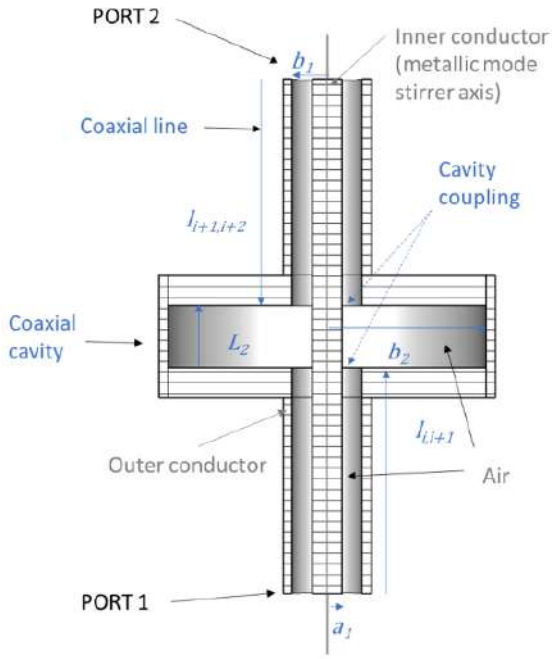

Figure 2. Cross section of coaxial cavity used for high-power band-stop filters allowing the introduction of metal axes in microwave ovens. Figure reproduced from [4] under Creative Common license [3].

Calibration techniques

In GEM, a significant amount of work has gone into creating our own calibration methods.

We have focused mainly on coaxial-to-waveguide transitions, and now we are able to characterize those devices both under monomode and multimode conditions [5]. We are currently developing our own methods for calibrating coaxial probes.

Microwave-assisted waste recycling

Over 3 million metric tons of end-of-life tires (ELTs) are produced annually in Europe, posing serious storage and environmental issues.

Under grant agreement number 870,000, the European Union's Horizon 2020 research and innovation program funded the project "VALUE-RUBBER: Recycling technology to introduce rubber from end-of-life tires into production lines as a virgin rubber substitute." This allowed us to design and evaluate a microwave-assisted applicator that was able to recycle rubber from tires in the automotive sector by devulcanizing it and performing further mechanical processing [6].

Additionally, at GEM, we are creating microwave applicators to recycle wastewater from landfills or car washes. Under the project "Application of low-loss dielectric molds to improve the efficiency of microwave evaporation for wastewater recovery" under grant reference 22234/PDC/23, this research has been funded by the Fundación Séneca, a regional research and technology foundation from the Gobierno de la Región de Murcia. This funding implies collaboration with the firm GETRAME S.L.

Axion and gravitational waves detection with microwave cavities

The axion is a hypothetical particle that possesses the properties required to make up the dark matter.

Currently, numerous worldwide collaborations, notably RADES (Relic Axion Dark-Matter Exploratory Setup), in which GEM participates, are planning and carrying out experiments employing microwave resonant cavities to detect the presence of the axion in the galactic halo that surrounds us. If this discovery is confirmed, one of the most pressing questions in current astronomy—understanding the nature of dark matter—will be addressed. This research began in 2016 and continues with the project "Development

of broadband haloscopes for axion detection in BabyIAXO and solenoid magnets. Improvement in volume, quality factor, noise temperature, and mass range" under grant agreement PID2022-137268NB-C53. This research work was totally funded by the State Research Agency of Spain (Ministry of Science and Innovation) and FEDER (Fondo Europeo de Desarrollo Regional- a European Regional Development Fund) funding. Our goal in this project is to construct microwave cavities with the best quality factor, volume, and the ability to tune in the widest frequency range possible while coordinating at both the national and European level. In this case, paradoxically, the power level of the detected signals from axion conversion is expected to be more than 260 dB below the usual power levels used in microwave heating applications, but the expertise in microwave cavity design can help a lot in the construction of this type of detector (microwave haloscope) [7]. The group participates too in the ERC Synergy project "DarkQuantum", which will research in the next six years on new cavity – qubit systems for reducing the noise in axion detection experiments below the standard quantum limit.

These detection techniques can also be applied to the detection of gravitational waves, and we are currently cooperating with researchers from the Instituto de Física Corpuscular (IFIC), at the Universidad de Valencia, and from the Institut de Física d'Altes Energies (IFAE) at the Universidad Autónoma de Barcelona to analyze and create microwave sensors capable of detecting gravitational waves at high frequencies.

Other research activities:

Other recent research activities include the optimal generation of radioelectric maps using interpolation techniques, the use of microwave energy to improve plant germination and food sterilization, and the development and construction of microwave-assisted cloth dryers (also funded by Fundación Séneca under grant agreement 21640/PDC/21), which may result in the grant of a new patent in the coming months.

In the next few months, a new research assistant will join the GEM research group (supported by Fundación Séneca under the Saavedra Fajardo program) and will conduct research on antennas for magnetic resonant imaging, expanding our study lines.

For further reading

1. Pérez-Campos, R.; Fayos-Fernández, J.; Monzó-Cabrera, J. Permittivity measurements for raw and boiled quinoa seeds versus temperature, bulk density, and moisture content. *Curr. Res. Food Sci*, 2023, 6, 100528, DOI: 10.1016/j.crfs.2023.100528.
2. Benhamou, S.M. et al. Dielectric, magnetic and electromagnetic shielding properties of Poly-(3,4ethylenedioxythiophene)-maghnite associated with different fillers with any non-canonical shape. *Measurement*, 2022, 194, 111049, DOI: 10.1016/j.measurement.2022.111049.
3. https://creativecommons.org/licenses/by/4.0/.
4. Monzo-Cabrera, J. et al. A Novel Bandstop Filter Based on Two-Port Coaxial Cavities for the Installation of Metallic Mode Stirrers in Microwave Ovens. *Electronics*, 2022, 11, 1989, DOI: 10.3390/electronics11131989.
5. Lozano-Guerrero, A.J. et al. Multimodal Retrieval of the Scattering Parameters of a Coaxial-to-Waveguide Transition. *IEEE Transactions on Microwave Theory and Techniques*, 2021, 69 (12), 5241-5249, DOI: 10.1109/TMTT.2021.3121416.
6. https://cordis.europa.eu/project/id/870000
7. García-Barceló, J.M. et al. Methods and restrictions to increase the volume of resonant rectangular-section haloscopes for detecting dark matter axions. *J. High Energ. Phys*. 2023, 2023, 98, DOI: 10.1007/JHEP08(2023)098.

About the author

Juan Monzó Cabrera is Full Professor at the Universidad Politécnica de Cartagena (UPCT) related to telecommunication studies. He has worked as the Director of Transfer of Research Results Office and co-director of the Entrepreneurship Office at this university. He has also acted as the General Secretary for AMPERE EUROPE, as a member of the management committee of this association and as General Director of Research and Universities at the Regional Goverment of Región de Murcia. He is part of the research group of Electromagnetism and Matter in the UPCT, activity that has combined with innovation and technology transfer. Among other publications, he is co-author of more than 50 international publications in specialized scientific journals, as well as coinventor of 11 patents. He has been a researcher in around 50 projects with private and public funding, three of them with European funds. His research areas are related to microwave heating and drying, permittivity measurements, waste water recovery, axion detection, waveguide calibration procedures, electromagnetic compatibility and dosimetry and microwave oven design.

Advanced Ceramics Research Group at Loughborough University, United Kingdom

Bala Vaidhyanathan

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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**).

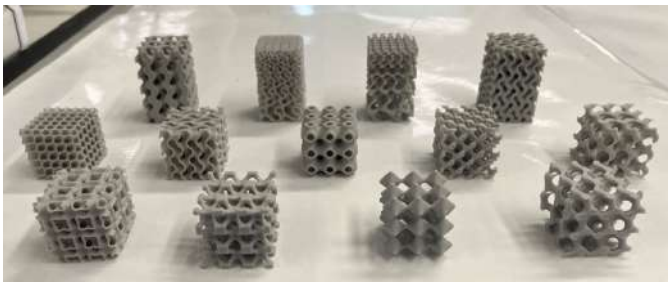

Figure 2. Examples of products worked on at ACRG.

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.

Ricky's Afterthought:

The Case for a Journal

A.C. (Ricky) Metaxas

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New format of the Newsletter

Issue 117 of the Newsletter was the first that had not included any scientific papers as such. This will continue for the foreseeable future.

Dan Slocombe in Issue 117 wrote about the establishment of the European Microwave Energy Journal (EMEJ) sponsored by Cardiff University Press. It is an item that was discussed many times in the past and finally it looks as though this will materialise. So scientific papers will now be included in the peer review EMEJ so allowing the Newsletter to concentrate on profiles of individual researchers and groups, company news and announcements of projects and other activities relating to the promotion of RF and microwave energy for ISM applications.

Let us however reflect back at numerous attempts to establish such a Journal. The preeminent Journal in our field of activity is the Journal of Microwave Power with its inaugural issue in1966. In addition researchers deemed prudent to publish in other Journals with higher impact factor such as the IEEE Transactions on Magnetics, IEEE Transactions of Plasma Science, IEEE Antennas and Propagation Magazine, IEEE Transactions of Microwave Theory and Techniques, the Journal of Physics D: Applied Physics, Nature, IET Proceedings of Science Measurements and Technology and Applied Physics Letters.

What is staggering is the breadth of the Journals of all disciplines that include papers on various aspects on utilisation of RF and Microwave energy. The list is endless, however, glancing "randomly" through the reference section of the papers that Prof Willert-Porada published concerning the 8th International conference on Microwave and High Frequency Heating held at Bayreuth in 2001 revealed the following: Drying Tech. J., AIChE Journal, J of Food Engineering, Int. J. of Food Science. and Tech., Food Techn., J. of Appl. Polym. Sci., Metalurgia, Phys. Rev. B, Ceram. Trans., J. Amer. Ceram. Soc., Ceramic Bulletin, Ceram. Trans., J. Mat. Sci., J. Phys. Chem. Solids, SIAM J. Appl. Math., J. Engin. Math., J. Phys. Chem., Chem. Soc. Rev., J. Org. Chem., Tetrahedron, J. Phys. Org. Chem., Appl. Catal. B, J. of Comput. Phys., J. of Appl. Computat. Electromagn. Soc., COMPUMAG, Plasma Sources Science and Technology, and a host of papers presented at numerous MRS (Materials Research Society) and PIERS (Progress in Electromagnetic Research Symposia) annual meetings. Occasionally papers appeared in the International Journal of Hyperthermia where RF or microwave was the prime energy source. This shows quite clearly the multidisciplinary nature of RF and microwave energy as applied to processing a host of materials and the necessity of having a couple of dedicated and complimentary Journals where our papers could be published.

I was the Guest Editor of the Journal of Microwave Power in 1987 when I pointed out to Geoffrey Voss, the then Editor in Chief, that there were many applications in electroheat or electro-technology that fall outside microwave frequencies and it would be interesting if these were included in the Journal. The decision was then taken shortly afterwards to change the title to the Journal of Microwave Power and Electromagnetic Energy. Special Issues followed on Radio Frequency industrial applications, Infrared Energy, Exposure effects, Microwave Oven Design and performance and so on.

This was during the time when I was involved heavily in teaching topics on electroheat to 4th year

undergraduates at the Engineering Department of Cambridge University. When my textbook associated with that course was published in 1995 I approached my publishers, J Wiley and Sons with the view to start a Journal of Electroheat encompassing many topics including RF and Microwaves. I wrote copious letters to various bodies in an attempt to elicit support for such a Journal but alas my publishers thought that there was not a sufficient body of researchers that warrant the introduction of such a Journal. I was also then the Editor of the British National Committee of Electroheat (BNCE) Newsletter which covered many developments in the field of Electroheat and electro-technology from DC to laser frequencies. I knew that I could get a sufficient number of good peer review papers for such a venture. Alas, with the privatisation in the early 1990's of the Electricity Supply Industry in the UK many of the activities in electroheat were downgraded and left me powerless to pursue such a venture. In fact BNCE, as an entity which was supported by the Electricity Council, was shut down with the consequence that all its operations were terminated. Many pamphlets were commissioned by BNCE up to that point using experts from the Electricity Council Research Centre or indeed by eminent academics on various aspects of Electroheat. One such for example was the pamphlet written by Prof Bill Milne at the Engineering Department in Cambridge about industrial applications of lasers. I have in my procession copies of various monographs and pamphlets, of about 30-50 pages in length, which I am willing to give away to whoever is interested to assist one's teaching or research activity (see list below).

So we continued with the Journal of Microwave Power and Electromagnetic Energy where occasionally special Issues focussing on other non-microwave applications appeared. AMPERE came into existence and with it the birth of the quarterly Newsletter which included articles supporting RF and microwaves activities, biographies and other news items. Enter Eli Jerby who was a strong advocate of a Journal supporting our activities and who aptly demonstrated during his two years as Editor in Chief of the AMPERE Newsletter during 2015-2017 that there were sufficient good papers which could form the basis of such a Journal. Alas, we could not find somebody to continue his excellent work and after he stepped down we reverted to publishing one of two technical papers per issue.

Hopefully the new European Journal of Microwave Energy will also encompass RF applications and will complement the Journal of Microwave Power and Electromagnetic Energy.

If anybody is interested in receiving any of the following do email me your full address.

Monographs

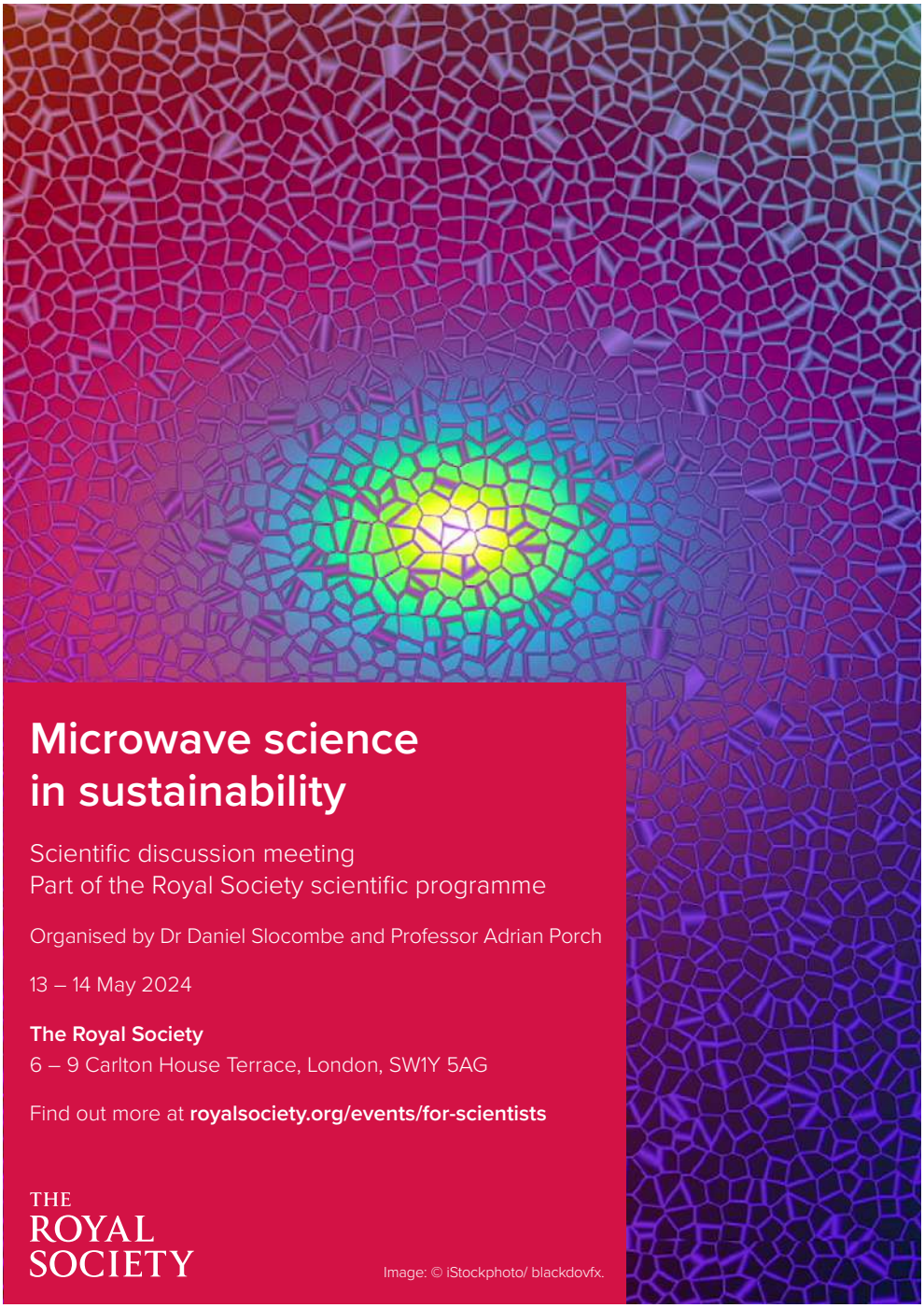
- Lasers and their industrial applications by WI Milne
- Heating with Electromagnetic fields-A unified approach by AC Metaxas 2 copies
- The arc furnace by DJ Swinden
- Direct Resistance Heating by EC Davies
- Electric Discharges for Heating by JE Harry

Pamphlets

- Plasma Heating for Industrial processes
- Electric heating elements (Sheathed)
- Electric heating elements (Unsheathed)
- Heat transfer for induction heating 2 copies
- The electrode boiler
- Induction heating 2 copies
- Heat pumps-an option for energy efficient and clean energy

Royal Society Discussion Meeting: Microwave Science in Sustainability

Can we harness recently discovered microwave laser technology for efficient 6G communications? Can microwaves solve our waste plastics problem, produce clean hydrogen and high-performance batteries? An innovation revolution has been taking place in the microwave spectrum that could impact global sustainability. In this meeting, researchers working across the sciences will come together to discuss recent breakthroughs and confront major challenges. This event is free to attend and intended for researchers in the field. Both virtual and in-person attendance is available, but advance registration is essential. More information can be found at https://royalsociety.org/science-events-and-lectures/2024/05/microwave-science/ or to register, follow the link https://www.eventbrite.co.uk/e/microwave-science-in-sustainability-tickets-863587993937?aff=oddtdtcreator.



IMPI 58

Registration is open: https://netforum.avectra.com/eWeb/Shopping/Shopping.aspx?Site=IMPI&WebCode=Shopping
Registration fees: $775 IMPI Members/$875 Non-Members. $495 Student Members/$595 Student Non-Members. Registration includes: in-person attendance at all sessions, Welcome Reception, two continental breakfasts and luncheons, three coffee breaks, access to the Exhibit Hall, copy of conference Proceedings and unprecedented networking opportunities over the 2 1/2 days! Attendees may choose to add-on: Group Dinner at Fogo de Chao ($65) and/or Short Course(s): $275 Members/$325 Non-Members.

Spouse/Guest Program: IMPI 58 will feature a Spouse/Guest Program to include the Welcome Reception on 5/29/24, Group Dinner on 5/30/24 and a Farewell Brunch on 5/31/24. Registration will open soon.
Keynote Speaker Announcements:
"**Microwaves in Chemical Industry: Scale up Challenges and Modeling Approaches**" to be delivered by Pranjali Muley, Microwave Research Scientist, Center for Microwave Chemistry, National Energy Technology Laboratory (United States)
"**Microwave & RF process solutions to deliver positive food choices for consumers**" to be delivered by John Bows, R&D Director, PepsiCo (United Kingdom)
Hotel Rooms: At the Hyatt Regency Reston are available for a special group rate of $239 per night, plus applicable taxes, on a first-come, first-served basis. THE ROOMS AT THE SPECIAL RATE ARE SELLING QUICKLY! To book your room follow the link: https://www.hyatt.com/en-US/group-booking/RESTO/G-IMPI.

Thank you to Muegge-Gerling for serving as the Platinum Sponsor at IMPI 58!
SPONSOR & EXHIBITOR packages are now available! These will sell out quickly! Secure your spot today. More information at the following links:
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CONFIRMED EXHIBITORS AT IMPI 58 (18): Muegge-Gerling, SAIREM, Richardson Electronics, QWED, Stellant Systems, Microwave Techniques, Symphony Microwaves, Ampleon, pinkRF, Odyssey Technical Solutions, IMPI's Solid State RF Energy Section, WavePIA, TRUMPF Huettinger, MKS, 3DRFE, Mini-Circuits, RFHIC and Microwave Amps Limited.

Call for Papers is Closed. Acceptance Notices were emailed to authors on February 23rd. As a reference, the Call for Papers is available at https://impi.org/wp-content/uploads/2024/01/2024_Call_for_Papers_IMPI58_Extended.pdf. Authors, please use IMPI 58 Word Template (available at https://impi.org/events/symposium/#:~:text=IMPI%2058%20Word%20Template) for your 3-page submission, which is due in mid-March. The Author Contact Form is also available as a reference at https://impi.org/wp-content/uploads/2024/01/IMPI-58-Author-Contact-Form-in-Word.doc.

Special Session: THz Technology and Applications, Call for papers available at https://impi.org/wp-content/uploads/2023/11/THz-special-session-call-for-papers.pdf.

5GCMEA 2024

Keynote Speakers

- **Prof. Georgios Stefanidis**: Chemical Process Intensification via Microwave-Driven Dynamic and Cyclic Thermal Operation.
- **Mr. John F. Gerling**: IMPI – Past, Present and Future Influence on the Advancement of Microwave and RF Power Applications.
- **Prof. Hui Shang**: Strengthening mechanism of microwave-matter interaction—the application of microwave technology in petroleum and environmental fields.
- **Dr. Jun-ichi Sugiyama**: Induction Heating and Maxwell's Equations.
- **Dr. Parag Prakash Sutar**: Current Status and Future of Sustainable Microwave Heating Technologies in India.

Invited Speakers

- **Dr. Chun Hsiung Tsai**: Efficient and Stable Activation by Microwave Annealing of Nanosheet Silicon Doped with Phosphorus above its Solubility Limit.
- **Mr. Mark Murphy**: Solid State RF Energy Solutions are Shaping the Future.
- **Prof. Joseph Auresenia, PhD, RChE, FPIChE**: Application of Microwave Energy in the Production of Carbon Nanotubes (CNTs) through Microwave Enhanced Chemical Vapor Deposition and CNT Modification as Bifunctional Catalyst.
- **Dr. Xiangyu Michael Jie**: Microwave-initiated Heterogeneous Catalysis for Plastic Waste Upcycling.

FURTHER INFORMATION ARE AVAILABLE AT: https://www.5gcmea2024.jp/

UIE 2024

UIE 2024
CONFERENCE
ELECTRIFICATION OF INDUSTRIAL THERMAL AND MANUFACTURING PROCESSES

NICE **FRANCE**
OCTOBER 8-11, 2024

MAIN TOPICS

Main topics of the UIE conferences :

- Induction heating
- Resistance heating
- Microwave heating
- Magnetic pulse forming/joining/welding
- Electromagnetic stirring
- Melting
- Metal recycling and purification
- Electrification of industrial processes
- Electroheating technologies and sustainability
- Computational Electromagnetism
- Benchmarks for model validation
- Process design and optimization
- Machine-learning
- AI & EPM
- Digital twins
- Predictive maintenance
- Power quality
- Security issues
- Electromagnetic wave exposition and health issues
- ...

FURTHER INFORMATION ARE AVAILABLE AT: https://uie2024.sciencesconf.org/?lang=en

AMPERE 2025

We wish to announce that during the 20th International Conference on Microwave and High-Frequency Applications: AMPERE 2025 to be held in Bari, Italy, 15-18 September 2025, a new one-day pivotal event dedicated to microwave and radiofrequency industrial applications, called the **AMPERE 2025 INDUSTRY DAY** will be staged.
It will be a unique meeting point for end-users, experts and enthusiasts of these technologies who want to discuss industrial scaled-up applications and share ideas, results, problems, and solutions.

There will be an Industry Day-only option, limited to one-day registration for industrial participants who wish to attend only the AMPERE 2025 INDUSTRY DAY. This does not include industry speakers, who must register for the full conference. This registration option covers all technical and social conference activities scheduled for the day.

Distinguished industrial speakers will reveal interesting details of how microwaves and radio-frequency can enhance modern industrial processes in two interactive sessions chaired by prominent experts in state-of-the-art industrial applications:

SESSION A - Industrial Microwave Heating
Main topics: Food Processing, Microwave Chemistry, Materials Production and Curing

SESSION B - Industrial Microwave Plasma
Main topics: Power-to-X including hydrogen production, industrial and gem diamonds

Speakers from the industry will have 20-minute for the presentation followed by a 5-minute interactive Q&A session from the audience.
The INDUSTRY DAY will be rounded off with short presentations by AMPERE 2025's industrial sponsors and exhibitors, and networking social events with delicious local food and drinks.

During one of the social events, the AMPERE President will award the special "AMPERE SCALE-UP" prize to highlight the value of the most remarkable industrial microwave application among those presented at the INDUSTRY DAY.

The new AMPERE Prize will be awarded after taking into account the results of a joint vote by the members of the AMPERE Industrial Committee and by all participants at the AMPERE 2025 INDUSTRY DAY.

The AMPERE 2025 INDUSTRY DAY, which will be held in a spacious conference room, is open to all registered academic and industrial participants who wish to explore world best practices that have allowed advanced R&D efforts to be transformed into real industrial applications with high added value.
For more information, please visit AMPERE website: https://www.ampereeurope.org/.

About AMPERE Newsletter

AMPERE Newsletter is published by AMPERE, a European non-profit association devoted to the promotion of microwave and RF heating techniques for research and industrial applications (http://www.ampereeurope.org).

New structure of the AMPERE Newsletter

At a management meeting during AMPERE23 it was decided that in view of the introduction of the new scientific Journal entitled "European Journal of Microwave Energy" supported by CUP, no technical papers will be published in future Issues of the Newsletter. Instead, AMPERE welcomes submissions for short bios on individuals, articles, research proposals, projects, briefs as well as news.

AMPERE Disclaimer

The information contained in this Newsletter is given for the benefit of AMPERE members. All contributions are believed to be correct at the time of printing and AMPERE accepts no responsibility for any damage or liability that may result from information contained in this publication. Readers are therefore advised to consult experts before acting on any information contained in this Newsletter.

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