AMPERE Newsletter

Trends in RF and Microwave Heating

http://www.ampere-newsletter.org

Issue 122 **April 18, 2025**

In this Issue: **Page**

ISSN 1361-8598

Current research activities on electromagnetics and microwave technologies at ENSEEIHT Toulouse

Junwu Tao

Département Electronique, Energie Electrique & Automatique, ENSEEIHT, Toulouse Institut National Polytechnique Toulouse, France

Contact E-mail: jun-wu.tao@enseeiht.fr

Toulouse INP - ENSEEIHT is one of the French engineering schools renowned for its training of engineers specialized in microwave techniques and wireless communications systems. In parallel, teachers conduct research activities related to microwave techniques: modeling and design of microwave devices, modeling and characterization of interactions between electromagnetic waves and real or artificial environments, development of specific numerical methods in electromagnetism for device design and inverse modeling for characterization.

Study of EM Wave/Living Environment Interactions

Human exposure to electric and magnetic fields (EMF) is an integral part of modern societies. Several studies have shown that exposure of living systems to EMF can affect vital cellular processes. However, many results from in vitro and in vivo studies remain controversial.

The lack of sufficient scientific data on animal models exposed to EMF has raised various concerns. As part of a research project funded by the French National Agency for Food, Environmental and Occupational Health and Safety (ANSES), our team partnered with the I2MC laboratory (Institute of Metabolic and Cardiovascular Diseases) to study the myocardial capacity for mitochondrial oxidative phosphorylation under prolonged electromagnetic stress (**Figure 1**).

To assess the biological effects of radiofrequency electromagnetic fields on living cardiac cells, we used a transverse electromagnetic cell (TEM cell). In order to define the dielectric properties of the biological medium, the technique of measuring samples reported on a microstrip transmission line was used. The TEM cell used in an in vitro experiment was modeled by a full-wave electromagnetic software, allowing the evaluation of the Specific Absorption Rate: the main parameter of exposure to electromagnetic fields.

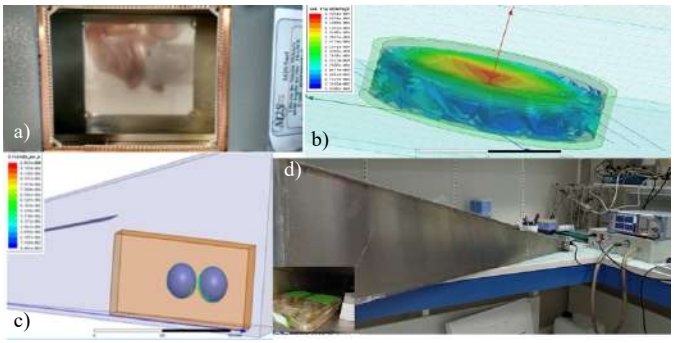


Fig. 1. (a) TEM cell. (b) SAR calculation for TEM Cell in vitro study. (c) SAR calculation of in vivo study in GTEM cell. (d) GTEM cell setup for in vivo study.

In vivo experiments were performed in a Giga-TEM (GTEM) cell to accommodate cages (up to 4) in which the animals were exposed to EMF. We used a solid-state radiofrequency generator with a fixed frequency of 915 MHz (WSPS-915–1000). In the construction of the numerical model, the Webster was modeled by the equivalent volume sphere. The first study uses a relative permittivity of 55 and an equivalent conductivity of 3S/m. Several exposure campaigns were carried out, with the exposure time varying between 48h and 72h.

Both in vitro and in vivo short-term studies found no evidence that EMFs affect antioxidant and apoptosis status in cardiac cells and tissues [1]. Further studies examining dynamic changes in oxidative stress and apoptosis after long-term cardiac cell exposure to EMFs are warranted. These data provide an important reference in relation to the

cellular antioxidant defense system and programmed cell death in response to electromagnetic stress.

Development of RF devices based on metamaterials

Metamaterial-based devices have considerable potential in communication and sensing applications ranging from RF to THz frequencies.

In the field of sensors, the use of metamaterials often leads to high sensitivity of RF signals to changes in environmental parameters such as the presence or absence of chemical or molecular compounds. We are working with former PhD students of our team on the design of metamaterial-based sensors. The devices developed include several cancer cell detection devices, a cell for characterizing water-ethanol mixtures, and other types of sensors [2]. An example is given in **Figure 2** on the feasibility of cancer cell detection.

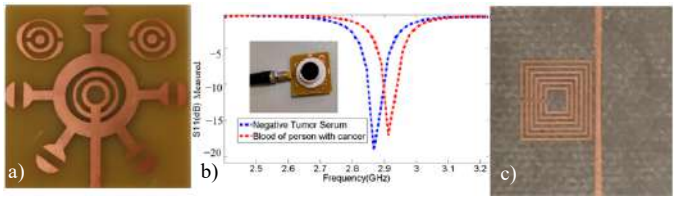


Fig. 2. a) Corona- shaped metamaterial biosensor. b) Resonant frequencies to distinguish negative/ positive tumor serums. c) Metamaterial biosensor for water ethanol mixture characterization.

Design of Metal Waveguide Devices for Power Microwaves

The ability to study and design devices in different shapes of waveguide and cavities is a legacy of our team for several decades, and one of the highlights of teaching in microwave engineering at Toulouse INP-ENSEEIHT.

An original design of a rectangular TE_{10}-to-circular TE_{01} mode converter was undertaken using small ridge elements (**Figure 3**). The result is a device compact enough for application at 915MHz. However, the stability of the circular TE_{01} mode as a function of payload variation remains to be studied.

Fig. 3. Waveguide mode-converter (a) Output vector electric field. (b) Rectangular to circular waveguide transition. (c) Input reflection of rectangular TE_{10} mode.

Other research activities

Other recent research activities in our team include:

Modeling and numerical methods: improving existing numerical methods for electromagnetism and developing methods or models dedicated to innovative electromagnetic applications.

A collaboration between CNES (French National Space Agency), MVG (Microwave vision Group), and LAPLACE is taken for the study of Guided Structures with metamaterial Wall.

A model dedicated to this type of structure was developed based on a modal development. Initially allowing the calculation of propagating and evanescent modes in structures with rectangular or cylindrical cross-sections, the code has been improved in terms of computation time by relying solely on a finite element calculation for this part. The analytical functions defining the modes and their mode admittance matrix have been defined for use in a modal matching code. This code is therefore a hybrid code since it uses both a finite element and modal calculation. It now also allows the determination of reflection and transmission coefficients in different cylindrical waveguide arrangements including metamaterial walls, as well as the determination of an electric field map at a given position in the guide.

HF passive circuit design and characterization: developing new circuit topologies, technological implementation and integration/development of microwave filter syntheses, developing measurement methods, and characterizing homogeneous or inhomogeneous media.

One study carried out in collaboration with ONERA (Office Nation d'Etudes et de Recherches Aérospatiales) is transmit-Array Antennas. This is an interesting antenna topology based on the use of planar transmitting arrays, also called discrete lens

antennas. These devices are typically illuminated by a primary source (single source or array of compact sources) illuminating a laminated metal-dielectric structure [3].

Microwave/plasma interaction: developing circuits integrating plasma zones, studying and improving plasma generation using RF sources [4].

For further reading

1. L. Savchenko, I. Martinelli, D. Marsal, V. Zhdan, J. Tao, O. Kunduzova, "*Myocardial capacity of mitochondrial oxidative phosphorylation in response to prolonged electromagnetic stress*," Frontiers in Cardiovascular Medicine 10, 1205893, Front. Cardiovasc. Med., 07 June 2023, Sec. Cardiovascular Biologics and Regenerative Medicine, Volume 10 – 2023.
2. N. Dadouche, Z. Mezache, J. Tao, E. Ali, M.d Alsharef, A. Alwabli, A. Jaffar, A. Alzahrani, A. Berazguia, "*Design and Fabrication of a Novel Corona-Shaped Metamaterial Biosensor for Cancer Cell Detection*," Micromachines 2023, 14(11), 2114; https://doi.org/10.3390/mi14112114.
3. A. de Oliveira Cabral Junior, H. Kaouach, A. Barka, "*Wideband and High-Efficiency Circularly Polarized Unit-Cell for X and Ka-Band Transmitarrays*," IEEE Open Journal of Antennas and Propagation, Vol. 5, Issue 4, August 2024.
4. V. Babitski, T. Callegari, L. Simonchik, J. Sokoloff, M. Usachonak,B. I. Stepanov, "*The transmission spectrum switching speed of electromagnetic band gap plasma structure*," Journal of Physics: Conference Series, Volume 1393, 14th International Conference "Gas Discharge Plasmas and Their Applications" 15–21 September 2019, Tomsk, Russia.

About the author

Junwu Tao received the B.Sc. degree in electronics from the Radio Engineering Department, Huazhong (Central China) Universitry of Science and Technology, Wuhan, China, in 1982, the Ph.D degree (with honors) from the Institut National Polytechnique of Toulouse, France in 1988, and the Habilitation degree from the University of Savoie, France in 1999. From 1983 to 1991, he was with the electronics laboratory at INP, Toulouse, France, from 1991 to 2001 has was with the microwave laboratory (LAHC) at the university of Savoie, Chambéry, France, where he was an associate professor in electrical engineering. Since September 2001 he is a full professor at the Institut National Polytechnique of Toulouse. He is a research Fellow with Laboratory of Plasma and Conversion Energy (LAPLACE) and involved in the numerical methods for electromagnetics, microwave and RF components design, microwave and millimeter-wave measurements and microwave power applications. He was a member of the committee that moved the AMPERE association to France in 2008, and continued to take up a constructive role in the life of the association, being a member of the scientific committee up to the present day. He notably organized the 13th AMPERE conference in 2011 in Toulouse, France.

Microwave radiation: A breakthrough for nanotechnnology

Katarzyna Matras- Postołek

Vice-Dean for Evaluation and International Cooperation,
Cracow University of Technology,
Faculty of Chemical Engineering and Technology,
Department of Biotechnology and Physical Chemistry
Leader of the Functional Nanomaterials Research Group (www.matrasmaterials.com)

Contact E-mail: katarzyna.matras-postolek@pk.edu.pl

Microwave reactors are used for fast and simple synthesis of materials used in applications such as gas purification, water treatment, energy storage, and drug delivery. While microwave heating is commonly used in households to quickly warm food, microwave ovens can also be used by chemists in

advanced laboratories as powerful tools for synthesizing various materials, including nanomaterials.

Thanks to microwave-assisted synthesis, chemists can precisely control nanocrystal size and its surface properties. This often poses a challenge when using traditional techniques and conventional heating methods. Additionally, microwave synthesis is not only significantly faster, but also generally more environmentally friendly when we compare it to other nanomaterial production methods.

There are many publications, including review publications, that highlight the advantages of microwave irradiation in the broad field of nanomaterial synthesis. Their authors emphasize its efficiency, sustainability, and unique ability to fine-tune material properties [1,2]. In recent years, numerous studies have repeatedly demonstrated the remarkable advantages of microwave heating technology over conventional heating methods, including:

- rapid volumetric heating,
- higher selectivity,
- faster chemical reaction rates,
- shorter reaction times,
- greater product yields.

Thanks to microwave technology, we can quickly produce nanomaterials in the liquid phase, resulting in relatively low costs, energy savings, and high efficiency. This also makes the production process move faster towards practical applications [1,2].

The scientists from the Cracow University of Technology (CUT) in Poland, within the Functional Nanomaterials team led by prof. Katarzyna Matras-Postołek, have been successfully using microwave irradiation for many years to control the synthesis of inorganic semiconductor nanomaterials, including sulfides, selenides, and tellurides [3,4]. More recently, they have also focused on carbon nitride materials as potential photocatalysts. Most of the nanomaterials produced show unique optical properties and have been applied as catalysts for the degradation of organic water pollutants.

The CUT team reported [4] the microwave-assisted synthesis of highly crystalline 2D ZnSe and ZnSe:Mn nanoplates in the form of 3D microflowers in just a few minutes (**Figure 1**). They demonstrated that the microwave-assisted solvothermal method results in ZnSe and ZnSe:Mn nanocrystals (NCs) with smaller sizes and higher surface areas compared to those obtained under similar conditions using conventional heating. Additionally, they showed that the photocatalytic activity of the ZnSe:Mn nanoplates under UV light, in the photodegradation of Methyl Orange (MO), exceeded that of the undoped NCs. ZnSe:Mn NCs with 6% Mn doping exhibited significant photocatalytic activity in the degradation of MO under UV light.

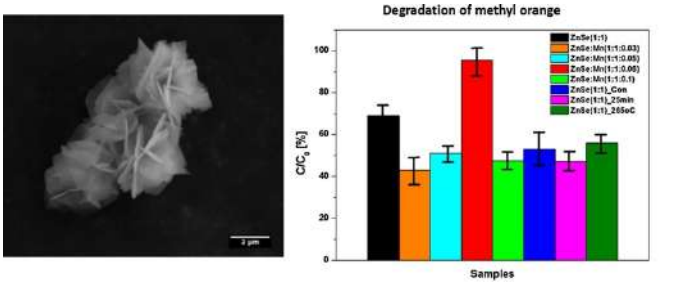


Fig. 1: SEM micrographs of the 3D microflowers of ZnSe NC synthesized by MW irradiation (right) and the comparison of efficiency of photocatalytic degradation of MO for different ZnSe and ZnSe:Mn NCs (left) ([4], (Copyright 2019, Science Direct).

The Functional Nanomaterials group at Cracow University of Technology

Cracow University of Technology is home to an active research group (**Figure 2**), called Functional Nanomaterials, based at the Faculty of Chemical Engineering and Technology. This group is led by Professor Katarzyna Matras-Postołek, who also serves as the Vice-Dean for Evaluation and International Cooperation. The research group focuses on the synthesis and characterization of functional nanomaterials with controlled composition and size, as well as their potential applications, including in optoelectronics and photocatalysis. The luminescent properties of the nanomaterials which the group developed also allow to use the nanomaterials in biology and optoelectronics. The group members have the opportunity to get to know the latest methods of synthesizing inorganic nanomaterials. Their research places significant emphasis on surface modification of the nanomaterials and the impact of stabilizers on

their electrical and optical properties. The research group has established strong collaboration with Jagiellonian University in Krakow (Poland), AGH University of Science and Technology in Krakow (Poland), FH Münster University of Applied Sciences (Germany), and University of Jinan (China).

The scientific experience of the group covers the following research areas:

• Development and characterization of inorganic nanocrystals with luminescent properties, including core-shell nanostructures and polymer nanocomposites

• Research on the potential application of nanomaterials in the development of high-performance heterogeneous photocatalysts

• Design of nanomaterials for biosensor applications

• Application of nanomaterials in the development of hybrid optoelectronic devices (photovoltaic cells, electroluminescent diodes)

• Development of inks for printing optoelectronic devices based on nanomaterials

• Surface modification of developed nanomaterials

Fig. 2: Photo of the Functional Nanomaterials Team at Cracow University of Technology lead by prof. Matras-Postołek (Photo by Jan Zych, CUT).

For further reading

1. Y.J. Zhu, F. Chen, Microwave-assisted preparation of inorganic nanostructures in liquid phase. Chem. Rev. 114, (2014), 6462-6555.
2. K. Pranaw, T. J. Toops, A Review of Microwave-Assisted Synthesis-Based Approaches to Reduce Pd-Content in Catalysts. *Catalysts* 10 (2020) 991.
3. K. Matras-Postolek, S. Sovinska, A. Zaba, P. Yang, Microwave-assisted heating versus conventional heating in solvothermal and non-solvothermal synthesis of photocatalytic active $ZnSe{\cdot}0.5N_2H_4$ and $ZnSe:Mn{\cdot}0.5N_2H_4$ anisotropic colloidal quasi-two-dimensional hybrid nanoplates, Chem. Eng. Process. 122 (2017) 346-356.
4. K. Matras-Postołek, S. Sovinska, A. Węgrzynowicz, Synthesis and characterization of ZnSe and ZnSe:Mn nanosheets and microflowers with high photoactive properties by microwave-assisted method. Chem. Eng. Process. 135 (2019) 204-216.

About the author

Prof. Katarzyna Matras-Postołek, a chemist by education, is a graduate of Cracow University of Technology (CUT). From 2006 to 2012, she worked as a researcher at the Institute for Optical Technologies at Münster University of Applied Sciences in Germany. She earned her Ph.D. from CUT in 2010. After nearly seven years in Germany, she returned to Poland in 2013 to continue her work at CUT. In 2019, she obtained her habilitation in chemistry. Currently, Katarzyna Matras-Postołek is a professor at the Faculty of Chemical Engineering and Technology at CUT. Since 2019, she has been the Vice-Dean for Evaluation and International Cooperation at the Faculty and a Member of the Research Excellence Council of CUT. Her research focuses on functional nanomaterials, particularly semiconductor nanocrystals and their applications in optoelectronics and photocatalysis. She received several prestigious scholarships, including one for outstanding young scientists in Poland (2016). In 2015, she participated in the TOP 500 Innovators program, which included a nine-week internship at the University of California, Berkeley, USA. Since 2014, she has been a visiting professor at the University of Jinan, China, and, since 2019, a scientific member of the international AMPERE organization. She has authored 75 publications listed in the Philadelphia database and has led multiple research projects funded by institutions such as the Foundation for Polish Science (Homing Plus), the National Science Centre (Opus Lap, Sonata Bis, Polonez Bis), the National Centre for Research and Development (Project Lider), and EU funds (Erasmus Project). Katarzyna Matras-Postołek's contributions to applied research have been internationally recognized. In 2015, she was awarded a gold medal at the 43rd International Exhibition of Inventions in Geneva.

Microwave research at the Wrocław University of Environmental and Life Sciences

Adam Figiel

Department of Thermal Technology and Process Engineering, Institute of Agricultural Engineering
Wrocław University of Environmental and Life Sciences

Contact E-mail: adam.figiel@upwr.edu.pl

The Department of Thermal Technology and Process Engineering consists of 8 members. Studies performed at the Department include the use of microwaves in convective drying, vacuum drying and during the desorption phase in freeze-drying. Research problems concern the influence of drying parameters on product quality and energy consumption of the process. The drying process is also modelled using mathematical equations. The laboratories are equipped with two vacuum-microwave dryers, a spouted bed dryer with microwave heating and a hybrid freeze dryer with a microwave generator. The department cooperate with research units in Poland and abroad that use microwaves in the drying process.

European projects with work packages involving the use of microwaves:

1. B70/0005/18 (ERA-NET CO-FUND FACCE SURPLUS2) "Use of protein-carbohydrate waste raw materials in bio-refineries (PROWASTE)" 01.01.2019 – 31.12.2021.
2. SF-CO/FERBLEND/3/2021 (ERA NET SUS FOOD 2 and CORE Organic Co-funds Joint Call 2019) „The use of fermentation to increase the functionality of waste products from the oil and cheese industries (FERBLEND)" 01.05.2021 – 30.04.2024.

For further reading

1. Mohsen Gavahian, Pratik Nayi, Klaudia Masztalerz, Antoni Szumny, Adam Figiel. Cold plasma as an emerging energy-saving pretreatment to enhance food drying: Recent advances, mechanisms involved, and considerations for industrial applications. Trends in Food Science & Technology, 2024, vol. 143, s.1-13.
2. Klaudia Masztalerz, Krzysztof Lech, Tomasz Dróżdż, Adam Figiel, Anubhav Pratap Singh. Effect of electric and electromagnetic fields on energy consumption, texture, and microstructure of dried black Garlic. Journal of Food Engineering, 2024, vol. 375, s.1-10.
3. Ebrahim Taghinezhad, Mohammad Kaveh, Antoni Szumny, Adam Figiel, José Blasco. Qualitative, energy and environmental aspects of microwave drying of pre-treated apple slices. Scientific Reports, 2023, vol. 13, s.1-19.
4. Choong Oon Choo, Bee Lin Chua, Adam Figiel, Klaudiusz Jałoszyński, Aneta Wojdyło, Antoni Szumny, Jacek Łyczko, Chien Hwa Chong. 2022. Specific energy consumption and quality of Citrus hystrix leaves treated using convective and microwave vacuum methods, J Food Process and Preservation, 46, 10, 1-14.
5. Ameena Ali, Choo Choong Oon, Bee Lin Chua, Adam Figiel, Chien Hwa Chong, Aneta Wojdylo, Igor Piotr Turkiewicz, Antoni Szumny, Jacek Łyczko. 2020. Volatile and polyphenol composition, anti-oxidant, anti-diabetic and antiaging properties, and drying kinetics as affected by convective and hybrid vacuum microwave drying of Rosmarinus officinalis L. Industrial Crops&Products.
6. Joanna Cichowska-Bogusz, Adam Figiel, Angel Antonio Carbonell-Barrachina, Marta Pasławska, DorotaWitrowa-Rajchert. 2020. Physicochemical Properties of Dried Apple Slices:Impact of Osmo-Dehydration, Sonication, and Drying Methods. Molecules.
7. David Bernardo López-Lluch, Marina Cano-Lamadrid, Francisca Hernández, Aleksandra Zimmer, Krzysztof Lech, Adam Figiel, Ángel Antonio Carbonell-Barrachina, Aneta Wojdyło. 2020. Hydroxycinnamic Acids and Carotenoids of Dried Loquat Fruit cv. 'Algar' A_ected by Freeze-, Convective-, Vacuum-Microwave- and Combined-Drying Methods. Molecules.
8. Majerska J., Michalska A., Figiel A. 2019. A review of new directions in managing fruit and vegetable processing by-products. Trends in Food Science & Technology, 88, 207-219.
9. Chua L.Y.W., Chua B.L., Figiel A., Chong C.H., Wojdylo A., Szumny A., Choong T.S.Y. 2019. Antioxidant activity and volatile and phytosterol contents of Strobilanthes crispus dehydrated using conventional and vacuum microwave drying methods. Molecules. MDPI. 2019, 24(7):1397
10. Wen Chua, L.Y., Chua, B.L., Figiel, A., Chong C.H., Wojdyło A., Szumny, A., Lech, K. 2019. Characterisation

of the convective hot-air drying and vacuum microwave drying of cassia alata: Antioxidant activity, essential oil volatile composition and quality studies. Molecules. MDPI. 24, 1625.

About the author

Professor Adam Figiel (https://orcid.org/0000-0002-3443-1269) graduated in 1987 at the Wrocław University of Environmental and Life Sciences, where he successively obtained scientific degrees in the field of agricultural engineering. In the years 2013-2017 he was the Director of the Institute of Agricultural Engineering. Currently, he is the head of the Department of Thermal Technology and Process Engineering at the Institute of Agricultural Engineering. He has experience in research on food engineering as well as food processing using drying methods. In particular, he is interested in the drying kinetics, the influence of pre-treatment and drying parameters on the quality of the dried product and the energy consumption of the process. He is the author of over 190 scientific papers (h index=34), 6 chapters in monographs and two patents. He managed 9 projects with particular emphasis on the use of R&D results. He is a member of the Polish Society of Agrophysics and the Polish Society of Agricultural Engineering as well as the editorial board of Current Microwave Chemistry and Polish Journal of Food Engineering. He is the assistant editor in the Food and Bioprocess Technology journal. He gained scientific experience at Canadian, Spanish, and Malaysian universities as part of scholarships, internships, workshops, and scientific consultations. During 5-month internship at the University of British Columbia (Vancouver, Canada), he conducted research on vacuum-microwave drying.

Ricky's Afterthought:

Solar power device captures carbon dioxide from the air to make sustainable fuel

A.C. (Ricky) Metaxas

Life Fellow St John's College Cambridge UK
Contact E-mail: acm33@cam.ac.uk

In this Issue I would like to inform our members of a major research activity headed by Fellow Johnian Erwin Reisner, Professor of Energy and Sustainability in the Yusuf Hamied Department of Chemistry at the University of Cambridge, on a solar power device that eventually produces sustainable fuel. Below we reproduce the article which appeared recently on the St John's College website:

Solar power device captures carbon dioxide from the air to make sustainable fuel

Cambridge researchers have developed a reactor that pulls carbon dioxide directly from the air and converts it into sustainable fuel, using sunlight as the power source.

The researchers, led by Professor Erwin Reisner (**Figure 1**), a Fellow of St John's College, say their solar-powered reactor could be used to make fuel to power cars and planes, or the many chemicals and pharmaceuticals products we rely on. It could also be used to generate fuel in remote or off-grid locations.

Fig. 1: Prof. Erwin Reisner.

Unlike most carbon capture technologies, the reactor does not require fossil-fuel-based power, or the transport and storage of carbon dioxide, but instead converts atmospheric CO_2 into something useful using sunlight. The results are reported in the journal, *Nature Energy* [1].

Carbon Capture and Storage (CCS) has been touted as a possible solution to the climate crisis, and has recently received £22bn in funding from the UK government. However, CCS is energy-intensive and there are concerns about the long-term safety of storing pressurised CO_2 deep underground, although safety studies are currently being carried out.

"Aside from the expense and the energy intensity, CCS provides an excuse to carry on burning fossil fuels, which is what caused the climate crisis in the first place," said Professor Reisner, Professor of Energy and Sustainability at the University of Cambridge. "CCS is also a non-circular process, since the pressurised CO_2 is, at best, stored underground indefinitely, where it's of no use to anyone."

"What if instead of pumping the carbon dioxide underground, we made something useful from it?" said first author Dr Sayan Kar from Cambridge's Yusuf Hamied Department of Chemistry. "CO_2 is a harmful greenhouse gas, but it can also be turned into useful chemicals without contributing to global warming."

The focus of Professor Reisner's research group is the development of devices that convert waste, water and air into practical fuels and chemicals. These devices take their inspiration from photosynthesis: the process by which plants convert sunlight into food. The devices don't use any outside power: no cables, no batteries – all they need is the power of the sun.

The team's newest system takes CO_2 directly from the air and converts it into syngas: a key intermediate in the production of many chemicals and pharmaceuticals. The researchers say their approach, which does not require any transportation or storage, is much easier to scale up than earlier solar-powered devices.

The device, a solar-powered flow reactor, uses specialised filters to grab CO_2 from the air at night, like how a sponge soaks up water. When the sun comes out, the sunlight heats up the captured CO_2, absorbing infrared radiation and a semiconductor powder absorbs the ultraviolet radiation to start a chemical reaction that converts the captured CO_2 into solar syngas. A mirror on the reactor concentrates the sunlight, making the process more efficient.

The team is currently working on converting the solar syngas into liquid fuels, which could be used to power cars, planes and more – without adding more CO_2 to the atmosphere.

"If we made these devices at scale, they could solve two problems at once: removing CO_2 from the atmosphere and creating a clean alternative to fossil fuels," said Dr Kar. "CO_2 is seen as a harmful waste product, but it is also an opportunity."

The team says that a particularly promising opportunity is in the chemical and pharmaceutical sector, where syngas can be converted into many of the products we rely on every day, without contributing to climate change. It is building a larger scale version of the reactor and hope to begin tests in the spring.

If scaled up, the researchers say their reactor could be used in a decentralised way, so that individuals could theoretically generate their own fuel, which would be useful in remote or off-grid locations.

"Instead of continuing to dig up and burn fossil fuels to produce the products we have come to rely on, we can get all the CO_2 we need directly from the air and reuse it," said Professor Reisner. "We can build a circular, sustainable economy – if we have the political will to do it."

The technology is being commercialised with the support of Cambridge Enterprise, the

University's commercialisation arm. The research was supported in part by UK Research and Innovation (UKRI), the European Research Council, the Royal Academy of Engineering, and the Cambridge Trust.

For further reading

1. S. Kar et al., Direct air Capture of CO_2 for Solid Fuel Production in Flow. Nat. Energy (2025). https://doi.org/10.1038/s41560-025-01714-y.

AMPERE's web project: Progress, improvements, and future

Paolo Manini[1], Cristina Leonelli[2]

[1]AMPERE webmaster

[2]Department of Engineering "Enzo Ferrari", University of Modena and Reggio Emilia, Modena, Italy

Contact E-mail: cristina.leonelli@unimore.it

AMPERE's website has continued to evolve, reaching significant milestones that reflect steady growth in both usability and audience engagement. We're excited to share the key elements driving our progress, along with new strategies that are shaping a more dynamic and user-focused platform.

Organized and Accessible Content

One of the most impactful improvements has been the reorganization of our content. Articles, resources, and updates are now grouped into clearly defined categories, making it easier for visitors to find exactly what they're looking for.

This structured approach not only improves navigation but also ensures that the right information is available to the right audience. By creating an intuitive and logical content hierarchy, we've minimized the time users spend searching for information while maximizing their satisfaction.

SEO: A Path to Greater Visibility

To ensure that our platform reaches as many people as possible, we've invested heavily in refining our search engine optimization (SEO) strategies. This includes optimizing keywords, improving meta descriptions, and improving page structures. The result? A noticeable increase in organic search traffic. More users are discovering our site through search engines, demonstrating the power of tailoring digital content to align with search algorithms while maintaining a user-first approach.

A Growing and Engaged Audience

Our analytics continue to show a steady increase in real visitors (those who actively interact with the platform). The most popular sections (currently the pages "Homepage", "Events", "About Us", "Newsletter", and "Issue 120") show that our content resonates with users' interests.

Advanced tools like Matomo allow us to dive deeper into user behavior, giving us insights into how visitors navigate the site, how long they stay, and what keeps them coming back. These data-driven improvements ensure that our platform remains relevant and engaging.

The graph below (**Figure 1**) compares the website's organic visits from September to those in October, highlighting a clear improvement over time.

The data below (**Figure 2**) provides a comprehensive overview of the website's performance over the two months in question. It shows not only an increase in the frequency of visits and the number of users but also a growing interest in the content, which has successfully reached a wider audience.

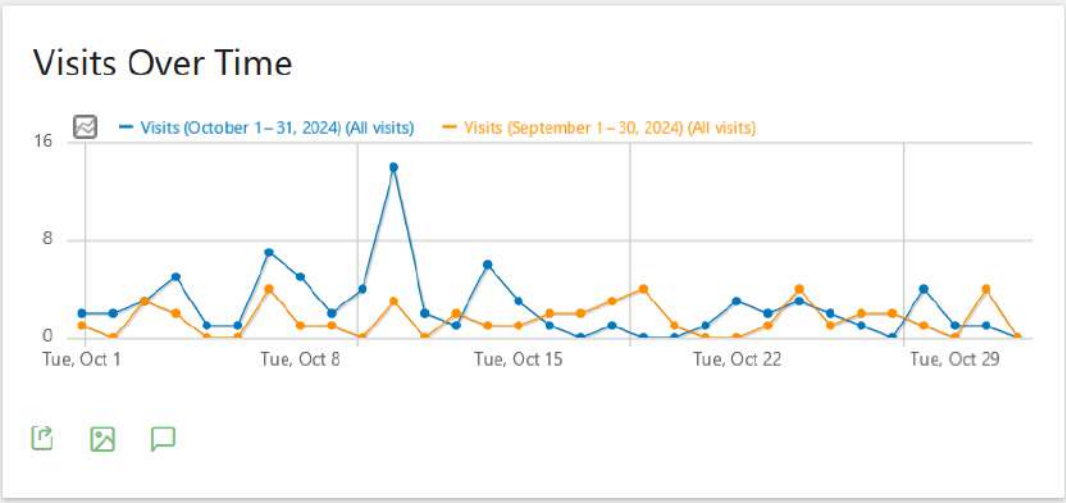


Fig. 1: Comparison of the September 2024 and October 2024 organic visits to the AMPERE website.

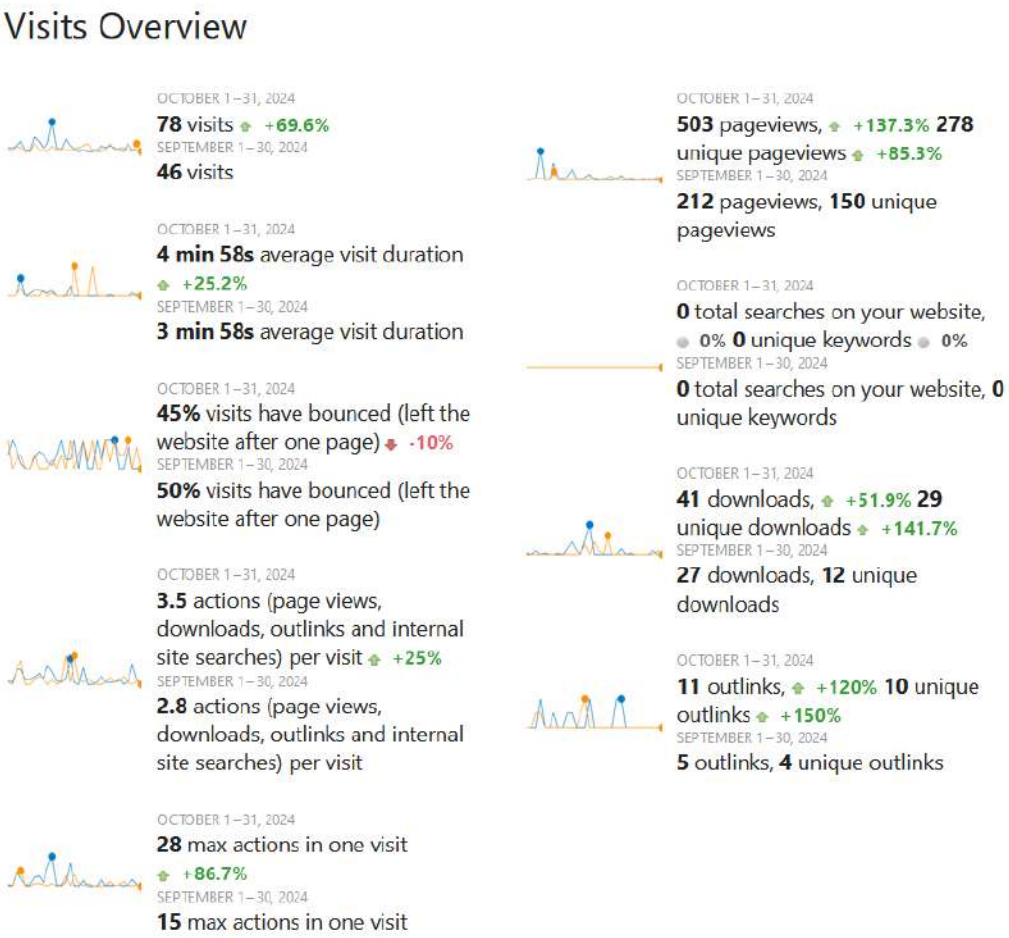


Fig. 2: Overview of the AMPERE website performances over September and October 2024.

Faster, Smarter Technology

Thanks to our Content Delivery Network (CDN), content is delivered quickly and seamlessly, regardless of the user's location. This efficiency improves the user experience, especially during periods of high traffic, and has a positive impact on our SEO, as search engines prioritize sites with optimal loading speeds.

The chart below (**Figure 3**) shows that, over the last 30 days, our website handled a total of over

224.79k requests through the Cloudflare CDN network. A significant proportion of these requests (128.25k) were served directly from the cache, ensuring faster load times and reducing strain on our servers. A cache is a system that stores copies of frequently requested content, allowing it to be delivered more quickly to users without having to repeatedly retrieve it from the main server. This demonstrates the efficiency of our technological infrastructure, providing a seamless experience for users.

The following chart (**Figure 4**) illustrates the growth of our audience, with 10.77k unique visitors recorded over the last 30 days. The daily peak reached 891 users, showing that our site continues to attract an increasing number of visitors. These figures reflect the success of our content and SEO strategies in making our platform more accessible and engaging. In addition to human visitors, the site is increasingly being noticed by search engines and automated monitoring tools (bots and crawlers). This aspect is crucial to strengthening our online presence and making it easier for users to find us.

Looking Ahead

These advances are just the beginning. The increased visibility, engagement, and accessibility of our platform motivates us to continue innovating. By listening to our audience and leveraging technology, we aim to create an even richer experience.

We're deeply grateful to our growing community for their trust and participation. As we move forward, we remain committed to providing quality content, streamlined usability, and the tools to keep our audience informed and connected.

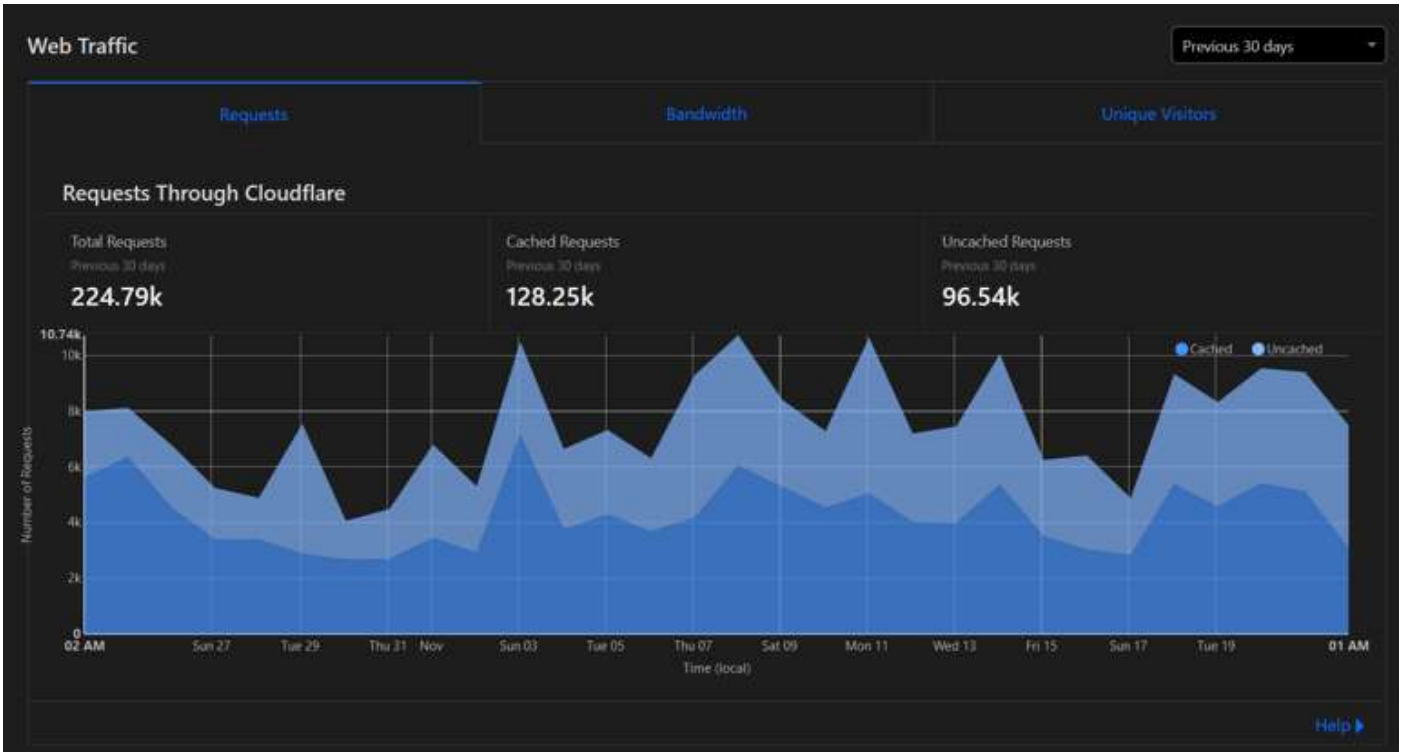


Fig. 3: Requests through Cloudfare over a period of 30 days.

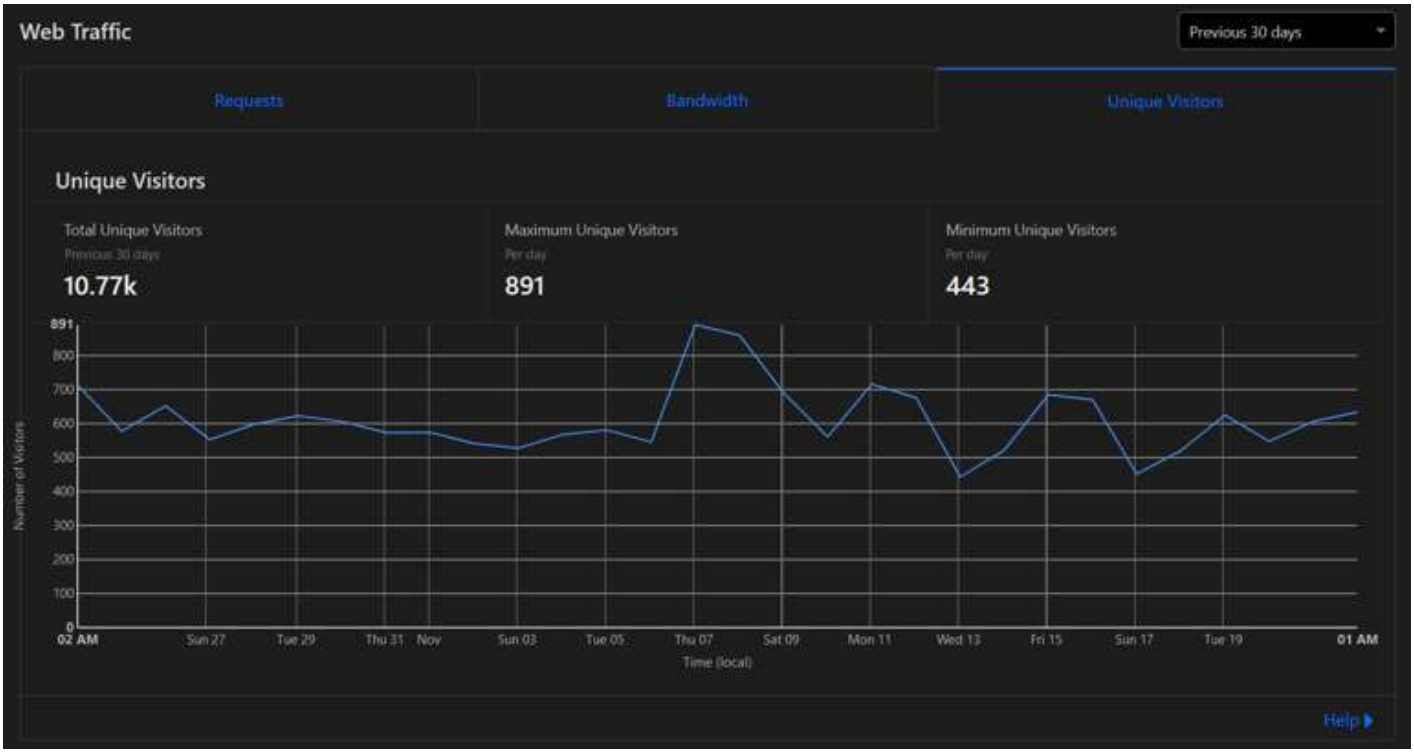


Fig. 4: Website traffic over the same period of 30 days.

IMPI's press release: IMPI signs agreement of cooperation with IEEE's Microwave Theory and Technology Society (MTT-S)

February 27, 2025 - The International Microwave Power Institute (IMPI), the leading scientific organization dedicated to connecting the global microwave and RF energy community, has entered into an Agreement of Cooperation with IEEE's Microwave Theory and Technology Society (MTT-S). IEEE MTT-S is widely regarded as the preeminent society for professionals working in the microwave and RF field. On January 19, 2025, IMPI President, Mr. John F. Mastela, and IEEE MTT-S President, Dr. Goutam Chattopadhyay, were on hand at the IEEE MTT-S AdCom Meeting, in the Sheraton Puerto Rico Resort & Casino, San Juan, Puerto Rico, for the signing ceremony.

This Agreement of Cooperation follows mutual interest in pursuing the cooperation of the Technical Societies on membership development and professional activities. Core tenants of the agreement include: encouraging both parties to have their members join each other's societies, organizing joint technical events or social meetings, promoting the societies Distinguished Speaker Series and Webinars, exploring publication opportunities and promoting each other's conferences and trade shows. In furtherance of these goals, IMPI has extended complimentary membership to IEEE MTT-S Student Members and both parties will participate in IEEE MTT-S 2025 International Microwave Symposium (https://ims-ieee.org/) and IMPI's 59th Annual Microwave Power Symposium (https://impi.org/events/symposium/).

"I look forward to establishing a deeper working relationship with the distinguished members of IEEE's MTT-S and IMPI. Together, we will work hand in hand to unlock the potential of our combined membership, knowledge and skill sets to reach our mutual objectives and goals. I'm confident this collaboration will bring great benefit not only to both Institutes but to the populations we serve," Mastela stated.

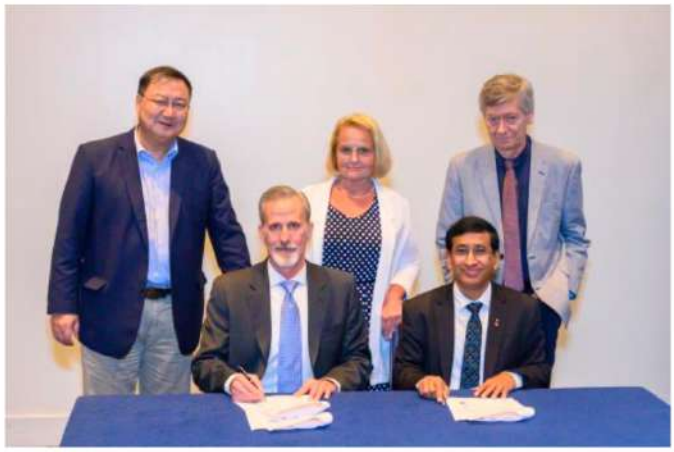
Mastela and Chattopadhyay were joined by Dr. Ke Wu, Chairman, IEEE MTT-S Inter-Society Committee; Dr. Malgorzata Celuch, IEEE MTT-S: AdCom – Elected Member 2024-2026, MarCom Chair 2025, and IMPI Corporate Member; and Dr. Vadim Yakovlev, IMPI Fellow/Board Member, IEEE Senior Member, at the signing.

In their joint statement, Celuch and Yakovlev put the Agreement in a historical context: "The earlier activities aiming to build a bridge between IMPI and IEEE MTT-S can be traced back to the 1970s. These works were led by Dr. John Osepchuk (1927-2024), the legendary figure and Fellow of both societies, and culminated in the Joint Workshop by the MTT-S and IMPI in San Francisco in May 1984.

Reviving that tradition, we were organizers of two microwave-power workshops at the IEEE MTT-S International Microwave Symposia (IMS) in Boston (2009) and San Diego (2023); in the last endeavor, we worked together with Dr. Zoya Popovic, IEEE Fellow. The Workshops were very successful and resulted in formation (in 2010) and renewal (in 2024) of the IMS Technical Area embracing non-communications microwave technologies and material properties. We deeply regret that John Osepchuk did not see the path

towards formalizing the collaboration between the two societies completed as he passed away just two months before the Agreement was signed. The MoU indeed signifies the creation of a long overdue framework for more productive cooperation of the professionals from both closely allied communities."

For additional information on IMPI (https://impi.org/) and the IEE MTT-S (https://mtt.org/), please visit their respective websites.



Photos Compliments of IEEE MTT-S. January 19, 2025

CONTACT:

Molly Poisant, Executive Director, IMPI
(E): molly.poisant@impi.org; (M) +1 804 836 7125

IMPI 59 Symposium program released

The 59th Annual Microwave Power Symposium - **IMPI 59** will take place **June 24-26, 2025** at the Westin Edmonton in downtown Edmonton, Alberta, Canada. The full program is now available at https://www.ampereeurope.org/wp-content/uploads/2025/03/Schedule-of-Events-IMPI-59_Final_Website_2-28-2025.pdf.

9th European Process Intensification Conference (EPIC 2025)

Dear Colleagues and Friends,

It is with great pleasure that we invite you to join us for the **9th European Process Intensification Conference (EPIC 2025)**, which will be held from **June 4th to 6th, 2025, in the historic Zappeion Megaron in Athens.** This iconic venue, a symbol of Greek heritage, provides a fitting backdrop for our gathering.

Process Intensification (PI) is a key driver of innovation and sustainability in the process industries, offering significant improvements in resource and energy efficiency, process economics, and environmental performance. The chemical process industry, long a cornerstone of progress, now faces even greater significance as we confront global challenges like the climate crisis, pandemics, international conflicts, and the need for secure food and water supplies. As scientists in the field of Process Intensification, our task i to harness renewable energy and resources, delivering cutting-edge solutions to these pressing issues.

We look forward to welcoming you to Athens.
Warm regards,

George Stefanidis
Local Host

Important Dates

September 23rd, 2024
Abstract Submission opens

February 4th, 2025
Deadline for abstract submission

February 28th, 2025
Notification for abstract acceptance

April 14th, 2025
Early Registration deadline

June 3rd, 2025
Regular Registration deadline

June 4th, 2025
On site Registration

For more information, please visit the Conference website at https://epic-2025.com/.

AMPERE 2025 Conference: some updates

With over 160 abstracts submitted and more than 200 delegates expected, the 20th edition of the International Conference on Microwave and High Frequency Applications will be held in Bari, Italy, from the 15th to the 19th of September.

This edition is sponsored by Platinum Sponsor, Muegge Group, and a number of exhibitors are now reserving their place to show attendees the latest innovations in the field.

Two Short Courses planned for 15 September will focus on Microwave Technologies for Sensing, Industrial, Agrifood, Medical Applications and on Microwave Assisted Chemistry. Parallel sessions on Chemistry/biochemistry and processing, Dielectric and magnetic materials properties, Solid state technology, Design of applicators and components, Medical and biological applications, Energy production (incl. renewables), Plasma phenomena and processing, EM modelling and numerical techniques, Measurements and metrology, Biomass and waste processing, Process intensification & Food processing, Industrial equipment and scale up, and a full day dedicated to industrial applications will follow. The AMPERE 2025 INDUSTRY DAY is a special one-day event dedicated exclusively to global industrial microwave and radio frequency applications. It will be a unique meeting point for end-users, experts and enthusiasts of these technologies who want to discuss industrial scale-up applications and share ideas, results, problems and solutions. A one-day registration is also available to attend this event.

A wide range of organised day or half-day tours have been arranged for accompanying persons to visit Bari, Pompei, Alberobello & Matera or Trani & Castel del Monte.

A number of rooms have been reserved at a reduced rate in two mid-range hotels, the Hotel Auditorium (3' walk from the conference venue) and the Campus Hotel (25' walk). For further information please visit: https://ampere2025.org/venue-lodging/.

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.

AMPERE Newsletter

ISSN 1361-8598

https://www.ampereeurope.org/newsletter/