AMPERE NEWSLETTER

A Newsletter devoted to RF and MW heating in the range 1MHz to 20 GHz ISSN 1361-8598

www.ampereeurope.org

EDITORIAL

I am pleased to present in this issue a contribution from MAG-Microwave Application Group at Università degli Studi di Modena e Reggio Emilia, Italy, which is led by Professor Cristina Leonelli. In this occasion, they describe their research activities and facilities. It is a pleasure to see the high interaction between this research group and the surrounding industry.

Once again, Dr. Metaxas writes the afterthought piece. This time he explains that bacteria in microwave fields die due to thermal effects rather than due to electric field interaction with their tissues. Therefore, only thermal conditions are the responsible of E. coli sterilisation.

I take this opportunity to wish you all the best for this Christmas season and for the upcoming New Year, especially for those colleagues living in areas with social difficulties.

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RESEARCH AT MAG-MICROWAVE APPLICATION GROUP IN MODENA, ITALY



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The research activity of the MAG-Microwave Application Group started formally in the year 1995 with a national grant, a first nationwide research program funded by CNR (National Research Center), at the Department of Materials and Environmental Engineering at the newly born (1990) Faculty of Engineering, University of Modena and Reggio Emilia, Modena campus.

The leadership of Prof. Gian Carlo Pellacani passed to Prof. Cristina Leonelli which continued to direct the research in the direction of materials processing and synthesis assisted by high power microwaves (Figure 1). During the last decade MAG has successfully managed to gather Italian researchers and industrialists in national meetings and Short Courses for Ph.D. students in the framework of four national projects funded by the Ministry of University and Technological Research (2001-2009).

During the past few years, the growing interaction with national and international partners from industry and some universities allowed to enlarge the laboratory equipment (13 facilities, operating at 2 different ISM frequencies- 2.45 GHz, 5.8 GHz) (Figures 2-4) and publications (more than 100), with an increasing number of young students involved in research. In this framework, the first book on dielectric heating, written in Italian, focussing on microwave processing of materials, was edited at MAG and published in 2008. It collected the contributions of 12 research groups located in universities, national laboratories and private companies.

Figure 1: Four of MAG members: Paolo Veronesi, Cristina Leonelli, Roberto Rosa and Antonino Rizzuti (from right to left).

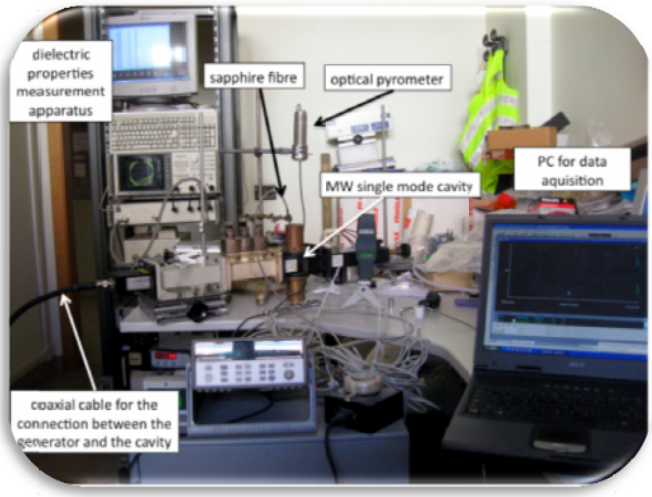

Figure 2: 2.45 GHz Single mode applicator with temperature monitoring sensors and dielectric properties probe in the background.

Originally focussed on inorganic materials synthesis and processing, the interest of MAG expanded to cover numerical simulation, applicator design and processing of a wide variety of materials. Several topics studied in the labs have been scaled up to

pilot or industrial scale production, like the heat treatment of textile fibres, drying of water-based paints, hospital waste and saline solutions sacks sterilisation, defrosting of ready meals, microwave plasma sources for a total of 8 patents (ES2469944, ITRE20130028, EP2647485, ITRE20100036, KR100917973, ITBO20080609, ITTO20040062, US2008029493). Consultancy with industry is still the main source of financial support.

Other more basic research themes remained at the lab scale, for example the study of microwave-metal interactions, microwave assisted combustion syntheses, joining of dissimilar materials, batch and continuous flow synthesis of inorganic nanoparticles and green extraction - of phytochemicals. The group has been listed among the 8 labs in the world for the application of microwave heating to metals in the year 2007 (M. Gupta, E. Wong, Microwaves and metals, John Wiley and Sons, (Asia) Pte Ltd, Singapore). Recently acquired MAG equipment includes a 750W solid state microwave source operating at 2.45 ± 0.05 GHz and a 5.8 GHz source (magnetron, 1000W max output CW) feeding a single mode applicator. The latest research areas are in situ synthesis of intermetallic compounds and of functionally graded materials for sealing, coating and joining composite materials based on carbon fiber technology; combustion synthesis of solutions for the production of complex mixed oxides for electronic applications; carbo-reduction and recycling of metallurgical slags or oxides and continuous flow nanoparticle productions for high performance composite and optoelectronic devices.

Figure 3: 5.8 GHz cavity with top observation hole in cut-off and manual 3-stub-tuner.

Besides material processing, the research activity at MAG is also significantly focused on the multi-physics numerical simulation, as a powerful tool to design better

applicators, as well as to shorten the time to acquire market penetration, or to help reach a deeper understanding of the phenomena occurring during microwave-matter interactions. In-house developed software as well as two commercial software packages are currently used by the MAG's researchers in this field: Concerto (FDTD) and Comsol Multiphysics (FEM). The need for reliable material parameters, supporting numerical simulations, extended the research areas of MAG towards the measurement of dielectric properties, especially of solutions to be used for nanoparticle synthesis. Measurements as a function of temperature or the degree of advancement of the reaction are currently performed in the 0.3-3 GHz range by the open-ended coaxial probe technique with a dedicated thermosetting equipment (Agilent 8753D vector network analyser + 85070E dielectric kit probe).

Figure 4: MILESTONE s.r.l. continuous flow 2.45 GHZ multimode cavity with external pump and control unit

EVENTS

17th Seminar "Computer Modeling in Microwave Power Engineering" – Methods and Models for Microwave Processing of Materials

March 11-12, 2015

Bled, Slovenia

Organized by Industrial Microwave Modeling Group (IMMG), Department of Mathematical Sciences, WPI, USA, and Laboratory for Simulations of Materials and Processes (LSMP),Institute of Metals and Technology (IMT), Ljubljana, Slovenia

For more information please visit:
http://www.wpi.edu/+CIMS/IMMG/Seminars/

or contact:

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2015 International Microwave Symposium (IMS2015)
17 - 22 May 2015 in Phoenix, Arizona, USA

Authors are invited to submit technical papers describing original work on radio-frequency, microwave, millimeter-wave, and terahertz (THz) theory and techniques. For more information please visit:
http://www.ims2015.org/

***1st URSI Atlantic Radio Science.* Conference (URSI AT-RASC)**
18 - 22 May 2015, Gran Canaria, Spain

The newly established triennial URSI Atlantic Radio Science Conference (URSI AT-RASC) is the 3rd URSI flagship conference besides the triennial URSI General Assembly and Scientific Symposium and the triennial AP-RASC conference (AsiaPacific Radio Science Conference).

This 1st URSI Atlantic Radio Science Conference will have an open scientific program composed ofsubmitted papers within the domains covered by all ten Commissions of URSI.

For more information please visit:
www.at-rasc.org

IMPI 49 Symposium
June 16-18, 2015, Kona Kai Resort, San Diego, California, USA

The symposium will accept contributions in all areas of research, development, manufacture, engineering, specification and use of microwave and radio frequency energy systems for non-communication applications, including food technology, chemical and material processing, and new emerging technologies.

For more information please visit:

http://impi.org/wp-content/uploads/2014/10/2015_Call_for_Papers_IMPI.pdf

AMPERE 2015
15th International Conference on Microwave and High Frequency Heating
Cracow, September 14 - 17, 2015.

The 15th International AMPERE conference on Microwave and High Frequency Heating will be staged at Krakow University of Technology, which is based at Krakow, Poland.

The conference will be held during 14-17 September 2015. As with previous conferences in the series the first day will be dedicated to staging short course(s). Details will be published online in due course at www.ampereeurope.org

For more information please visit:
http://ampere.pk.edu.pl

Process Intensification for safe and sustainable process reindustrialization of Europe
September 27th-October 1st
Nice, France

Integrated in the European Congress of Chemical Engineering, EPIC5 provides an excellent opportunity for academics, industrialists and technology providers to present the latest developments on Process Intensification in the academic and industrial sphere and communicate their present views and vision for the future to the largest possible audience.

For more information please visit:
http://www.ecce2015.eu/index.php/epic5

EPM 2015, 8th International Conference on Electromagnetic Processing of Materials
The conference is open for any kind of materials processing involving electric or magnetic fields. It intends to bring together people from academic institutions, industry and related equipment manufacturers.

For more information please visit:
http://epm2015.sciencesconf.org/

NEW BOOK ABOUT RF HEATING

It is very rare to be informed that a new book about various processes on industrial heating is solely on RF. The book is entitled: ***Radio Frequency Heating in Food Processing: Principles and Applications*** and is edited by George B.Awuah, Hosahalli Ramaswamy and Juming Tang. It was published by the CRC Press on Dec 2014 and the two ISBN numbers are as follows: Print Book ISBN: 978-1-4398-3704-7, eBook ISBN: 978-1-4398-3705-4.

This is a comprehensive book on all aspects of RF heating with 22 chapters contributed by separate groups around the world. It comprises of theory, dielectric properties, measurements, computational techniques, free running and 50 OHM type of high power generators and finishing off with a host of industrial applications which includes baking, roasting, drying, sterilization and many other.

The editors should be congratulated for their efforts in completing this task and putting some respectability to a topic which for long has been regarded as the poor sister of microwave heating.

AN AFTERTHOUGHT: BACTERIA IN HIGH MICROWAVE E-FIELDS

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Last issue featured an article by Prof Oliver Kappe on the myth of non-thermal effects in organic synthesis. Some years ago my colleagues and I at the E.U.G. at the Dept. of Engineering reached a similar conclusion when studying the influence of moderately high microwave electric fields (E-fields) on Escherichia coli (E. coli) suspensions.

It was thought that any lethal action on living cells might be due to the interaction of the E-field and the cell membrane. The investigation, therefore, involved subjecting media carrying the bacteria to E-fields established at the centre of a TM_{010} single mode resonant cavity operating at 2450 MHz as shown below. The distribution of the E-field in such a cavity is that of Bessel exhibiting a high field at the centre of the cavity.

The solution carrying the bacteria after exiting the resonant cavity was cooled and pumped up again through the cavity and this cycle was repeated many times.

This procedure ensured that the E. coli suspensions did not exceed their optimum temperature for survival, of around 36°C, as they exited the resonant cavity. The source power was 1.5 kW and was delivered to the carrier medium, which flowed through a pipe of diameter 2R=2.5mm while the effective cavity length was 6 cm. The size of the matching aperture ensures that the V.S.W.R. is close to unity which allows practically all the incident energy to be retained within the cavity and absorbed in the fluid medium with very little reflected power towards the iso-circulator. Samples taken periodically and examined using established techniques revealed no bacterial deaths. Calling the effective loss factor of the carrier medium, which includes the bacteria suspensions, ε'' (possibly a mixture of aqueous NaCl with other compounds) substitution of the above stated parameters in the well-known power per unit volume expression gives an $E_{rms}=1.93/\sqrt{\varepsilon''}$ kV/cm. If the loss factor lies in the range $0.5<\varepsilon''<10$ then the resulting E-field at the centre of the cavity is in the range $2.7>E_{rms}>0.6$ kV/cm. It has to be emphasized that any investigations on bacterial lethality must be carried out at the highest E-fields possible and that means single mode resonant cavities as compared to travelling wave or multimode cavities where considerably much lower fields are established. Having confirmed that no lethal effects were observed with such a level of E-fields the flow was gradually reduced enabling the temperature of the solution carrying the bacteria within the cavity heater to increase. Samples examined at an exit temperature of just over 66°C confirmed that all the E-coli in the solutions were destroyed. So lethality was caused by a heating effect and not the moderately high E-Fields within the applicator.

For the sake of completeness, however, there is a paper[1] in the literature that reports the killing of E coli bacteria when subjected to high pulsed dc fields of the order of 12 kV/cm with a pulse repetition frequency of 1 in every 5 s. Industrial microwave equipment used to process a variety of materials, from foodstuffs to ceramics and from paper to chemicals have working E-fields in the applicators that never reach such values.

REFERENCES:

1. H Hülsheger, J Potel, EG Niemann, "**Killing of bacteria with electric pulses of high field strength**", **Radiation and Environmental Biophysics,** 20, 53-65, 1981

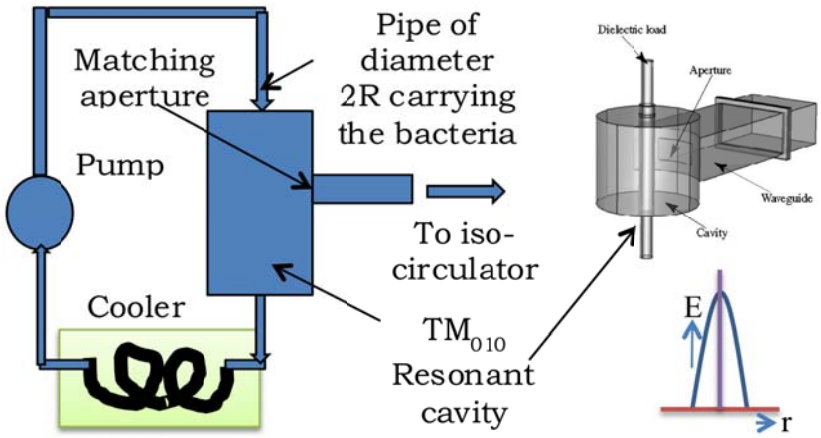

Figure 1. 1.5 kW Microwave and water flow system for E.coli bacteria processing

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Association of Microwave Power in Europe for Research and Education (AMPERE Europe)